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Agrivoltaics technology assessment in Seychelles

Technical cooperation outcome

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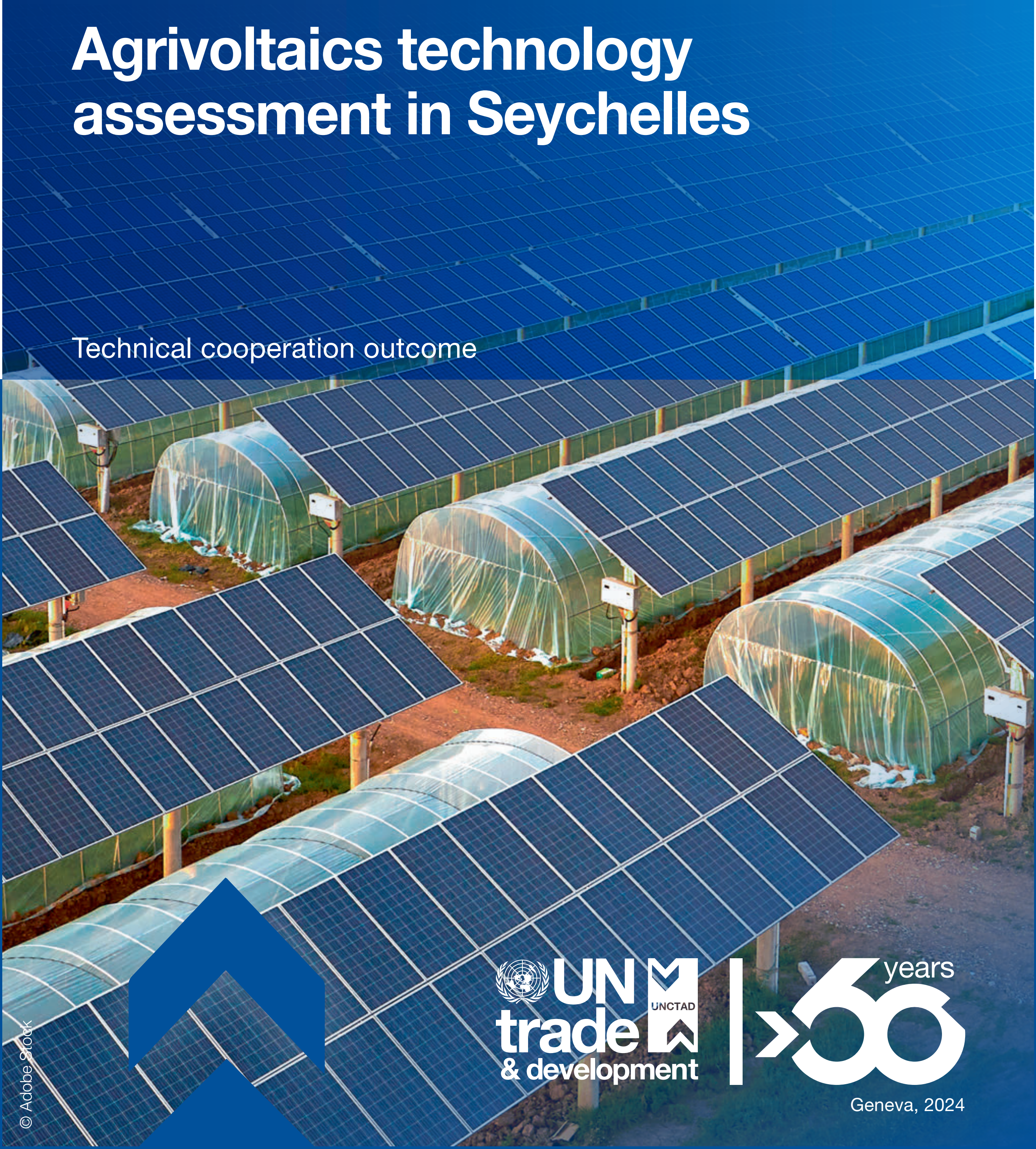

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Abbreviations

ACE	agrivoltaics for controlled-environment crop production
BTI	DSTI's Business, Technology and Innovation Incubator
COVID-19	coronavirus disease (of 2019)
CSA	climate-smart agriculture (Strategy)
DSTI	Division of Science, Technology and Innovation
EG	Expert Group
FAO	Food and Agriculture Organization of the United Nations
FGD	focus group discussion
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IDC	Island Development Company
MACCE	Ministry of Agriculture, Climate Change and Environment
MFNPT	Ministry of Finance, National Planning and Trade
MIEI	Ministry of Investment, Entrepreneurship and Industry
MW	megawatt
NDS	National Development Strategy
NIS	National Innovation System
PUC	Public Utilities Corporation
PV	photovoltaic
R&D	research and development
SBS	Seychelles Bureau of Standards
SC	Steering Committee
SEC	Seychelles Energy Commission
SIAH	Seychelles Institute for Agriculture and Horticulture
SIB	Seychelles Investment Board
SIDS	small island developing State
SPA	Seychelles Planning Authority
STI	science, technology and innovation
STIPS	Science, Technology and Innovation Policy and Strategy
SWOT	strengths, weaknesses, opportunities and threats
TA	technology assessment

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Executive summary

This report presents the results from the technology assessment (TA) of agrivoltaics for controlled-environment crop production (ACE) undertaken by the Government of Seychelles under the guidance of UNCTAD. It is the primary outcome of the UNCTAD pilot Project on Technology Assessment in the Energy and Agricultural Sectors in Africa to Accelerate Progress on Science, Technology and Innovation (STI).[1] "Technology assessment" refers to the systematic evaluation and analysis of the potential impacts, benefits, risks and challenges associated with the introduction, adoption or modification of a specific technology. The goal of TA is to provide informed insights that can guide decision makers, policymakers and stakeholders in making well-informed choices regarding the development, deployment or regulation of technology.

Moreover, this report marks an important step towards the integration of photovoltaic (PV) technology into agriculture, aligning with the country's objectives outlined in the National Development Strategy 2019–2023. Core problems in Seychelles are food and nutrition insecurity, the country's vulnerability to geopolitical instability, and the adverse effects of local climate on crop production, which have been exacerbated by climate change. ACE is well-positioned to address these issues for two main reasons. First, this technology has the potential to guarantee the production of freshly grown vegetables throughout the year. Second, it can help mitigate the adversity of the local climate and climate change on crop production, in particular torrential rainfall, high temperatures and humidity.

The pilot project was guided by the UNCTAD TA methodology (UNCTAD, 2022), which proposes a seven-step approach to implementing TA in developing countries. The methodology requires establishing two entities: the Steering Committee (SC) and the Expert Group (EG). It outlines a structured approach to select the technology, define the goals of the TA, identify the methods to develop and analyse the evidence base and formulate policy recommendations.

As a result, this report provides an overview of the national development plans and policy documents and strategies concerning ACE. Additionally, this report examines the status of the agriculture and energy sectors, which have been analysed in terms of the strengths, weaknesses, opportunities and threats (SWOT) vis-à-vis the opportunities and challenges of the technology. The SWOT analyses reveal that, in general, there are a number of strengths related to policies and strategies being put forward by the government. Those strengths present opportunities for the deployment of ACE. However, some weaknesses are mainly associated with regulations, research and development (R&D), capacity-building, and institutional organization, which present significant threats to the successful adoption of the technology.

By mapping the Seychelles National Innovation System (NIS), this report also helps understand the level of readiness and preparedness of the country's innovation ecosystem for implementing the technology. The mapping exposes that the linkages between the different actors and stakeholders in the NIS are generally weak, thus presenting a challenge to creating an enabling environment to support the deployment of the technology.

Inputs from the EG and public engagement activities were integral to the present TA. These efforts identified several barriers to adopting the technology, encompassing issues related to funding, incentives, land availability, technical competencies, institutional organization, and policies and regulations.

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[1] For more details, see https://unctad.org/project/technology-assessment-energy-and-agricultural-sectors-africa-accelerate-progress-science.

The TA has further identified a number of broad impacts that the technology would potentially have on the country. This includes technological, economic, social, and cultural impacts. Special attention was given to how the technology would negatively affect vulnerable groups, such as women and low-income farming communities, who are particularly challenged regarding funding opportunities. Because this technology is nascent in Seychelles, the analysis employs international scientific and empirical literature to assess its potential effects.

Finally, the report offers solutions to barriers and challenges and identifies actors responsible for overcoming them. As a result, a set of policy recommendations that need to be considered for the successful implantation of the technology are provided. These include:

- Addressing regulatory gaps to allow for the integration of PV into agriculture. This will require setting up a national task force to re-evaluate the existing regulatory and policy frameworks by considering how marginalized groups, particularly women and low-income farming communities, are impacted by the new technology and assessing the resources needed to enforce new regulations and standards.
- Reviewing the Seychelles Energy Policy 2010–2030 to accommodate ACE. This will entail the assessment of alternative policy options to suit the needs of the technology, as well as the establishment of a monitoring and evaluation framework for the implementation of the revised policy.
- Evaluating the impacts of ACE quantitatively by undertaking rigorous economic, environmental, social and cultural impact assessments.
- Facilitating access to funding mechanisms for piloting ACE projects before scaling to fully commercialized ventures. This will require several measures, including the provision of start-up funds and support for start-ups through the DSTI’s Business, Technology, and Innovation Incubator (BTI).
- Clarifying and, if necessary, improving the effectiveness of or expanding the incentives for ACE by introducing new incentive schemes to support start-ups and carrying out periodic assessments of the efficacy of the incentive schemes.
- Measures should be put in place within the NIS to support the adoption of ACE better. This will entail the development of programmes to strengthen the linkages and create synergies between actors and stakeholders within the NIS, among other actions.
- Enhancing the institutional capacity for training, R&D, laboratory infrastructure, and regional and international collaboration to support the technology implementation. This will be facilitated by, for instance, creating a national committee to develop action plans and programmes to accomplish these objectives.
- Reassessing the current land allocation system to determine how agrivoltaics can be integrated into agricultural production. This will entail several steps, including setting up a new agricultural land management system and formulating a new and effective mechanism to allocate land to support the technology implementation.
- Establishing measures to ensure an effective supply chain to support the technology, including, for example, the development of smart procurement and inventory systems and, in the event of disruptions that impact those adopting the technology, the establishment of a scheme to compensate losses.
- Ensuring that ACE is accessible to women and traditional and low-income farmers. This will require several measures, such as the execution of a census to identify marginalized actors in the agriculture sector and the development and implementation of training programmes for women and traditional and low-income farmers.
- Educating and raising awareness on ACE by collaborating with mainstream media for sensitization to demystify the belief that soilless crops create health risks, among other initiatives.

The importance of the UNCTAD TA pilot project cannot be overstated as Seychelles emerges from the challenges brought about by the COVID-19 pandemic and the resulting disruption of the global food supply chain. Ongoing conflicts in Ukraine and the Middle East have further aggravated the stability of the worldwide food supply chain, exacerbating the issues related to local food production and the importation of food supplies into the country. In this context of uncertainty, the TA pilot project has built capacity in STI to ensure that appropriate technologies are adequately assessed to help the country navigate local and global crises.

1.

Introduction

The UNCTAD Project on Technology Assessment in the Energy and Agricultural Sectors in Africa to Accelerate Progress on Science, Technology and Innovation, which involves Seychelles, South Africa and Zambia as pilot countries, was initiated in Seychelles in 2019 following the submission of an expression of interest by the country.

The project focuses on building the Seychelles' capacity to undertake TA, and it is especially targeted at STI policymakers and other stakeholders. It also proposes policies and mechanisms (know-how) to support the learning, diffusion, and adoption of technologies in the energy and agriculture sectors.

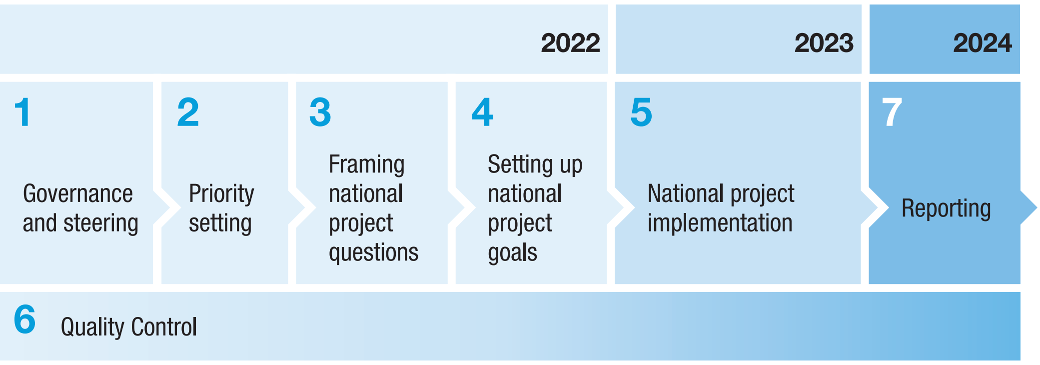
The project was officially launched with the first stakeholder workshop organized jointly by UNCTAD and DSTI in March 2022. This event also served to identify key stakeholders, define priority sectors, and compile an initial list of technologies in agriculture to be considered for assessment, including:

- Climate-proof technologies for mitigation and adaptation to climate change;
- Digitization of supply chain, value chain, and distribution chain in the sector;
- Green technologies in the sector that are environment friendly;
- Technologies that will help the optimization of space, which is a scarcity for a small island State;
- Precision agricultural technologies that allow farmers to maximize yields by controlling every variable of crop farming, such as moisture levels, pest stress, soil conditions, and microclimate.

The project provides Seychelles **with tools for informed decision-making**

Figure 1

The timeline of the TA proposed at the first stakeholder workshop

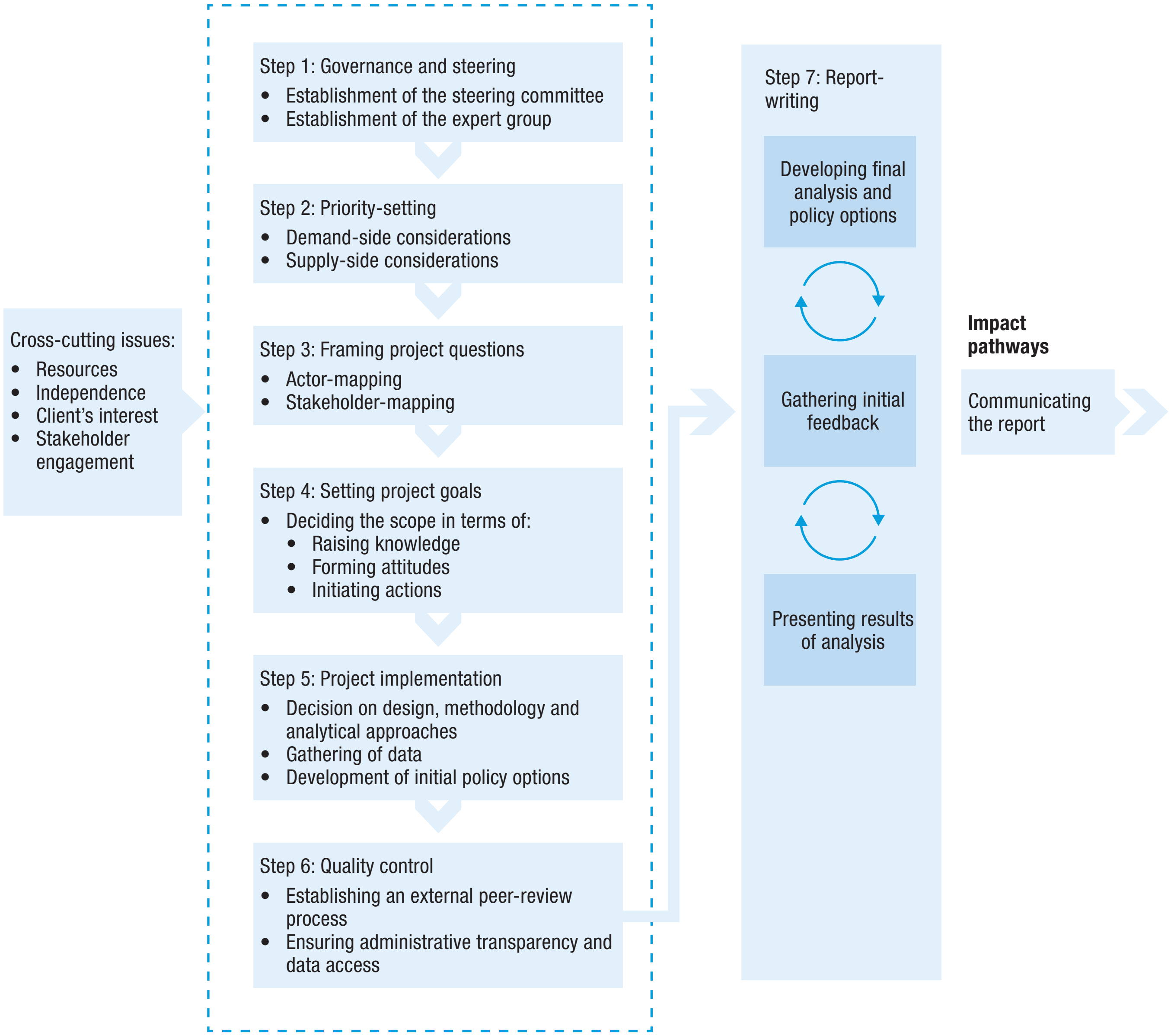


Source: UNCTAD.

The project also outlined a proposed implementation timeline, as illustrated in figure 1, following the seven steps of the UNCTAD TA methodology.[2]

The UNCTAD TA methodology was developed to address the inexperience and challenges developing countries may encounter when conducting TA. The key steps of the overall TA process are outlined in figure 2. Given that Seychelles had not embarked on any TA initiatives before participating in the project, the UNCTAD TA methodology provided the required guidance.

Figure 2
The steps of the UNCTAD TA methodology



Source: UNCTAD (2022).

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[2] For a detailed explanation of the seven steps of the UNCTAD TA methodology, see UNCTAD (2022).

2.

The technology assessment process in Seychelles

Seychelles conducted its technology assessment through a structured and collaborative process, engaging key stakeholders to guide the national effort. This approach allowed for a comprehensive understanding of local needs, ensuring the policy recommendations emanating from the TA genuinely address those needs.

The first step in executing the TA was the establishment of its two guiding entities, namely a Steering Committee (SC) and an interdisciplinary Expert Group (EG).[3] The MIEI appointed the SC, which included members from the government, knowledge-based institutions, and the private sector. The role of the SC was to provide governance and leadership to the TA, and its roles and responsibilities encompassed:

- Setting priorities for the TA;
- Providing overall support and strategic direction on the implementation of the project;
- Establishing the EG;
- Identifying key stakeholders to be involved in the different stages of the project;
- Providing oversight and strategic alignment on the two focus areas of the project (agriculture and energy);
- Providing strategic support, oversight, and guidance to UNCTAD and the EG to implement the TA project;
- Reviewing and approving reports of the EG;
- Providing inputs and reviewing and approving the action plan for the project for implementation;
- Tracking, evaluating, and monitoring progress based on the objectives of the TA;
- Disseminating information to the relevant stakeholders.

The EG, established shortly after the SC, comprised technical experts specializing in agriculture, energy, public-utility services, and the private sector, focusing on the farming community and PV suppliers. The EG was responsible for validating the inputs and suggestions of the various participants in the process.

The project advanced to its second step after establishing the two entities around which the TA is built. This entailed prioritizing technologies for assessment, which required expanding the initial list of technologies formulated during the first stakeholder workshop. This expansion was guided by comprehensive literature reviews of the national development plans, relevant policy documents, policy strategies, and the status of the energy and agriculture sectors, which are detailed in subsequent sections. Key at this stage was the guidance provided by the SC to the EG, helping the latter's understanding of relevant policies and strategies to inform technology selection. The literature review was essential in gathering information on relevant policy documents and policy strategies in the agriculture and energy sectors. DSTI carried out and analysed a number of policies, strategies, regulations, funding opportunities, incentives, infrastructures,

Through extensive discussions, **agrivoltaics was identified as a focus area**

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[3] A full description of the SC and EG is provided in appendix 1.

institutional organization, R&D capability, and innovation and technological capability. This process also incorporated SWOT analyses of the agriculture and energy sectors, conducted in collaboration with the EG, to provide a comprehensive overview of potential technologies for assessment.[4]

To conclude this step, in May 2023 the SC and EG deliberated on the expanded list of technologies and decided that ACE would be the target of the TA.[5] The choice was driven by the technology's potential to boost Seychelles' capability in energy, food and nutrition security, as well as its ability to mitigate the adverse effects of climate change and other external shocks that affect crop production. After reaching this decision, an exhaustive examination was conducted of the potential applications of ACE in consideration of local conditions and context. Technical inputs from the EG complemented this review.

Mapping stakeholders helps understand **linkages within the national innovation ecosystem**

The third step involved framing project inquiries and identifying key actors and stakeholders associated with the technology under assessment. This process employed an adapted version of Mendelow's Matrix, as described in chapter 7, to categorize stakeholders based on their level of influence and interest.[6] Additionally, a mapping of the Seychelles NIS was conducted to discern the interconnections among actors and stakeholders in the system. This mapping provided valuable insights into the functionality of the NIS and an understanding of the strength of linkages between various actors and stakeholders.

Before engaging in the fourth step (setting project goals), the TA first addressed the fifth step (project implementation), which involved the development of methods to gather empirical evidence for informing the TA and shaping policy recommendations. This phase included public engagement through focus group discussions (FGDs), guided by questions addressing the potential impacts of the technology, barriers to its implementation, and the establishment of goals.[7] FGDs were conducted among various groups, including policymakers, regulators, farmers, and consumers,[8] The process yielded valuable primary data relating to the questions discussed, the positive and negative impacts of the technology, and the gaps in policy.

The TA then addressed the fourth step, which entailed determining the goals of the assessment, with a focus on three primary objectives: raising knowledge, forming attitudes or opinions, and initializing action. These goals were established based on feedback from the FGDs, and the results of this process were then shared with the EG members and DSTI for their consideration.

Finally, the interim findings of the TA were shared with the EG for validation and approval by the SC. This process preceded the final data analysis aimed at formulating policy recommendations. The final TA report, including its policy recommendations and complemented by an internal action plan, underwent final validation during a concluding stakeholder workshop in March 2024.

Figure 3 illustrates the TA process mentioned above, focusing on the substantive activities undertaken.

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[4] The initial drafts of the SWOT analyses were distributed to the EG via email. DSTI followed up via phone calls to ensure timely responses. Subsequently, after receiving feedback from the EG, the final versions of the SWOT analyses were formulated. In turn, these finalized versions were reviewed and approved by the SC.

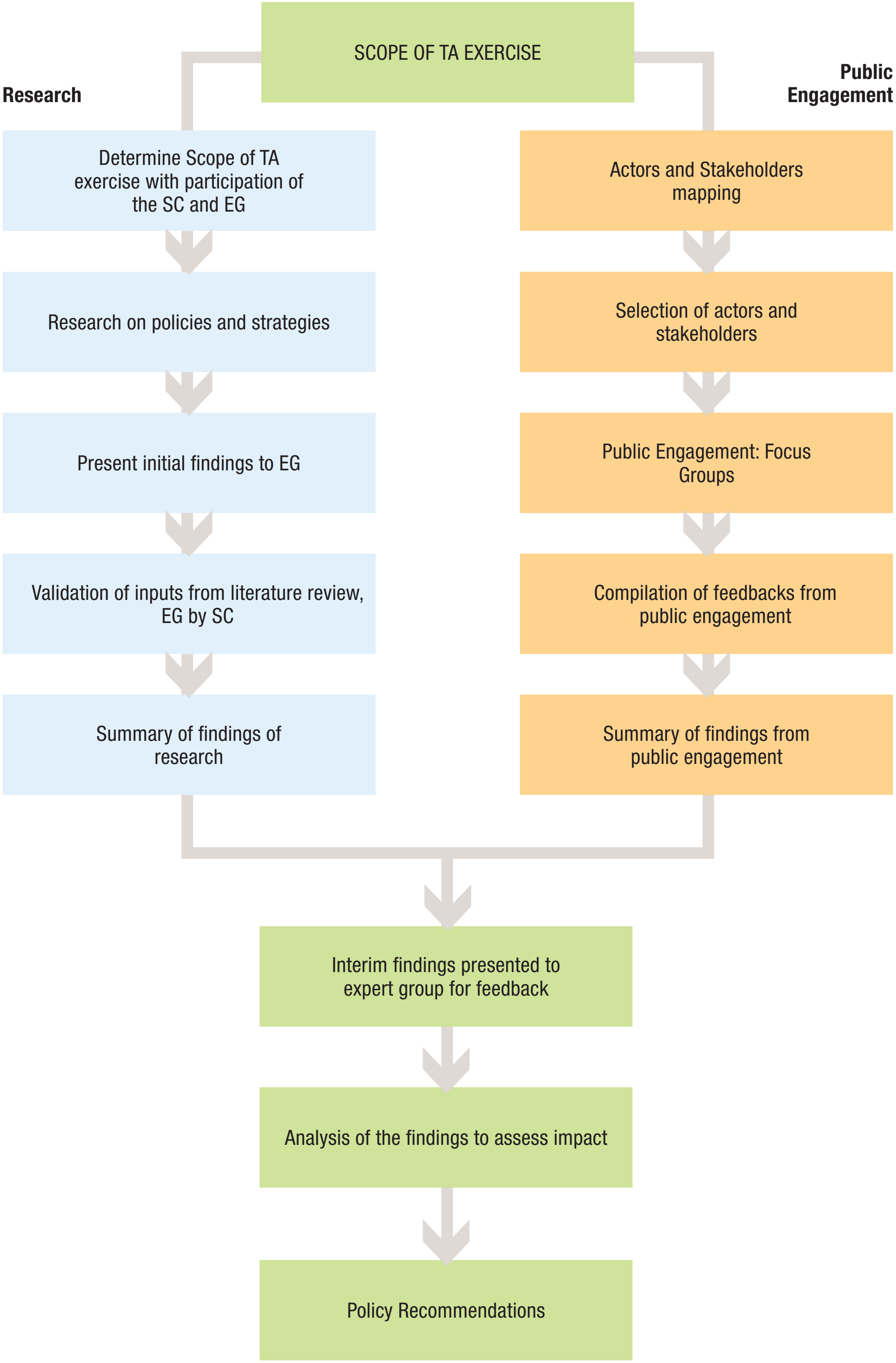
[5] The decision was reached during a joint meeting of the SC and EG. However, due to an insufficient quorum, the decision was not fully ratified at the time of the meeting. The meeting concluded with the resolution that the SC would engage with all absent members of the EG to confirm the technology selection. This process was conducted through email correspondence and received unanimous support from all EG members. Subsequently, the SC reconvened and officially approved the decision.

[6] The stakeholder and actor mapping process was carried out with the following steps: (1) a stakeholder and actor mapping matrix was developed and shared with the EG to identify the stakeholders and actors that would be participating in the focus group discussions; (2) the stakeholders' and actors' positions within the NIS were identified; (3) the DSTI validated and confirmed the list of stakeholders and actors.

[7] The questions are listed in appendix 2.

[8] The list of participants is given in appendix 4.

Figure 3
Substantive activities undertaken during the TA



Source: UNCTAD.

3.

The policy context

Seychelles' strategic direction in energy and agriculture is framed by a comprehensive policy mix to foster sustainability and innovation. These policies shape the demand and supply aspects of technology integration, highlighting the country's commitment to enhancing resilience and promoting renewable solutions in key sectors.

This chapter reviews the main national development plans and relevant policy documents that helped formulate both demand- and supply-side considerations for selecting the technology. Five main elements were analysed: the Seychelles Energy Policy 2010–2030; the Food and Nutrition Security Policy 2013; the Science, Technology and Innovation Policy and Strategy (STIPS) 2016–2025; the National Development Strategy (NDS) 2019–2023; the Climate-smart Agriculture (CSA) Strategy.[9]

Seychelles Energy Policy 2010–2030

The vision of the Seychelles Energy Policy 2010–2030 (Republic of Seychelles, Energy Commission, 2010) for the development of the energy sector towards 2030 is supported by the following objectives:

- Affordability of basic energy services to the whole population;
- Diversification of the energy base, with a long-term objective of the energy supply to derive 100 per cent from renewable sources. The policy's target for 2020 was 5 per cent, and it is 15 per cent for 2030;
- Energy supply in Seychelles will be based on both public and private participation and ownership;
- Energy supply must not give rise to pollution exceeding critical levels;
- Demand for energy services should always be met with the most energy-efficient technologies. The aim is to decrease energy intensity by at least 10 per cent in 2020;[10]
- Recognizing the dominance of oil as a primary energy source for many years to come, the policy emphasizes the importance of maintaining energy security by ensuring access to a minimum of nine months' worth of petroleum product stocks at all times;
- Energy will be priced to consumers at its actual cost;
- Investments will be made to reinforce the image of Seychelles as energy-conserving, greenhouse-friendly and sustainable;
- The energy vision for Seychelles will be reviewed and adjusted based on cross-sectorial energy scenarios.

The diversified energy base of Seychelles shapes its energy mix, leveraging ample resources from wind, solar, and ocean energy.

Energy policy targets 100% renewable energy, **emphasizing affordability and sustainability**

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[9] The 2010 technology needs assessment in the energy sector that was carried out under the leadership of Seychelles Energy Commission also helped select the technology to be assessed, but it is not fully reviewed here.

[10] Energy intensity refers to the amount of energy consumed per unit of economic output, typically measured as energy use per unit of gross domestic product or another economic metric.

Seychelles' STI strategy stresses **integrating STI into agriculture and energy**

Food and Nutrition Security Policy 2013

The Food and Nutrition Security Policy 2013 states that over 72 per cent of the food consumed in Seychelles is imported and that adverse climatic conditions present a challenge to ensuring food security. The policy pursued the following objectives:

- Ensure food security for all Seychellois through efficient and effective agricultural production and sustainable fisheries, balanced by the importation of healthy and nutritious food;
- Improve and optimize the nutritional status, health and well-being of all Seychellois;
- Strengthen and align institutional resilience and capacity to effectively and appropriately respond to changes and shocks in food and nutrition security needs, including an adequate and responsive knowledge and science base;
- Optimize the use of scarce national resources such as land, labour, capital, technology and management, and enhance the agriculture sector's contribution to job creation and the development and implementation of a dynamic, sustained and determined awareness campaign on the benefits of healthy eating and well-being.

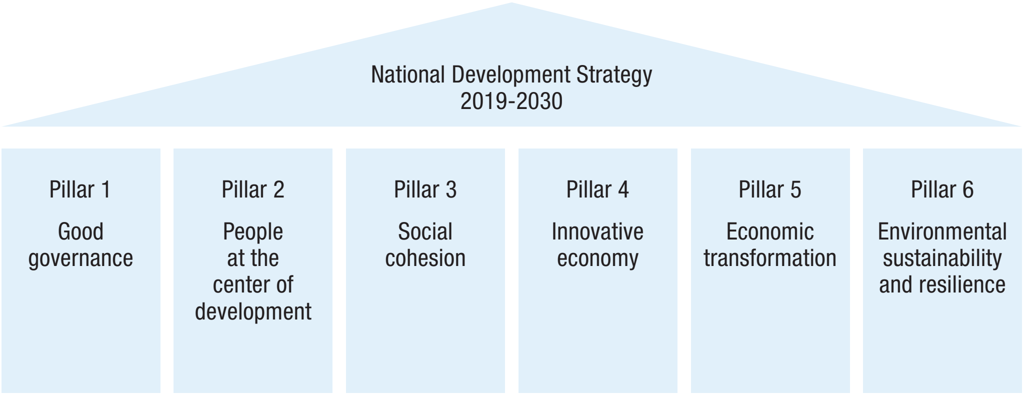
Science, Technology and Innovation Policy and Strategy 2016–2025

The STIPS 2016–2025 calls for Seychelles to transition from an economic efficiency-driven economy to an innovation-driven and knowledge-based economy. Moreover, it emphasizes the agriculture and energy sectors for the integration of STI across those sectors and their respective programmes.

National Development Strategy 2019–2023

The NDS 2019–2023 provides the direction for socioeconomic development priorities, and it is the first five-year strategic plan of the Seychelles Vision 2033. Figure 4 illustrates its priority pillars. The most relevant pillar for the TA on ACE is pillar 6, which refers to environmental sustainability and resilience. It states that Seychelles seeks to protect its natural environment and human and ecological health while driving innovation and enhancing Seychellois's quality of life. Increasing the country's energy and food security is also paramount to maintaining resilience, as the country is currently almost entirely reliant on imported fossil fuels for electricity and imported food for its national needs.

Figure 4
Priority pillars of the NDS 2019–2023



Source: Republic of Seychelles Ministry of Finance, Trade, Investment and Economic Planning (2019).

Pillar 6 puts both agriculture and energy sectors as top developmental priorities.

Climate-smart Agriculture Strategy

The Seychelles CSA Strategy gives an overview of the challenges of the agriculture sector (Republic of Seychelles, Ministry of Agriculture, Climate Change and Environment, Department of Agriculture, 2023).

Agricultural land in Seychelles is estimated at 1,540 hectares, representing 3.4 per cent of the country's total land area. In 2015, arable land constituted about 0.3 per cent of the land area, while permanent crops occupied 3 per cent. Coupled with the problem of agricultural land scarcity, climatic adversity such as seasonal rainfall affects crop production consistency throughout the year.

According to a study by the Food and Agriculture Organization of the United Nations (FAO) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) on the adoption of the CSA Strategy in Seychelles (2019), it is essential to prioritize the following measures:

- Increasing public awareness of agricultural climate change adaptation and mitigation and the CSA concept;
- Mobilizing private funds at the local and international levels to finance CSA;
- Encouraging participatory R&D to develop locally appropriate CSA for farmers;
- Mainstreaming climate change in agriculture and economic development policies;
- Encouraging a multi-stakeholder approach to identifying and prioritizing the most applicable CSA practices for large-scale promotion.

The same study highlights that CSA technologies present opportunities for addressing climate change challenges and for economic growth and development of the agriculture sector. Crop production under plastic-covered structures in Seychelles was initiated decades ago. The objective of such innovation was to help the farmers to increase and sustain production throughout the year. This was important as production fluctuated between the south-east monsoon and north-east monsoon. Finally, the Global Science Partnership Interim Report[11] provides an assessment of several CSA practices and technologies that aim to build resilience to climate hazards. Integrating solar energy into agriculture is among those practices and technologies (Global Science Partnership, 2023).

> Innovation and smart practices **help agriculture adapt to climate change**

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[11] The Global Science Partnership Interim Report was presented under the Climate Legacy Project funded by the United Kingdom of Great Britain and Northern Ireland government. It was a follow-up from COP26 and Seychelles took part in the pilot project under the thematic of a net-zero food system and building resilience. Through the citizen-engagement stage of the project, a number of technologies that would contribute to a net-zero food system and building resilience were identified. This helped the selection of the technology by providing a list of existing technologies in the agriculture sector.

4.

An overview of the agriculture and energy sectors

Seychelles' agriculture and energy sectors face obstacles due to limited resources, high import dependence, and significant climate risks. The dominating small-scale agriculture sector is facing challenges due to its fragmentation, while energy production relies on fossil fuels despite ambitions for more renewables. Sector analyses identified growth opportunities and underlined the impact of infrastructure gaps, geopolitical risks, and market instability on future resilience.

Agriculture sector

The Seychelles agriculture sector is still in the early stage of development. It contributes slightly less than 2 per cent to the country's gross domestic product at current market prices.

The fragmented production landscape consists of 648 registered farmers, of which 74 per cent are crop farmers, 15 per cent are livestock farmers, 8 per cent are practicing mixed farming, and 3 per cent are processors and exporters. A total of 8,662 householders practice some form of backyard farming (Republic of Seychelles, Ministry of Agriculture, Climate Change and Environment, Department of Agriculture, 2023).

The main crops cultivated are tropical fruits, vegetables, herbs, and root crops, which are based on small-scale production systems. The cultivation of cash crops such as coconut, tea, and vanilla has been in accelerated decline over the past decades. However, a renewed political commitment exists to reverse the trend (Republic of Seychelles, Ministry of Agriculture, Climate Change and Environment, Department of Agriculture, 2023).

The vast majority of farmland (98 per cent) is under open field cultivation, with only 7.2 hectares (2 per cent) that have protected shade house infrastructure. Recently, there has been increased interest in this latter system of farming. At a national level, 65 per cent of farms are located in mountainous areas, whereas 30 per cent are on flat land. There are, however, marked differences in farmland distribution between the two main islands; Praslin has 75 per cent of farms located on flat land, whereas on Mahe 72 per cent of farms are located in mountainous areas (Republic of Seychelles, Ministry of Agriculture, Climate Change and Environment, Department of Agriculture, 2023).

Crop production faces numerous challenges, including adverse seasonal climatic conditions such as monsoon rains, prolific weed growth, and high pest and disease incidence, all of which significantly reduce yields. The impacts of climate change exacerbate these challenges. Moreover, according to Chalgynbayeva et al. (2023), assessments by the United Nations Task Team for the Global Crisis Response Group suggest that the COVID-19 pandemic and the war in Ukraine

Agriculture is challenged **by climate and limited arable land** have led to substantial increases in food and energy prices, intensifying pressure on the sector from external shocks.

Based on the aspects above, the agriculture sector is challenged to attain national food and nutrition security and is far from achieving food sovereignty.[12] In this context, the Seychelles agriculture sector needs technological innovation to pursue food and nutrition security and reduce its vulnerability to external shocks. To better understand the status of the agriculture sector, a SWOT analysis was conducted (table 1). This analysis drew from the above policy documents and the latest economic and climatic trends.

Table 1
SWOT analysis of the agriculture sector

Strengths	Weaknesses
• Good post-COVID-19 economic recovery • Presence of policy and strategic frameworks that align with the NDS • Active adoption of CSA by farmers • Effective implementation of the Food and Nutrition Security Policy • Well-established institutional organization, including ministries, departments and agencies • Ministry portfolio fosters synergies between agriculture, energy, climate change, and environment sectors under one umbrella • Access to credit under special schemes with low interest rates, including the Agricultural Development Fund and the Seed Capital Grant Scheme • Incentive schemes in place in support of farmers such as tax rebates and subsidies for inputs	• Inadequate capacity and capability in the sector for the adoption of new technology • Inadequate capacity and capability in agricultural research and extension services • Lack of funding for research • Weak knowledge-based institutions to support modern technologies in the sector • Absence of regulatory framework to support new technologies in the sector • Weak supply chain for new technologies • High dependency on technology transfers from foreign sources • Insularity of Seychelles • Scarcity of arable agricultural land • Gender disparity in the sector, with more men than women in the sector by a substantial margin
Opportunities	**Threats**
• High local demand for fresh agricultural products • Great emphasis on food and nutrition security • Interest of youth in the sector with innovative solutions • Availability of DSTI's BTI • Growth in the tourism sector and service industry, which stimulates increased demand for locally grown agricultural products • Easy access to procurement of new technologies • Reintroduction of climate-resilient crop species	• Impact of climate change affects agricultural production • Geopolitical instability that directly enhances risks associated with insularity factors • Market volatility that affects currency exchange rates • Fluctuations in supply-chain cost for agricultural inputs • Enhanced vulnerabilities as a small island developing State (SIDS) • Biosecurity challenges due to the high level of imported agricultural products • Continuous shifts in political leadership within the sector, spanning from senior positions to lower tiers of authority • Disruption in after-sales services for newly adopted technologies, leading to consumer challenges due to inadequate support from product and service providers • Availability of cheaper imports of agricultural products from the region

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[12] FAO (2014) defines food sovereignty as a holistic approach emphasizing farmers' control over the food system.

Energy sector

Seychelles is among just four African countries with 100 per cent access to electricity (Etongo D and Naidu H, 2022). However, with 90 per cent of electricity sourced from fossil fuels, the country faces a growing challenge in curbing greenhouse gas emissions. Moreover, the susceptibility to fluctuations in oil prices further complicates efforts to achieve sustainable development objectives. In light of this situation, the objectives outlined in the Seychelles Energy Policy 2010–2030 seem ambitious, especially as the country's renewable energy share stands at less than 5 per cent as of 2023 and will need to increase significantly to reach the target of 15 per cent by 2030.

Numerous projects have been initiated or are currently progressing to meet these targets. For example, through the Wind Farm Project, eight wind turbines were installed in 2013 with a 6 MW capacity, while another 3.5 MW capacity was achieved through four solar power projects in Seychelles. With the ongoing construction of a 5 MW floating solar power plant on Mahe Island, clean energy's share is expected to increase by an additional 5 per cent upon completion. A SWOT analysis was performed to illustrate the energy sector's status further. The results of this analysis are presented in table 2.

In summary, both the agriculture and energy sectors face significant challenges due to their heavy reliance on imports. Agriculture grapples with imported food, while energy relies on fossil fuel imports.

> Energy sector faces **high fossil fuel dependence and funding challenges**

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Table 2
SWOT analysis of the energy sector

Strengths	Weaknesses
• Good post-COVID-19 economic recovery • Presence of policy and strategic frameworks that align with the NDS • Vision to achieve 100 per cent renewable energy by 2050 and a target of 15 per cent by 2030 • Well-established institutional organization, including ministries, departments and agencies • Ministry portfolio fosters synergies between agriculture, energy, climate change and environment sectors under one umbrella • Presence of a clear national roadmap for transitioning from fossil fuel to renewables • Identification of the energy mix based on technology foresight and technology needs assessment • Access to credit under special schemes with low interest rates • Incentive schemes in place in support of installation of PV systems	• Inadequate capacity and capability in the sector for the adoption of new technology • Absence of regulatory framework to support the technology • Lack of funding for research in the sector • Weak knowledge-based institutions to support modern technologies in the sector • Weak supply chain for new technologies • High dependency on technology transfers from foreign sources • Insularity of the country • Old and inadequate grid system to efficiently manage the supply of renewable energy in the system and lack of funding for its modernization • Consumer mindsets and attitudes to energy consumption • Inability to attract funds in the sector, as Seychelles is considered as a high-income country • Poor development of public-private partnerships in the sector • Risk-averse local investors • Gender disparity
Opportunities	**Threats**
• Increased public awareness and national demand for renewable energy • Great emphasis on the reduction of national carbon footprint across economic sectors. This is related to the nationally determined contributions as a commitment to the Paris Agreement on climate change • Interests of youth in the sector with innovative solutions • Availability of DSTI's BTI • Growth in the tourism sector and service industry, which stimulates increased demand for clean energy to sustain Seychelles' image as a pristine destination • Easy access to procurement of new technologies • Growth in the sector	• Geopolitical instability that directly increases risks associated with the insularity of Seychelles • Market volatility that affects currency exchange rates • Fluctuations in supply-chain cost for energy inputs • Continuous shifts in political leadership within the sector • Disruption in after-sales services of newly adopted technologies • Disruption of new technologies and inability to adapt to new technologies • High risk in base-load power supply substitution for fossil fuel

5.

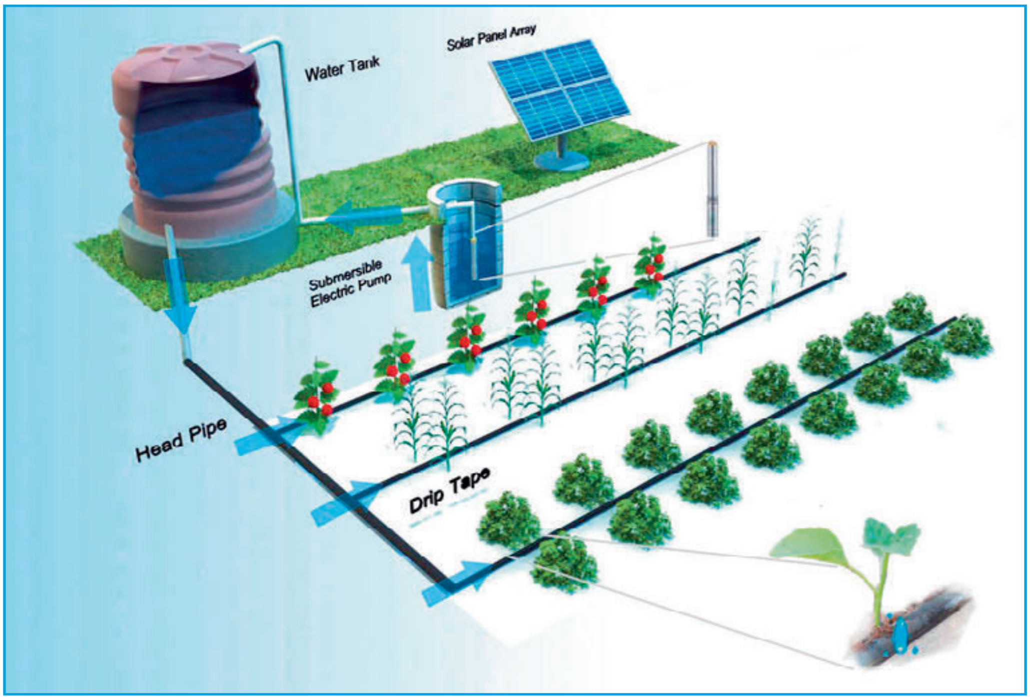
Agrivoltaic technology for controlled-environment crop production

Agrivoltaic technology has been identified as a promising solution for Seychelles to integrate solar power with agriculture to enhance land productivity and support sustainable development. This approach is expected to boost crop yields, improve energy efficiency, and deliver new income opportunities for farmers while contributing to its environmental goals, such as reducing carbon emissions. However, adopting this technology in Seychelles can be associated with challenges such as high start-up costs and the need for specialized skills and knowledge.

The analysis presented in the previous chapter shows that ACE holds the potential to contribute to a solution to the challenges confronting the food and energy sectors. Given that the technology under study is a fusion of two distinct technologies, namely photovoltaics and controlled-environment crop production, this section begins by independently examining each technology before exploring their combined application.

Figure 5

Concept of an agrivoltaic system



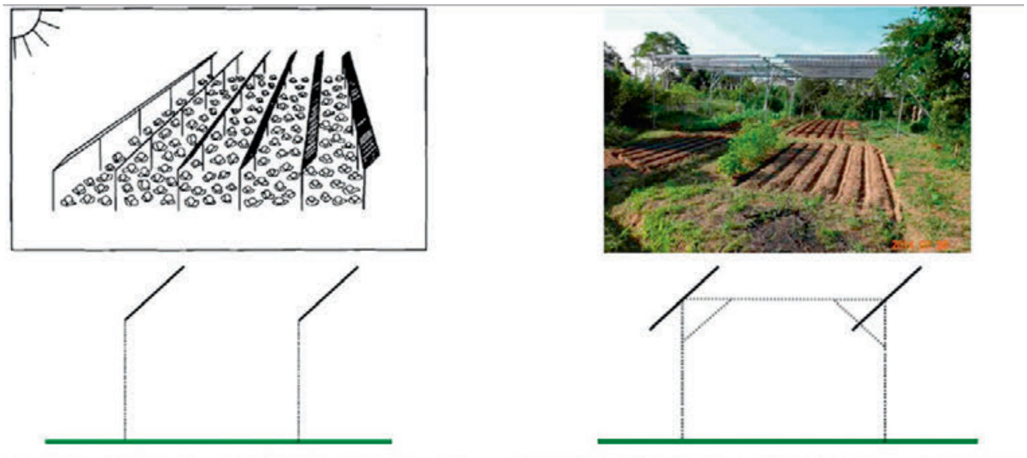
Source: Energy Industry Review (2021).

Figure 6

Concurrent utilization of land for both agricultural activities and PV

(a) Conceptualization designed by Goetzberger and Zastrow (1981)

(b) First model developed by Akira Nagashima in Japan (2020)



Source: Toledo and Scognamiglio (2021).

Agrivoltaics allows simultaneous crop **growth and electricity generation year-round**

Definitions of agrivoltaics and controlled-environment crop production

Generally speaking, an agrivoltaic system refers to integrating power resources into agricultural production processes, encompassing practices such as facility gardening, breeding and pastoral construction (Chalgynbayeva et al., 2023).

This approach, shown in figure 5, offers a novel mode of production, merging farming, power generation and agricultural activities. In this system, PV technology supplies electricity for all electrical components, including pumps, fans, humidity control, lighting and mechanical systems where top ventilation is utilized (Toledo and Scognamiglio, 2021).

Toledo and Scognamiglio (2021) highlight that the concept of a dual-use approach integrating both solar PV power and agricultural production was initially conceptualized by Prof. Adolf Goetzberger and Dr Armin Zastrow at the Fraunhofer Institute for Solar Energy Systems (Germany) in 1981. Subsequently, in 2004, Japanese engineer Akira Nagashima pioneered the first agrivoltaic system, also known as "solar sharing", utilizing a structure resembling a garden pergola (see figure 6) (Nagashima, 2020). A more encompassing definition is provided by the United States of America Department of Energy (2022), which describes agrivoltaics as enabling the concurrent utilization of land for both agricultural activities and PV power generation, allowing for the cultivation of crops, grazing of animals and generation of electricity on the same land.

Regarding controlled-environment crop production, the concept is related to controlled-environment agriculture, which employs controlled environments conducive to the growth of crops and plants. This typically involves cultivation in protected settings, often indoors, utilizing advanced technologies and intensive year-round growing conditions (Congressional Research Service, 2023). Standard indoor techniques may include vertical growth systems using soilless methods such as hydroponic,[13]

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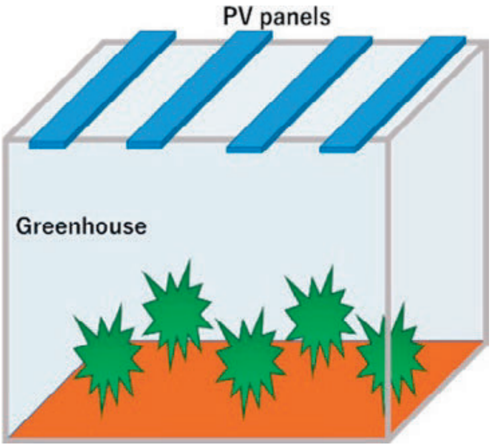
[13] Hydroponic systems involve the cultivation of plants without soil but with a water-based nutrient solution.

aeroponic[14] or aquaponic[15] production systems. Controlled-environment agriculture systems are designed to establish optimal growing conditions and maximize the productivity of crops and plants, typically within intensive closed-loop systems.

The integration of agrivoltaics with controlled-environment crop production is illustrated in figure 7, sourced from Sekiyama and Nagashima (2019) who examine what they term a “PV greenhouse”. In this innovative approach, PV modules replace a portion of the greenhouse’s transparent covering.

Figure 7
Concept of ACE



Source: Sekiyama and Nagashima (2019).

Opportunities and Challenges

The literature highlights the potential of ACE in addressing various issues, including those encountered by Seychelles. Sekiyama and Nagashima (2019) state that integrating PV technology into greenhouses offers a promising solution to the persistent competition for land resources between food and energy production. This approach enables continuous food cultivation and electricity generation throughout the year. Kumpanalaisatit et al. (2022) find that agrivoltaic systems offer dual revenue streams for entrepreneurs and agriculturalists derived from sales of both electricity and agricultural products such as crops and livestock. The economic impact of agrivoltaic systems extends to various stakeholders throughout the supply chain. These stakeholders, including upstream, midstream and downstream participants, can collaborate to enhance income levels and elevate living standards, thereby contributing to the national economy. Midstream stakeholders, such as community enterprises and agricultural processing facilities, play a crucial role in processing and marketing agrivoltaic crops, creating additional revenue streams and employment opportunities within the local community. This last element is supported by Chalgynbayeva et al. (2023), who highlight that developing agricultural plots, dedicated solar power plants, or repurposed land for agrivoltaic systems can generate revenue for communities and boost employment.

However, the literature also points to some uncertainties. Sekiyama and Nagashima (2019) emphasize the need for further research to assess the effectiveness of PV greenhouses, as previous studies have predominantly focused on agrivoltaic systems with stilt-mounted PV modules. Toledo and Scognamiglio (2021) highlight a challenge regarding the light and shade ratio in greenhouse roofing with integrated PV panels. These authors suggest dynamically regulating shading levels to optimize light delivery to crops according to their requirements, which is crucial in managing power demand. Maity, Sudhakar et al. (2023) highlight a research gap in identifying the primary weaknesses and threats associated with integrated PV systems within an agricultural context, and provide a SWOT analysis for agrivoltaic systems as shown in figure 8.

> Agrivoltaics could offer dual income streams **from crops and solar energy**

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[14] Aeroponic systems involve the cultivation of plants by suspending their roots in the air and periodically misting them with a water and nutrient solution.

[15] Aquaponic systems imply the integration of plant cultivation with fish or aquaculture production, utilizing wastewater from the latter to fertilize a linked plant system.

Figure 8
SWOT analysis of agrivoltaic systems

STRENGTHS	Enhanced PV efficiency Increased land use efficiency Reduction in GHG emissions High crop Yield Energy Access and rural electrification
WEAKNESS	Lack of awareness Limited to Shade tolerant plants Crop rotation is required. Weak regulatory measures Hidden costs like O&M, opportunity costs
THREATS	Land acquisition Lack of Policy developments Untested technology in long-run Cost concerns Pest and crop disease due to microclimate
OPPORTUNITIES	Decreasing Prices of Solar PV Growing Interest of MNCs Drivers of UN SDG goals 1, 7 and 11 Rural Employment benefits New market segment and potential Conservation of Biodiversity

Source: Maity, Sudhakar et al. (2023).


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6.

The crucial role of the national innovation system

Evaluating the national innovation system (NIS) is crucial for adopting the technology effectively. This includes understanding the system's capacity to inform policymakers and shape societal discourse on new technologies, the state of access to international knowledge, and whether solid linkages between knowledge generation and application within the NIS can be ensured.

Evaluating the national innovation system (NIS) is crucial for adopting the technology effectively. This includes understanding the system's capacity to inform policymakers and shape societal discourse on new technologies, the state of access to international knowledge, and whether solid linkages between knowledge generation and application within the NIS can be ensured.

The 2024 UNCTAD Seychelles STI Policy Review (UNCTAD, 2024) examined the NIS in Seychelles and performed a mapping exercise, the results of which are presented in table 3. As a SIDS, Seychelles has a relatively small NIS. While the system appears to have some functional linkages between its actors and stakeholders, the ecosystem remains quite dispersed.

Although some positive connections exist, particularly between government ministries and agencies within the economic, technological and innovation subsystems, overall linkages across the NIS are weak. The leading cause for the weak linkages may be attributed to the prevalent culture of departmental isolation within the government and the slow progress in digital integration efforts. Furthermore, challenges may stem from the ineffective implementation of the STI Integrated Governance System, which played a pivotal role in executing the STIPS 2016–2025. This is particularly evident in the relationships between the NIS and other subsystems, such as information and communication technology and the foreign sector, as illustrated in table 4.

Stronger stakeholder connections are vital for effective technology adoption

Table 3
Linkages among actors of the Seychelles NIS

Institutional linkages	Research outputs	Innovation ecosystem	Community-based linkages
Government ministries and agencies are the main actors providing support to the technology in terms of policy, regulations and standards	Public expenditure on R&D was about 0.19 per cent of the gross domestic product.	The BTI is in the implementation phase, focusing on the blue economy cluster.	Local farmer associations provide support to the farming community.
Low levels of inter-institutional trust between public- and private sector entities	Based on the R&D survey 2017, 149 researchers were recorded	Absence of a national innovation policy framework	Absence of a cooperative mode of production system
Low level of institutional linkages and trust among knowledge-based institutions	Most research is initiated by foreign scientists, who have funding from abroad; often the data are not shared.	A new industrial policy was developed and has been approved by the cabinet of ministers.	Farming communities are dispersed and structured as large, medium, small and backyard farming.
Public-private partnerships in both agriculture and energy sectors are low.	Government agricultural research laboratories are available but lack the technical capacities to run those infrastructures effectively.	Incubation space is seriously lacking.	All PV suppliers are centralized in the industrial development area on the main island.
Adopters of the technology are very limited in number	The agricultural research facilities are poorly staffed	Limited access to financing facilities	Limited access to financing facilities
Collaborative platforms (technology acquisition funding, technology) are weak.	No research facilities for PV, except for standards that are set by the Seychelles Bureau of Standards (SBS)		
	A framework for a national research foundation has been developed but not yet implemented.		
	A knowledge hub for all scientific data is in development.		

Table 4
Strength of linkages in the Seychelles NIS

	STI and industry	Executive and legislative arms of government, i.e., cabinet of ministers and the National Assembly	Technology and innovation subsystem: Economy	Technology and innovation subsystem: Industry	Other subsystems: Department of Information and Communication Technology	Technology and innovation subsystem: Foreign sectors
Policy and programme design and implementation	Strong	Strong	Strong	Strong	Strong	Strong
Regulation and implementation	Weak	Weak	Weak	Weak	Weak	Weak
Finance	Weak	Weak	Weak	Weak	Weak	Weak
Research, technology and education institutions	Weak	Weak	Weak	Weak	Weak	Weak
Support bodies	Weak	Weak	Weak	Weak	Weak	Weak
Firms	Weak	Weak	Weak	Weak	Weak	Weak

7.

Public engagement in the technology assessment

> **Stakeholder engagement is key to successfully adopting agrivoltaics in Seychelles. Through stakeholder mapping and focus group discussions, inputs from diverse groups, including policymakers, farmers, and community members, were gathered to identify challenges and build support. This participatory approach ensures that agrivoltaic technology is better positioned to address practical needs and barriers, fostering broader acceptance and implementation.**

Stakeholder and Actor Mapping Process

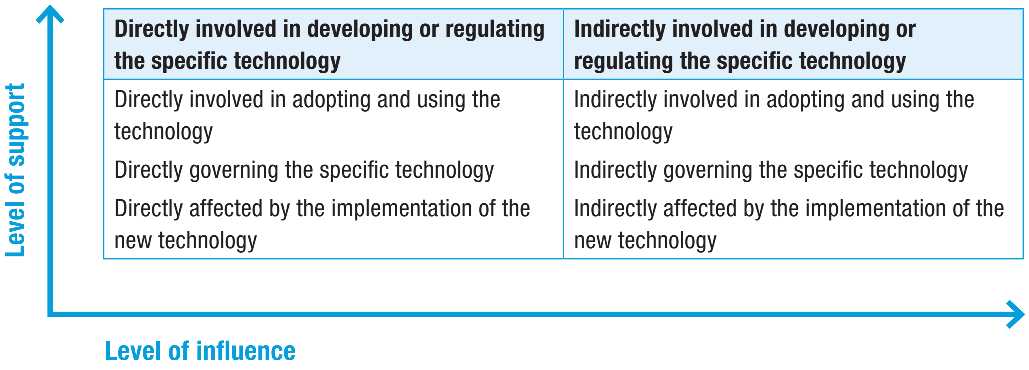
The stakeholder and actor mapping process was carried out through an adapted Mendelow's Matrix (Professional Academy, 2023).[16] As shown in figure 9, the matrix was adapted by replacing the axes of interest and power with the levels of support and influence stakeholders and actors may have in procuring and adopting the technology being assessed.

The resulting composition of actors and stakeholders is shown in table 5, while their roles are detailed in table 6. The latter indicates that several actors directly influence policies, regulations, and technology governance.

> Inclusive stakeholder engagement helps **drive meaningful insights and support**

Figure 9

Level of support and influence of actors and stakeholders using an adapted Mendelow's Matrix



Directly involved in developing or regulating the specific technology	Indirectly involved in developing or regulating the specific technology
Directly involved in adopting and using the technology	Indirectly involved in adopting and using the technology
Directly governing the specific technology	Indirectly governing the specific technology
Directly affected by the implementation of the new technology	Indirectly affected by the implementation of the new technology

Source: Professional Academy (2023).

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[16] Mendelow's Matrix was created in 1991 to analyse individual stakeholders by measuring their interest and power. It has been adapted for the purpose of the selection process of actors and stakeholders.

Focus group discussions reveal critical barriers and opportunities for agrivoltaics

Some entities listed in the tables collaborate with primary actors in formulating policies, regulations and standards, as well as ensuring compliance with national laws impacting all business activities, such as licensing and taxation. The MIEI, Ministry of Finance, National Planning and Trade (MFNPT), and Ministry of Health indirectly support the adoption and implementation of ACE through their respective policy frameworks, legislative measures, and regulatory oversight.

Focus group discussions

The actor and stakeholder mapping was used to conduct three sets of FGDs in July and August 2023. The attendance varied across sessions, with a total of 15 actors and stakeholders participating.[17] The FGDs were guided by questions that delved into various aspects surrounding the introduction and regulation of ACE in Seychelles. Participants were prompted to consider potential regulatory and governing issues that may arise, as well as challenges and barriers to adoption. Additionally, they explored the potential impacts of the technology, both positive and negative, on the economic, social, environmental, and cultural aspects of local communities.[18]

Table 5

Composition of actors and stakeholders

Directly involved in developing or regulating the specific technology	**Indirectly involved in developing or regulating the specific technology**
• Department of Agriculture • Department of Climate Change • Seychelles Energy Commission (SEC) • Public Utilities Corporation (PUC) • SBS • Seychelles Planning Authority (SPA)	• Seychelles Investment Board (SIB) • Seychelles Licensing Authority • Seychelles Revenue Commission • Special Committee for Food Security in the National Assembly
Directly involved in adopting and using the technology	**Indirectly involved in adopting and using the technology**
• Seychelles Institute of Agriculture and Horticulture • Farmers associations (all) • Farmers • Private farming entities • Hotels • Island Development Company (IDC)	• PV suppliers • Consumers who buy these products • Seychelles Chamber of Commerce and Industry • Seychelles Chamber of Commerce and Industry • Citizens’ engagement
Directly governing the specific technology	**Indirectly governing the specific technology**
• Ministry of Agriculture, Climate Change and Environment (MACCE) • Ministry of Land and Housing • Biosecurity Agency	• MIEI • MFNPT • Ministry of Health

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[17] A list of the participants of the FGDs is provided in appendix 4.

[18] The guiding questions are listed in appendix 2.

Table 6
Actors' roles in implementing the technology

Actors	Roles	Remarks
MACCE	The MACCE has the overarching responsibility for policies, regulations, and technology governance.	This ministry is very relevant to agrivoltaics as it has the portfolio to oversee the two sectors participating in the TA.
Ministry of Land and Housing	The Ministry of Land and Housing has the overarching responsibility for policies, regulation of land use and infrastructure.	By law and regulation, any infrastructure should receive approval from this ministry.
Department of Agriculture	As it falls under the MACCE, it has the prime responsibility for policies, regulations and governance of the technology	The Department of Agriculture, apart from policy oversight, provides research facilities and extension services to farmers. The department also provides training in new technologies, subsidies, and support to promoters in accessing funding.
Department of Climate Change	Works in conjunction with the Department of Agriculture to develop policies and regulations	Agrivoltaics is a climate-smart technology whose implementation depends on the joint oversight of the Departments of Agriculture and Climate Change.
SEC	Has the prime responsibility for policies and regulations in the energy sector	Agrivoltaics has to comply with the regulations set by the SEC.
PUC	Works in conjunction with the SEC and SBS in the development of policies, regulations, and standards	Agrivoltaics will have to comply with all regulations.
SBS	Works in conjunction with the SEC and PUC on standards	Agrivoltaics will have to comply with all relevant standards. The SBS oversees PV suppliers in collaboration with the SEC and PUC to ensure their products meet the approved national standards.
SPA	Responsible for infrastructure development	Agrivoltaics requires infrastructure and needs the approval of the SPA. The SPA provides guidelines for infrastructure development. Once promoters comply with all requirements, their plans are approved.
SIB	Acts as a one-stop shop for any investment in Seychelles for both domestic and foreign investments	Promoters in agrivoltaics need to go through the SIB for support in approving their projects.
Seychelles Licensing Authority	Responsible for oversight of all licensable activities at the national level	Promoters of PV technology are required to have a license to operate their business.
IDC	The IDC, which is mandated to develop the outlying islands of Seychelles, is one of the main agricultural producers and may need to adopt this technology to remain competitive.	Lately, the IDC has pledged to increase its agricultural output to help reduce the imports of certain crops that can be grown locally. This State-owned company is already investing in modern technology to enhance consistency in crop production.
PV suppliers	Agrivoltaics will open more business opportunities to PV suppliers	Local PV suppliers have been playing a key role in adopting PV as part of the energy mix. They are key in the integration of PV into crop production.
Private farming entities	The private farming entities are the most innovative within the farming community and they are most interested in agrivoltaics. They are putting pressure on the government to amend regulations and provide incentives for the implementation of agrivoltaics.	Private farmers may be large, medium or small based on their production output. The large and medium-sized farmers in crop production have been the most innovative. They are the ones that have introduced semi-controlled crop production using hydroponic technology.
Seychelles Revenue Commission	The Revenue Commission is responsible for taxation, excises and ensuring that all businesses have a tax identification registration.	The implementation of ACE requires the importation of taxable components. Furthermore, PV suppliers need to have a tax identification number to operate their business.

8.

Analysis of the findings

Analysis of findings, drawing from literature reviews, expert insights, and stakeholder consultations, shows that agrivoltaics offers several opportunities, including (a) access to low-interest funding, (b) institutional support for collaboration, (c) strong public demand for fresh produce and renewable energy, among others. Some key challenges include (a) high initial costs, (b) regulatory barriers, (c) limited access to capital for vulnerable groups, and more. Economic impacts cover (a) efficient land use, (b) job creation, (c) revenue from electricity sales, and others. Social impacts involve (a) potential marginalization of small-scale farmers, (b) technological disparities, and (c) market disruption, among others. Environmental impacts include (a) reduced carbon emissions, (b) water conservation, (c) mitigation of soil erosion, and more.

This chapter analyses the evidence gathered through the literature research, expert inputs and FGDs. Through this analysis, the opportunities, challenges and expected impacts are explored, guiding the formulation of policy recommendations.

Opportunities

Adopting ACE presents a range of opportunities to address challenges Seychelles encounters. Some of these opportunities include:

- The presence of a good post-COVID-19 economic recovery in the agriculture and energy sectors suggests a conducive economic environment for investment and development of agrivoltaic technology. This indicates potential financial stability and support for initiatives aimed at sustainable agricultural practices.
- The institutional set-up facilitates collaboration and coordination, particularly the ministerial portfolio fostering synergies between agriculture, energy, climate change, and environment sectors under the MACCE. This integration ensures a holistic approach to addressing sustainability challenges and optimizing resource allocation for agrivoltaic initiatives.
- Access to credit under special schemes with low interest rates, as well as incentive schemes supporting the installation of PV systems, presents opportunities for funding and financial support. This availability of financial resources reduces barriers to entry and promotes investment in agrivoltaic technology.
- The interest of youth in the sector, who are likely to create innovative solutions, coupled with the availability of the DSTI's BTI, contribute to a conducive environment for technological advancement and entrepreneurship. This fosters innovation-driven growth and the adoption of cutting-edge technologies in agrivoltaic practices.
- The increased public awareness and national demand for renewable energy,

Strong post-COVID recovery and incentives **boost agrivoltaic investment opportunities**

Table 7
Potential barriers to the implementation of the technology

Type of barrier	What can be done to overcome this barrier?	Who needs to be involved?	Who leads on overcoming this barrier?	What's the government's role?
Lack of investment and high costs	Provision of affordable loans	• MFNPT • Department of Agriculture • SEC • Commercial banks • Development Bank of Seychelles	MFNPT	• Provide guarantees for loans • Improve the ease of doing business to encourage investment
Regulatory and institutional framework challenges	Development of regulatory framework and establishment of improved institutional set-up	• MFNPT • Department of Agriculture • SEC	Department of Agriculture	Regulation and implementation mechanism Set up adequate institutions
Policy and strategic framework	Development of evidence-based policy and strategic framework	• MFNPT • Department of Agriculture • SEC	Department of Agriculture	Policy and strategy design, and implementation
Lack of training and technical knowledge for farmers	Technical capacity-building to support the implementation of the selected technology	Local knowledge-based institutions	Seychelles Institute for Agriculture and Horticulture	Infrastructure development and funding
Lack of incentives for farmers	Develop incentive schemes	• MFNPT • Department of Agriculture • SEC	MFNPT	Policy and funding
Government commitment and coordination	Enhance collaboration between relevant government agencies	Ministries and agencies, non-government actors and stakeholders	Department of Agriculture	Facilitate intergovernmental collaboration
Scarcity of land	Allocation of arable land	• Department of Agriculture • SPA • Department of Environment and Climate Change	Department of Agriculture	Make arable land available and accessible
Lack of R&D facilities	Enhance R&D facilities	• Department of Agriculture • Department of Environment and Climate Change • University of Seychelles • Seychelles Institute of Technology and other relevant knowledge-based institutions	Department of Agriculture	Enhance R&D capacity and capability, and increase R&D funding

coupled with high local demand for fresh agricultural products and emphasis on food and nutrition security, present significant market opportunities for agrivoltaic technology. This aligns with the vision of achieving renewable energy targets and reducing the national carbon footprint, contributing to achieving the United Nations Sustainable Development Goals.

Challenges

In spite of the opportunities, there are a number of barriers of different types to the effective adoption of the technology. These barriers include economic and infrastructural factors, physical resources, policies, regulations, institutional arrangements, knowledge and skills, R&D, and environment. A number of these barriers are listed in table 7 with suggested potential strategies to overcome them and identifying key stakeholders involved in the process. Additionally, the table delineates the leadership role necessary for addressing each barrier and examines the government's role in mitigating these challenges.

Expected impacts

The evidence gathered points to the expected economic, social and environmental impacts reviewed in this section.

Economic impacts

Agrivoltaic technology for controlled-environment crop production brings significant economic benefits for land use and energy costs. This is possible by optimizing land utilization for both agricultural and PV power generation purposes and simultaneously lowering energy costs and thereby overall production costs. While it requires an initial capital investment, energy costs over the medium to long-term are reduced by harnessing cheaper solar energy rather than traditional sources of energy. This integrated approach enables efficient land use, encompassing crop cultivation and electricity harvesting. Besides an increase in agricultural output, ACE may also generate revenue streams through the sale of electricity while also fostering employment opportunities. Particularly in Seychelles, where arable land is scarce, agrivoltaic solutions are pivotal in maximizing land productivity and enhancing crop yields per unit area. This is especially true for ACE, where PV technology is seamlessly integrated into the production system. From a macroeconomic standpoint, agrivoltaic practices contribute to narrowing the trade deficit by reducing food imports via import substitution. Moreover, agrivoltaic initiatives directly contribute to economic growth through various channels:

- Enhancing crop yields to ensure a consistent supply of locally produced agricultural goods, which in turn supports the tourism industry by promoting fresh, locally sourced products;
- Attracting increased investment in the energy and agriculture sectors;
- Creating employment opportunities in these sectors; boosting fiscal revenues through expanded business activities;
- Fortifying economic resilience against the impacts of climate change.

Social impacts

The introduction of agrivoltaic technology as an innovative disruptor in the agriculture and energy sectors can create several social consequences. These include:

- Technological disparity: The emergence of agrivoltaics may exacerbate divisions between traditional and modern farming communities, potentially widening the technology gap.
- Marginalization of vulnerable groups: Female farmers, who are generally engaged in subsistence, backyard and low-income farming, may face marginalization due to the substantial capital investment required by the technology. This could limit their participation and access to benefits.

- Limited access to capital: The small-farming community may encounter challenges accessing capital, potentially leading to their displacement within the industry.
- Competition for land: Intensified competition for land, driven by the implementation of agrivoltaic technology, may lead to the displacement of traditional farmers, women, and lower-income farming communities.
- Training gaps: Limited access to training in the new technology may hinder traditional farmers' ability to adopt and integrate agrivoltaic practices into their farming operations, thereby restricting their participation.
- Market competition: The lower production costs associated with agrivoltaic technology may disrupt market dynamics, potentially disadvantaging traditional farmers, women and low-income farmers who rely on traditional methods.

Environmental impacts

Finally, it is crucial to consider both the positive and negative environmental impacts of adopting ACE. Negative impacts include:

- Run-off contamination: Run-offs from production systems may impact ecosystems in surrounding production areas, potentially leading to contamination.
- Generation of physical waste: The disposal of materials such as used polythene, plastics, panels and batteries can contribute to environmental pollution.
- Impact on watersheds and groundwater: Run-offs may contaminate watersheds and groundwater, affecting local water sources and ecosystems.
- Effect on water tables: Groundwater sources, particularly in outlying islands, may be impacted by changes in water table levels.

However, despite these potential negative externalities, the implementation of ACE also offers several positive environmental impacts, including:

- Optimization of agricultural land: The technology enables the efficient use of agricultural land, maximizing productivity while minimizing environmental footprint.
- Reduction in pesticide use: Controlled-environment conditions help reduce the need for pesticides, promoting environment-friendly farming practices.
- Efficient water use: Localized irrigation systems optimize water use, minimizing water wastage and promoting water conservation.
- Reduction in carbon emissions: The use of PV systems reduces reliance on fossil fuels, leading to a reduction in carbon emissions and mitigating climate change impacts.
- Mitigation of soil erosion: Compared to traditional crop production methods, agrivoltaics helps reduce soil erosion, preserving soil health and fertility.
- Decrease in inorganic fertilizer use: The efficiency of irrigation systems reduces the need for inorganic fertilizers, minimizing environmental pollution and promoting soil sustainability.

Additional aspects with respect to the TA goals are listed in table 26 of appendix 5.

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9.

Conclusions and policy recommendations

ACE could help Seychelles advance the use of high-tech agricultural practices, but several policy gaps need to be addressed. 11 policy recommendations are proposed, including refining regulations, boosting institutional support, and offering financial incentives to attract investments. Raising public awareness and expanding training opportunities will ensure that the wider society benefits from ACE.

The present UNCTAD TA pilot project takes place at a time when the Department of Agriculture is drafting a new agriculture policy and strategy. In the new policy and strategy, one of the main goals is to increase the volume of local production in relation to a total consumption of local fruits and vegetables sustainably to 90 per cent by 2030 (Republic of Seychelles, Ministry of Agriculture, Climate Change and Environment, Department of Agriculture, 2023). Concurrently, the national agenda has highlighted the significance of agrivoltaics by considering funding in the 2024 budget to advance high-tech agricultural practices.

Despite the government's proactive steps toward addressing food and nutrition security through new policies, strategies, and incentives, several policy gaps still require attention for ACE's successful integration into the agricultural production system. As a result of the findings of this TA exercise, 11 policy recommendations are proposed.

Integrating solar power into agriculture **requires bridging regulatory gaps**

(1) Address the regulatory gaps to allow the integration of PV with agriculture

Despite the growing interest in agrivoltaics from governmental and private-sector entities, the absence of regulatory frameworks to facilitate such integration remains a notable challenge. This regulatory gap has been consistently highlighted in FGDs. It poses a significant obstacle, standing as the primary limitation hindering the widespread integration of PV into agriculture, despite stakeholders expressing strong intent to adopt the technology and demonstrated interest from numerous farmers. The following can be done to address this issue:

- Carry out a national exercise to take stock of all the existing regulations in both the agriculture and energy sectors;
- Re-evaluate the existing laws, regulations, and standards to accommodate the integration of PV into agriculture;
- Assess the resources needed to enforce new regulations and standards;
- Ensure that regulations consider marginalized groups, particularly women and low-income farming communities, impacted by the new technology.

Table 8

Requirements to implement policy recommendations addressing regulatory gaps for the integration of PV technology into agriculture

Actions	Requirements
Setting up a national task force	A national task force is needed to oversee the process to ensure that laws, regulations and standards are aligned to international norms for the new technology.
Review of existing laws, regulations and standards	Carry out a stakeholder analysis based on the current NIS status. This will clearly identify key stakeholders to be involved in the process.
Assignment of leadership roles	Leadership role assignment is critical to ensure responsiveness, outcome orientation, predictability, proportionality, and independence of the new regulatory framework.
Synergies and trade-offs	Evaluate synergies and trade-offs among existing laws, regulations, and standards across the energy and agriculture sector to support the new technology.
Resource allocation	Identify and make provision of resources for compliance with the new laws, regulations, and standards.

(2) Review the Seychelles Energy Policy 2010–2030 to accommodate ACE

Despite the existence of a long-term policy and strategic framework for energy, there is a prevailing sentiment that the framework requires review to better support the implementation of the strategy. Concerns have been raised regarding the lack of revisions to the framework, which has remained unchanged for over 12 years. Participants in FGDs generally agreed that conditions within both the energy and agriculture sectors have evolved significantly during this time. With the impending implementation of ACE, addressing the need for policy review has become imperative, and the following actions are required:

- Verify, define and detail the problem;
- Establish evaluation criteria;
- Identify alternative policy and strategic options;
- Assess alternative policy and strategic options;
- Identify and elaborate on the alternatives, and select preferred actions;
- Define an implementation, monitoring and evaluation framework for the revised policy.

Updating the Energy Policy supports agrivoltaic integration in Seychelles

Table 9

Requirements to address the issues related to the policy and strategic framework in the energy sector

Items	Requirements
Establish a national task force	A national task force is needed to lead the policy and strategic framework review.
Definition of the problems	Stakeholders should engage to define the problems with the existing policy and strategic framework.
Criteria for evaluation	Develop evaluation criteria for the current policy and strategic framework.
Alternative policy and strategic options	Identify and assess alternative policy and strategic options to suit the current environment, taking into account the need to accommodate the new technology.
Selection of policy and strategic options	Select the preferred policy and strategic options.
Monitoring and evaluation framework	Develop a monitoring and evaluation framework for the implementation of the revised policy.

Quantitative impact assessment should be conducted

(3) Evaluate quantitatively the impacts of ACE on the economy, culture, society and the environment

During one FGD, the SPA expressed significant concern over the absence of standards and regulations to mitigate and reduce the technology's environmental impacts. Other FDGs echoed this concern, emphasizing that Seychelles' pristine environment is key to its tourism industry, which serves as the backbone of the economy. This recommendation urges an evaluation of the overall impacts that they may have on the economy, culture, society, and environment.

Considering Seychelles' status as a SIDS with a unique, fragile, and pristine environment critical to its tourism-based economy, gauging these impacts is paramount. This can be performed through:

- Economic impact assessment of the technology;
- Environmental impact assessment of the technology;
- Social impact assessment of the technology;
- Cultural impact assessment of the technology.

Table 10
Requirements for the development of new standards and regulations

Type of impact	Requirements
Economic impact assessment	In view of the complexity of the assessment, the outsourcing of external expertise to carry out the following process is important to: • Establish strategic context; • Establish the need for expenditure; • Define the objectives and constraints; • Identify and prioritize strategic options; • Identify and quantify the monetary costs and benefits of options; • Appraise risks and adjust for optimism bias.
Environmental impact assessment	Reinforce the existing MACCE environmental impact assessment to accommodate the new technology.
Social and cultural impact assessment	• Assess who is likely to be impacted and how; • Identify the affected communities; • Identify and assess potential social and cultural impacts; • Develop management measures to mitigate adverse impacts and enhance benefits; • Develop monitoring and reporting mechanisms.

(4) Facilitate access to funding mechanisms for ACE pilot projects before scaling to fully commercialized ventures

Access to funding emerges as a concern for prospective adopters of the technology. Given its novelty, pilot projects require adequate funding mechanisms to ensure viability. The following can be done to support funding for piloting of the technology at the start-up phase:

- Provision of start-up funds for those venturing into the new technology;
- Support for start-ups through the DSTI's BTI;
- Establishment of a national innovation fund;
- Establishment of a funding mechanism through a consortium of commercial banks;
- Explore the possibility of microfinancing schemes.

> **ACE pilot projects** should be supported with funding

Table 11

Requirements for developing funding mechanisms

Items	Requirements
Start-up funds	Start-up funds such as grant schemes need to be put in place to support pilot projects.
Incubation facility	Build on the existing capacity and capability of the innovation ecosystem to support new ventures in agrivoltaics, specifically for the technology being assessed.
National innovation fund	Implement the recommendations for establishing a national innovation fund to support the adoption of the new technology.
Commercial banks consortium	Work with commercial banks to establish an investment mechanism to support start-ups.

(5) Clarify and, if necessary, improve the effectiveness or expand the incentives on ACE

Incentives for ACE adoption **should be enhanced and innovative**

Across various FGDs, there was a perception that farmers tend to be conservative and risk-averse, except for the younger start-ups in agriculture. To foster the adoption and successful implementation of technology, particularly in high-tech agriculture, there is a recognized need to enhance incentives, as also shown in table 26 of appendix 5. Although existing incentives in both the agriculture and energy sectors include subsidies for inputs and exemptions on the import of PV panels, the introduction of ACE introduces a new layer of complexity. This technological complexity entails additional costs. To address this, the following actions can be taken to support incentives:

- Put in place a committee to review all incentive schemes in both the agriculture and energy sector;
- Introduce new incentive schemes that will support the implementation of the technology;
- Put in place a mechanism for reviewing the schemes.

Table 12

Requirements for supporting incentives

Item	Requirements
Committee to review existing incentive schemes	Conduct a stakeholder analysis to set up a multidisciplinary committee to review all existing incentives in the agriculture and energy sectors.
New incentive schemes	Introduce new incentive schemes to support start-ups.
Mechanism to monitor and review the incentive schemes	Carry out periodic assessments on the effectiveness of the incentive schemes while analysing their socioeconomic benefits.

(6) Put in place measures within the NIS to better support the adoption of ACE

This recommendation suggests implementing measures within the NIS to support better the adoption of agrivoltaic technology for controlled-environment crop production. The recommendation is based on the identified potential barriers to implementation, as outlined in the SWOT analysis of both the agriculture and energy sectors (tables 1 and 2) and in table 7, which indicate weak linkages among actors and stakeholders in the system. The following actions can be taken to address these barriers:

- Carry out a situational analysis of all the linkages of the NIS;
- Carry out a diagnostic study on the causes of the weak linkages among actors and stakeholders of the NIS;
- Evaluate the results of both studies to assess the resources that are needed to strengthen the NIS to support the implementation of the technology;
- Develop programmes to strengthen the linkages of the NIS to build synergies to support the implementation of the technology;
- Make reference to the SWOT analysis of both the agriculture and energy sectors to address the challenges of the two sectors vis-à-vis the implementation of the technology;
- Address the potential barriers that have been identified in this study;
- Carry out an economic analysis addressing each of the identified barriers.

Existing NIS linkages **should be strengthened and new ones built**

Table 13
Requirements to address barriers to the adoption of the technology

Item	Requirements
Situational analysis of the NIS	Use the mapping results of the NIS to carry out an in-depth situational analysis of the status of the linkages among actors and stakeholders of the NIS in support of the implementation of the technology.
Diagnostic study of the NIS	It is important to have a diagnostic study of the NIS to understand the causes of the weak linkages between actors and stakeholders in the system in order to remedy the situation.
Evaluation of the results of the situational analysis and the diagnostic study of the NIS	Process and evaluate the results of the situational analysis and diagnostic study of the NIS to understand the status of linkages between actors and stakeholders.
Develop programmes	Develop programmes to strengthen the linkages to create synergies between actors and stakeholders within the NIS to support the implementation of the technology.
Address the weaknesses and threats in both the agriculture and energy sectors	Establish a working group to study the weaknesses and threats in both the agriculture and energy sectors to provide recommendations to improve the environment that is enabling the implementation of the technology.
Economic analysis	Set up the timeframe to address all the barriers and conduct an economic analysis of the process to make budgetary provisions.

Enhancing institutional capacity facilitates training, R&D and **international cooperation**

(7) Enhance the level of institutional capacity for training, R&D, laboratory infrastructure and regional and international collaboration to support the implementation of the technology

The current capacity and capability in R&D are insufficient to effectively implement agrivoltaic technology, as detailed in table 26 of appendix 5. Weaknesses in R&D, as highlighted by SWOT analyses of both sectors and training institutions, underscore the need for improvement. Strengthening training and R&D capacity and fostering regional and international collaboration is essential for successful technology implementation. This could be achieved through the following:

- Carry out a situational analysis to identify the gaps in the institutional capacity for training to support the implementation of the technology;
- Conduct an audit of the R&D facilities at the national level to support the implementation of the technology;
- Devise action plans and programmes to address the gaps in institutional capacity for training to support the implementation of the strategy;
- Develop action plans and programmes to address the gaps in R&D capacity to support the implementation of the strategy;
- Take stock of the current regional and international collaboration in both the agriculture and energy sectors;
- Develop regional and international collaborations to support the implementation of the technology.

Table 14

Requirements for strengthening institutional capacity for training

Item	Requirements
Gap analysis	Conduct a situational analysis to identify the gaps in institutional capacity for training to support the technology implementation.
Audit on R&D capacity	Conduct a new audit to update the data on R&D capacity to support the implementation of the technology using the existing methodology of the first audit carried out by the former National Institute for Science, Technology, and Innovation in 2018.
Action plans and programmes for R&D	Set up a national committee to develop action plans and programmes for R&D to support the implementation of the technology.
Audit on regional and international collaborations	Conduct an audit of regional and international collaborations in the agriculture and energy sectors.
Enhancement of regional and international collaboration	Build on the existing regional and international collaborations to support the implementation of the technology.

(8) Reassess the current land allocation system to determine how ACE can be integrated into agricultural production

Land scarcity and competition are ongoing challenges in Seychelles, with various conflicting interests vying for limited land resources. Policy recommendation eight addresses this issue, consistently highlighted throughout the TA process. The SWOT analysis of the agriculture sector and table 26 in appendix 5 also underline this challenge. The issue of land allocation to make land more accessible for agricultural development can be addressed in the following ways:

- Take stock of all land currently allocated to agriculture;
- Assess the potential of new land for agrivoltaics development;
- Put in place new mechanisms that will make land accessible to agrivoltaics as a high-tech agriculture industry;
- Put in place a system to manage all high-tech agricultural production as a new cluster.

Evaluating land use can **unlock new opportunities for agrivoltaics**

Table 15

Requirements for an effective agricultural land allocation system

Item	Requirements
Audit on existing agricultural land	Take stock of the current agricultural land availability and status to evaluate how agrivoltaics can be integrated into agricultural production.
New land allocation for agrivoltaics	As agrivoltaics, in principle, maximizes the benefit of land use as both energy and crops are produced in the same area, new land must be identified and allocated to the cluster of high-tech agriculture. Agrivoltaics should be classified as high-tech agriculture.
New mechanism for agricultural land allocation	Put in place a new, effective mechanism to allocate land to support the implementation of the technology within the high-tech agriculture industry segment.
New agricultural land management system	Set up a new agriculture land management system to support the implementation of the technology.

(9) Establish measures to ensure an effective supply chain to support the technology

A resilient supply chain can encourage ACE adoption

Seychelles' insularity presents businesses with supply chain challenges. The actors that are to implement the technology have voiced their concern on issues related to supply chain disruptions that affect their business operations, as reflected in table 26 of appendix 5. An effective supply chain to support the technology can be achieved in the following ways:

- Put in place institutional mechanisms for an effective supply chain for both the agriculture and energy sectors;
- Apply artificial intelligence for smart inventory of agriculture and energy sector inputs;
- Set up schemes that will support those adopting the technology to reduce the impact of volatility and disruption in the supply chain;
- Establish mechanisms to ensure that adequate after-sales services are in place to support the implementation of the technology.

Table 16

Requirements to ensure an effective supply chain to support the technology

Item	Requirements
Institutional mechanism for effective supply chains	As supply is vital for SIDS due to their insularity, an institutional mechanism must be put in place to minimize the impact of volatility and disruption in the supply chain that supports the implementation of the technology.
Application of artificial intelligence in the supply chain	Develop smart procurement and inventory systems using artificial intelligence for an effective supply chain to support the implementation of the technology.
Schemes to ensure production continuity	In the case of disruption that impacts those adopting the technology, a scheme to compensate for losses should be implemented to ensure production continuity.
After-sales services	To ensure continuity in production, after-sales services of equipment and other technological inputs and after-sales service support for those adopting the technology should be put in place.

(10) Ensure that the technology is accessible to women, traditional and low-income farmers

The traditional and low-income farming community, which includes a significant portion of the women active in agriculture, faces challenges in accessing resources, particularly financing, to adopt ACE technology in their production systems. This may widen the technological gap and, in turn, may exacerbate the marginalization of women, as also reflected in table 26 of appendix 5. To address this gender issue and enhance the inclusivity of women, measures to help traditional and low-income farmers can be implemented in the following ways:

- Carry out a census to know the number of women, traditional and low-income farmers actively practicing agriculture;
- Assess their capacity to adopt agrivoltaic technology;
- Develop and implement sensitization and awareness programmes for those segments of the agriculture community;
- Establish training programmes on the new technology;
- Foster small-scale production systems that will suit their needs;
- Put special incentives in place to support these agricultural community segments to help them adopt this new technology.

ACE technology should be accessible by **women and low-income farmers**

Table 17

Requirements to include women, traditional and low-income farmers in agrivoltaic production

Item	Requirements
Census on women, traditional, and low-income farmers	In order not to marginalize women, traditional and low-income farmers, a census should be carried out to understand these segments of the agriculture sector.
Assessment of capacity	Assess the capacity of these segments of the agriculture sector.
Sensitization and awareness programmes	Develop targeted sensitization and awareness programmes to empower women and traditional and low-income farmers to prepare and equip them to adopt the technology.
Training programmes	Develop and implement training programmes for women and traditional and low-income farmers.
Developing small-scale production systems	Assist women, traditional and low-income farmers to set up small-scale agrivoltaic systems.

Education programs can demystify agrivoltaics **and gain public support**

(11) Educate and raise awareness through programmes on ACE

There is a persistent misconception surrounding hydroponically grown vegetables related to beliefs that they present health risks, which poses a challenge to the selected technology as it integrates PV with hydroponic systems, as shown in table 26 of appendix 5. The general population can be educated on the new technology by means of the following:

- Develop sensitization and awareness programmes to educate the general population on the new technology;
- Introduce sensitization and awareness programmes on the new technology in all educational institutions;
- Disseminate information via media about the products that are produced using the new technology.

Table 18

Requirements for education on the new technology

Item	Requirements
Sensitization and awareness programmes for the general public	Develop and implement sensitization and awareness programmes on the technology to educate the general public.
Sensitization and awareness programmes for the education system	Develop and implement sensitization and awareness programmes across all levels of the education system.
Sensitization and awareness programmes through the media	Collaborate with the mainstream media for sensitization and awareness programmes to educate the general public to demystify the misconception that soilless crops present health risks.

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Appendix 1

Establishment of the steering committee and the expert group

A sound and inclusive governance structure is necessary for planning and implementing a good technology assessment. The structure was built around two entities: a Steering Committee (SC) and an interdisciplinary Expert Group (EG). For both, it was important to ensure gender balance.

Terms of reference for the governance of the SC were drafted by the Division of Science, Technology and Innovation (DSTI) and validated and accepted by the Ministry of Investment, Entrepreneurship and Industry. Subsequently, the Minister appointed the SC in October 2022. The Director General of DSTI, as the Chair of the SC, set up the EG, which is composed of government officials and experts in the agriculture and energy sectors, including members of the private sector. Regrettably, Seychelles (like many countries) has a gender disparity in science, technology, and innovation, but efforts have been made to ensure adequate female representation in both the SC and EG. The SC included more women than the EG. See table 19.

Table 19

Composition of the SC and EG

	SC		
Organization	**Male**	**Female**	**Total**
Government	3	5	8
Public Utilities	1	-	1
Academia	-	1	1
Private sector	3	-	3
Civil society	1	-	1
Total	**8**	**6**	**14**

	EG		
Organization	**Male**	**Female**	**Total**
Government	2	1	3
Public Utilities	1	-	1
Academia	0	-	-
Private sector	3	-	3
Civil society	5	-	5
Total	**11**	**1**	**12**

Source: DSTI.

The activities of the EG were directed and guided by the SC. The Chair of the SC assumed this responsibility with the support of DSTI. The EG was responsible for validating inputs from various participants involved in the process.

Tables 20 and 21 list the members of the SC and EG and their affiliations.

Table 20
List of SC members

Name	Designation
Ms Cynthia Alexander (Chair)	Ministry of Investment, Entrepreneurship and Industry (MIEI)
Ms Bernice Charles	Seychelles Energy Commission (SEC)
Mr Nelson Charles	MACCE
Ms Sara Estico	MACCE
Ms Nuette Gordon	University of Seychelles
Mr Roy Govinden	MACCE
Mr Andrew Jean-Louis	Consultant
Ms Linetta Joubert	Ministry of Agriculture, Climate Change and Environment (MACCE)
Ms Sylvie Larue	MACCE
Mr Guy Morel	Consultant
Mr Yves Morel	Suntech Pty Ltd
Mr Barry Nourice	Agricultural Producers Association of Seychelles
Mr Mamy Razanajatovo	SEC
Mr Laurent Sam	Public Utilities Corporation (PUC)

Table 21
List of Expert Group members

Name	Organization
Mr Andre Sopha (Chair)	Seychelles Farmers Association
Mr Steven Roseline (Vice-Chair)	Anse Boileau Farmers Association
Mr Danny Agathine	Val D'Endorre Farmers Association
Ms Cynthia Alexander	MIEI
Mr Wills Dogley	MACCE
Mr Peter Estico	Ministry of Culture, Youth, Sports and Community Development
Mr Pierre Harter	Sustainable 4 Seychelles
Mr Richard Hoareau	Energy Solutions Seychelles
Mr Gino Leon	PUC
Mr Theodore Marguerite	Consultant
Mr Daniel Morin	Grand Anse Mahe Farmers Association
Mr Radley Weber	Vetiver

Appendix 2

Guiding questions for focus group discussions

Questions for stakeholders directly and indirectly involved in regulating the specific technology:

1. In view of the fact that agrivoltaics application in a fully controlled environment in crop production has never been practiced in Seychelles, what are the possible regulatory issues that this technology may face if it has to be introduced?
2. Do you envisage that this technology, despite its potential benefits, will face major challenges due to regulatory measures that may discourage investment in the introduction of agrivoltaics applications in a fully controlled environment in crop production?
3. What are other challenges regulators may face in developing regulations for a technology that complements both the energy and agriculture sectors?
4. Do you have any other views to share?

Questions for stakeholders directly and indirectly governing the specific technology:

1. In view of the fact that agrivoltaics application in a fully controlled environment in crop production has never been practiced in Seychelles, what are the possible governing issues this technology may face if it has to be introduced?
2. Do you envisage that this technology, despite its potential benefits, will face major challenges due to governing issues that may discourage investment in the introduction of agrivoltaics application in a fully controlled environment in crop production?
3. What are other challenges those governing this technology may face as it complements both the energy and agriculture sectors?
4. Do you have any other views to share?

Questions for stakeholders directly and indirectly involved in adopting and using the technology:

1. What are the potential barriers (challenges) that agrivoltaics application in a fully controlled environment in crop production may present in its introduction in the local agricultural production system?
2. What can the government do to support the introduction of this technology?
3. How sustainable will this technology be, taking into account the failures in the past in controlled-environment production, e.g., hydroponics?
4. What are your general impressions on this technology?
5. Do you have any other views to share?

Questions for stakeholders directly and indirectly impacted (positively or negatively) by the implementation of the new technology:

1. How would agrivoltaics application in a fully controlled environment in crop production positively impact your lives, economically, socially and culturally?
2. How would agrivoltaics application in a fully controlled environment in crop production negatively impact your lives, economically, socially, environmentally and culturally?
3. What are your general impressions of the impact this technology on the local crop production system in relation to the communities at large?
4. Do you have any other views to share?

Appendix 3

Details of the focus group discussions and feedback from participants

Table 22

Actors directly or indirectly involved in regulating the specific technology

Questions	Actors directly or indirectly involved in developing and regulating the technology	Responses
1. In view of the fact that agrivoltaics application in a fully controlled environment in crop production has never been practiced in Seychelles, what are the possible regulatory issues that this technology may face if it has to be introduced?	1. Department of Agriculture 2. Department of Climate Change 3. Seychelles Energy Commission (SEC) 4. Public Utilities Corporation (PUC) 5. Seychelles Bureau of Standards (SBS)	1. Possible regulatory issues the technology may face if it is to be implemented 2. The energy sector has a clear regulatory policy and set of standards 3. The Department of Agriculture does not have limitations in its regulations 4. The Agricultural Act is being reviewed 5. There is no policy in agriculture (draft) 6. Best practices to be included in the drafting
2. Do you envisage that this technology, despite its potential benefits, will face major challenges due to regulatory measures that may discourage investment in the introduction of agrivoltaics application in a fully controlled environment in crop production?	1. Department of Agriculture 2. SEC	1. There are no existing regulations to address photovoltaic systems

Table 23
Actors directly and indirectly governing the technology

Questions	Actors involved directly and indirectly governing the technology	Responses
1. In view of the fact that agrivoltaics application in a fully controlled environment in crop production has never been practiced in Seychelles, what are the possible governing issues that this technology may face if it has to be introduced?	1. PUC 2. SBS 3. Seychelles Planning Authority (SPA)	1. SEC is going to be renamed. The bill has been passed and has to go to the national assembly for approval 2. PUC and SEC issues – new technology uses batteries 3. Standards established for PV systems 4. Policy, incentives and standards gaps in agriculture 5. Land allocation, regulating the panel height, especially in view of the fact that most of our agricultural land is near residential areas and regulating the disposal of old panels since it will be an environmental issue in communities
2. Do you envisage that this technology, despite its potential benefits, will face major challenges due to governing issues that may discourage investment in the introduction of agrivoltaics application in a fully controlled environment in crop production?	1. SPA	1. As the planning authority, we will have to assess the development plans on a case-by-case basis 2. The factors to consider would be the land use in the surrounding area 3. This development may pave the way to allow agricultural land use in a closed-off, controlled manner in areas where open-system agriculture is unfavourable
3. What are the regulations for compliance with standards for new and emerging technologies?	1. SEC 2. SBS	1. Technology transfer 2. Safety measures and standards 3. Waste management, e.g. generators 4. System integration, low harmonization.
4. What are the new procedures needed to be adopted or added in the planning approval process for agrivoltaics?	1. SPA	1. There are no additional procedures; the project will go through the existing procedures, as per our regulations

Table 24
Actors adopting and using agrivoltaic technology

Questions	Actors directly involved in adopting and using agrivoltaic technology	Responses
1. What are the potential barriers (challenges) that agrivoltaics application in a fully controlled environment in crop production may present in its introduction to the local agricultural production systems?	1. Private farming entities 2. Seychelles Institute for Agriculture and Horticulture (SIAH) 3. Photovoltaic (PV) suppliers	1. Capital investment 2. Maintenance cost 3. Installation fees 4. Operational cost 5. Importation cost 6. Access to finance 7. Declining crop yield when there is no sunlight 8. Will still rely on the grid (PUC) when there is no sunlight 9. Purchasing, installing and maintaining 10. Special ways for disposing of old photovoltaic cells (technology) will have to be implemented 11. Public misconceptions of PV and agrivoltaic technology 12. Investment issues and high cost-effectiveness 13. High maintenance 14. Trained workers for the instalment
2. What can the government do to support the introduction of this technology?	1. Private farming entities 2. SIAH 3. PV suppliers	1. The need to have a minister dedicated to the agricultural sector only 2. Certain PUC regulations can become a barrier, e.g., electricity cuts and grid systems 3. Farmers' production systems require extension services 4. Standards and regulations 5. Quality labour, capacity-building and also technicians that can support and advise accordingly 6. Incentives to access finance, e.g. lower interest rates and longer grace period 7. Broaden research on this technology 8. Find reliable and trustworthy suppliers 9. Limited local technical capabilities to implement hydroponic systems of production 10. Cost 11. Policy barrier 12. Lack of government support from the ministry 13. A lot of responsibility to run 14. No opportunities for SIAH students 15. Lack of a training programme in the field (trained technicians) 16. Topography and climate change 17. Training for installing the technology 18. Funding
3. How sustainable will this technology be, taking into account the failures in controlled-environment production in the past, e.g. hydroponics? In addition, what do you think are the reasons PV has not played a major role in agriculture and energy in the Seychelles?	1. Private farming entities 2. SIAH 3. PV suppliers	1. Precautions about what types of fertilizers and pesticides enter the country 2. The adoption of PV has been slow due to the regulations in place by PUC, so any endeavour to make use of PV is avoided 3. Lack of exposure and awareness 4. Some regulations may be preventing people from adopting this technology 5. It is in a controlled environment 6. High yield 7. More quality crops 8. Fast crop production 9. Slow technology 10. Lack of persistence 11. Lack of research 12. Expensive equipment 13. Untrained workers to be able to operate the technology

Appendix 4

Organizations and participants of the focus group discussions

Table 25
List of organizations and participants in the focus group discussions

Organization	Name of participant	Date
Community Development	Mr Peter Estico	21-Jul-23
Seychelles Energy Commission	Mr Mamy Razanajatovo Mr Guilly Moustache	21-Jul-23
Vetiver	Mr Radley Weber	21-Jul-23
Ministry of Agriculture, Climate Change and Environment, Department of Agriculture	Ms Sarah Calderin Estico Dr Nelson Charles	21-Jul-23
Agricultural Producers Association of Seychelles	Dr Barry Nourice	21-Jul-23
Public Utilities Corporation	Mr Laurent Sam	21-Jul-23
Division of Science, Technology and Innovation	Ms Susan Ambetsa Mr Raffaello Rotolo Ms Dorea Banane	21-Jul-23
Seychelles Planning Authority	Ms Melissa Jumaye Ms Amina Furneau Mr Arneau Cassime	26-Jul-23
Seychelles Institute of Agriculture and Horticulture	Ms Ghislaine William	07-Aug-23

Appendix 5

Technology assessment goals in terms of activity spheres

Table 26

List of technology assessment goals in terms of activity spheres

Impact dimension issue: Technological and scientific aspects			
Goal 1 Raising knowledge – both scientific and of technology assessment	**Expected impacts**	**Expected outcomes**	**Overview of consequences given**
	• Resistance in adopting this technology due to its complexity; • High maintenance cost of the technology; • Reliant on large surface area of PV and extended period of sunlight; • Very high purchase and installation cost of the technology; • Expected high operational cost at the outset; • High importation cost due to taxation; • Gaps in existing regulations may be barriers for the adoption of the technology; • Accumulation of waste from the technology such as disposed photovoltaic cells, batteries, run-offs from batteries, etc.	• Low interest in adopting the technology; • Increase in cost of products (high production cost will be passed on to the consumers); • Adopters of agrivoltaics may need large surface areas of production; • Reliance on the grid during overcast periods; • Barrier of entry of agrivoltaic technology due to gaps in regulations; • Environmental impact of the agrivoltaic technology due to industrial wastes.	• No improvement in local food production contributing to food and nutrition security; • Decline in crop yield when there are overcast weather conditions; • Some of the existing Public Utility Corporation (PUC) regulations may become barriers; • Increase in misconceptions of photovoltaic (PV) and agrivoltaic technology; • The adoption of agrivoltaics slow due to lack of standards and regulations.

Goal 2 Forming attitudes or opinions – priority-setting	**Expected impacts**	**Expected outcomes**	**Priorities set**
	• Quality labour, capacity-building and also technicians that can support the technology and advise accordingly; • Broaden research on this technology; • New action plans or initiatives to further scrutinize the problem at stake; • Find reliable and trustworthy suppliers; • No opportunities for the Seychelles Institute for Agriculture and Horticulture (SIAH); as the model school it needs the opportunity to be acquainted with the new technology; • Lack of training programmes in the PV field. There is no capacity at the SIAH for trained instructors/personnel for the technology and so students do not gain (there are also no trained technicians).	• Topography change due to climate change challenges; • Training for installing the technology needs to be done; • Funding needs to be created for successful implementation of the technology.	• Visions and scenarios on possible impacts and accompanying policy measures need to be introduced; • Standards and regulations; • Need for trained personnel for implementation of the technology; • Need for quality control in the importation of fertilizers and pesticides to be used in agrivoltaic production.
Goal 3 Initializing actions – reframing the debate	**Expected impacts**	**Expected outcomes**	**Actions**
	• New ways of governance of the technology in the agricultural sector; • Quality of labour; • Capacity-building programme and technical support; • Enhancement of research programme as well as infrastructure to support the technology; • New and reliable supply chain to sustain inputs geared towards the implementation of the technology; • New funding schemes beyond the existing ones; • New incentive schemes for procurement, installation and maintenance of this technology.	• Increased interest in the adoption of agrivoltaic technology; • Better prepared, skilled personnel to support the technology; • Increase of scientific and technological capacity to support the technology; • Provision of a reliable supply of inputs to support the technology; • Improved accessibility to finance; • Cost-effective introduction of agrivoltaics in the agricultural sector.	• Introduce new institutional set-ups, policies, regulations, standards and incentive schemes for the adoption of agrivoltaic technology; • Increase funding in R&D (striving to achieve the national target of 2 per cent gross domestic expenditure on R&D by 2025); • Increase government support in streamlining the procurement process in favour of the new technology.

Impact dimension issue: Societal aspects		
Goal 1	**Expected impacts**	**Expected outcomes**
Raising knowledge – social mapping	• Increased competition in demand for agricultural and residential land; • Aesthetic issues related to agrivoltaic infrastructure (Seychelles is perceived as a green pristine environment); • Increased competition in demand for water; • Employment opportunities in the community; • Improved supply of fresh vegetables throughout the year; • Structure of conflicts made transparent;	• Infrastructural development of agrivoltaics in the proximity of residential areas may create conflicts within communities; • Environmental degradation due to the effects of the agrivoltaic infrastructure; • Increased pressure on the watershed; • Enhancement of community economic contribution; • Contribution to food and nutrition security of communities.
Goal 2	**Expected impacts**	**Expected outcomes**
Forming attitudes or opinions – mediation	• Self-reflection among actors has been initialized; • Marginalization of traditional farmers due to agrivoltaic technology (technology divide between the traditional and modern farming community); • Women as subsistence and backyard farmers and low-income business marginalization due to the demand for high capital investment in the technology; • Access to capital is limited to small farming communities, which may lead to displacement of the same in the industry.	• Traditional farmers, women and lower-income farming communities may suffer displacement from competition due to land scarcity; • Limited access to training for traditional farmers may limit their participation in adopting the new technology; • Low production costs due to the technology may affect competition in the market against the advantage of traditional farmers, women, and low-income farmers.
Goal 3	**Expected impacts**	
Initializing actions – new decision-making processes	• Promote inclusivity in decision-making to cater to women and youth in land allocation; • Extension of incentives for agrivoltaic technology procurement to marginalized groups, e.g., women and youth; • Policies should be reviewed to include the marginalized; • Educate the general population on the new technology to address the myths of the danger posed by new technology, especially the myth of risks that have been associated with the consumption of crops considered by many to be “inorganic” (grown under soilless conditions).	
Impact dimension issue: Policy aspects		
Goal 1	**Expected impacts**	**Expected outcomes**
Raising knowledge – policy analysis	• Gaps in governance across the board between policymakers and the implementation of the regulations could have an impact on the adoption of agrivoltaic technology; • The absence of policies and regulations may have a negative impact on the implementation and governance of agrivoltaic technology.	• The Agricultural Act is being reviewed; • There is an existing draft policy and strategy for agriculture due to be validated soon; • There are no existing regulations to integrate PV into agriculture; • There are policy, incentive and standard gaps to support implementation of agrivoltaic technology.

Goal 2	Expected outcomes and impacts	Actions
Forming attitudes or opinions – restructuring policy debate	• Comprehensiveness in policies increased; • Policies evaluated through debate; • The National Energy Policy 2010–2030; • The draft Agricultural Policy and Strategy; • The National Food and Security Policy.	• Put measures in place to address barriers to the entry of agrivoltaic controlled-environment crop production (ACE); • Reassess the current land allocation system and put in place new mechanisms to make agricultural land more accessible; • Ensure that ACE is inclusively accessible to all so that women, traditional and low-income farmers are not excluded; • Increase the number of incentives allocated to ACE; • Put in place measures and develop new standards and regulations to reduce the impact of ACE; • Review the Seychelles Energy Policy 2010–2030 to accommodate ACE; • Improve the link between consumers and producers of agricultural produce to avoid post-harvest losses.

Goal 3	Expected impacts	Expected outcomes	Actions
Initializing actions – decisions taken	• Policy alternatives filtered.	• Accompanying measures taken to maximize benefits and minimize risks of a new technology; • New legislation and/or regulations passed, modifications in national and sector plans achieved; • Standards established for PV systems; • Enhanced safety measures and standards; • Waste management made more efficient, e.g. generators, system integration, low harmonization.	• Enhance the level of institutional capacity for training, R&D and regional and international collaboration to support the technology; • Address the regulatory gaps to allow the integration of PV into agriculture. Despite the interest both from government and private sector, there are no regulations in place to allow such integration; • Put in place measures to ensure an effective supply chain to support the technology as most of the inputs to the technology are imported; • Educate the general population on the new technology to address the myth of the danger posed by new technology, especially beliefs that there are risks associated with the consumption of inorganically grown crops; • Put in place funding mechanisms for piloting ACE projects before scaling to fully commercialized ventures.

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