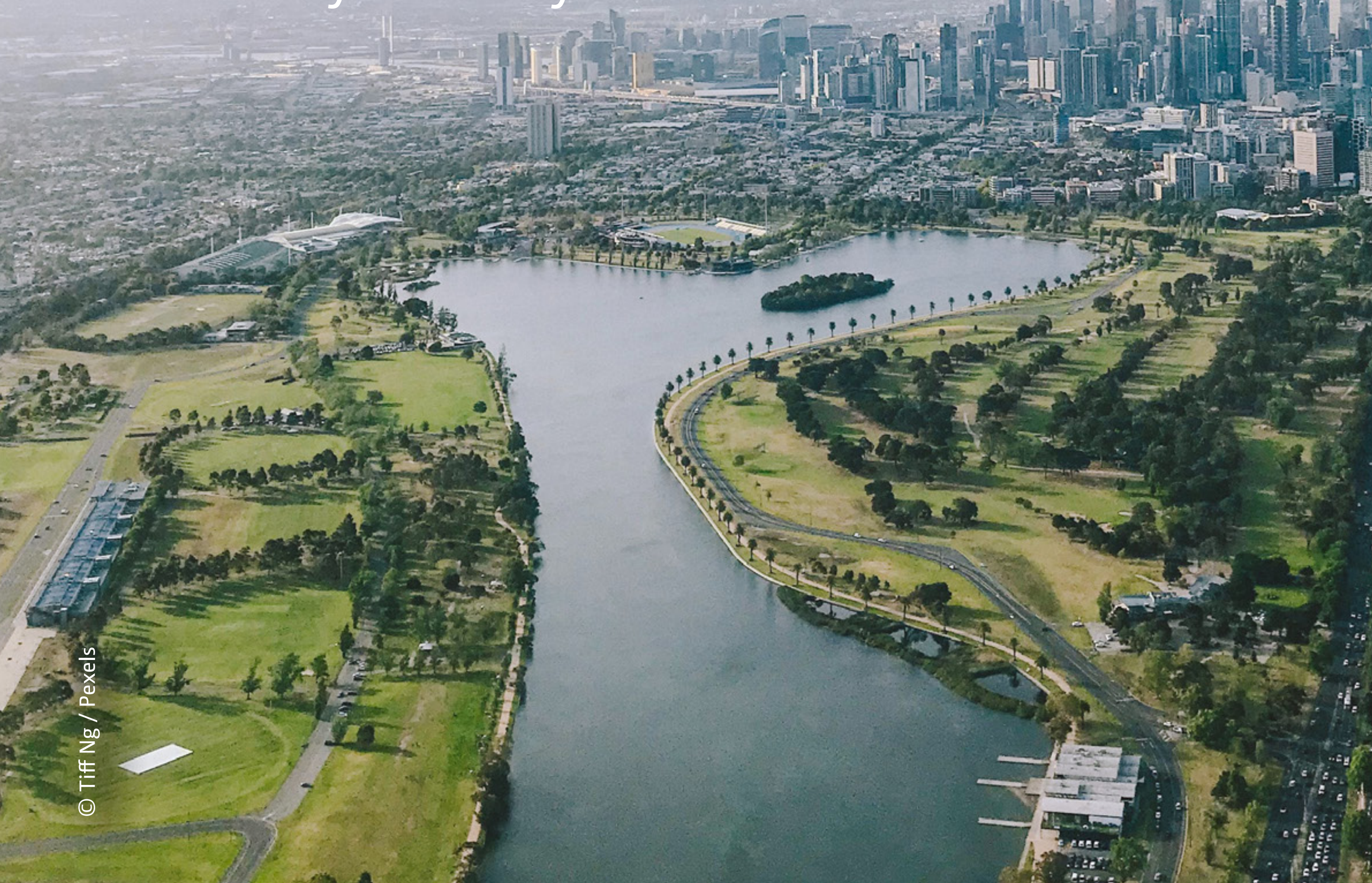
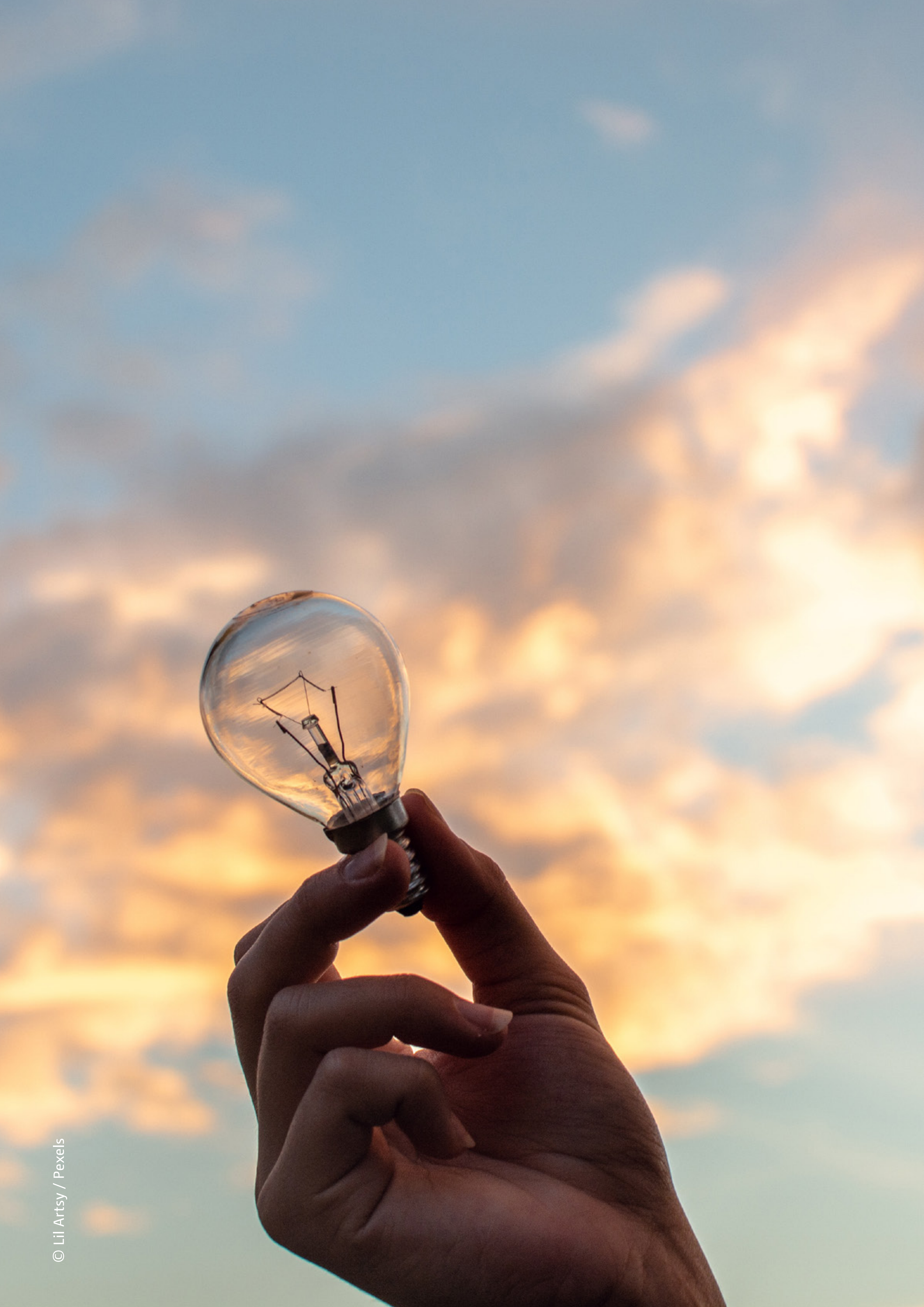
United Nations Climate Change
Technology Executive Committee

Good practices and lessons learned on the setup and implementation of National Systems of Innovation

Summary for Policymakers





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FOREWORD

As the latest IPCC report highlights, current commitments make it likely that warming will exceed 1.5°C during the 21st century and make it harder to limit warming below 2°C. It is evident that incremental steps are not good enough anymore and transformative change is needed. In the context of National Systems of Innovation this transformation is not just about the direction of the search but about the ambition level of the search.

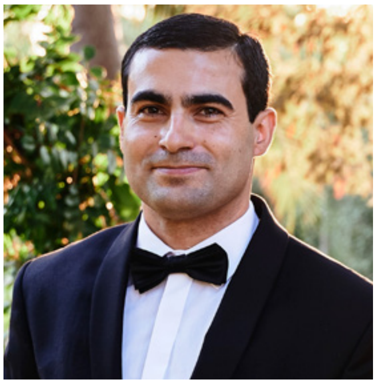
The Technology Executive Committee (TEC) has long since been analysing and highlighting the central role of innovation and National Systems of Innovation (NSI) in supporting international and national efforts to enhance action on climate change and address developmental challenges. The TEC's earlier work on NSI points to strong dependencies between a country's capabilities to implement and benefit from technological change and the strength of its NSI.

We know that innovations related to clean technologies and their effective national and/or international diffusion play a critical role in the pace and cost of climate action. In its first chapter dedicated to innovation and technology development and transfer, published in 2022, the IPCC highlighted the importance of supporting developing countries in strengthening their technological innovation systems and innovation capabilities in order to accelerate international collaboration on innovation (IPCC, AR6, WGIII, chapter 16). To this end, the TEC is pleased to present the *Summary for Policy Makers on good practices lessons learned on the setup and implementation of NSIs*. The recommendations provided can help policymakers chart a roadmap for strengthening their own national innovation systems – from the preparatory phase of developing an NSI to the design and implementation phase and the monitoring, evaluation, and revision of the NSI, including the role of the focal points to UNFCCC and links to NDCs. It draws on the larger compilation of six case studies that have successfully addressed the challenges of climate technology innovation in one way or another, leading to a well-functioning system, or parts thereof. This includes concrete examples of factors that have driven or impeded innovation processes and the measures and approaches that have improved their effectiveness. They cover mitigation- and adaptation-related activities, different sectors, top-down and bottom-up approaches to stimulate innovation, different functions of innovation systems, and different country groupings than technology transfer. Even though implemented in specific countries or sectoral contexts, the good practices shared can form a basis for cross-learning between sectors and regions. The analyzed cases also demonstrate the value of international cooperation on innovation, a concept introduced in the latest IPCC report and more reflective of the process needed than technology transfer.

As the TEC begins implementing its new workplan, as well as the joint work programme of the UNFCCC Technology Mechanism for 2023-2027, the TEC remains committed to supporting local innovation through an NSI approach, recognizing the transformative potential of NSI as an important enabler of technology transfer and development.

The Technology Executive Committee extends its appreciation for the expertise and inputs provided by representatives of observer organizations in the development of this TEC publication.

Stig Svenningsen
Chair of the Technology
Executive Committee



Ambrosio Yobánolo del Real
Vice Chair of the Technology
Executive Committee

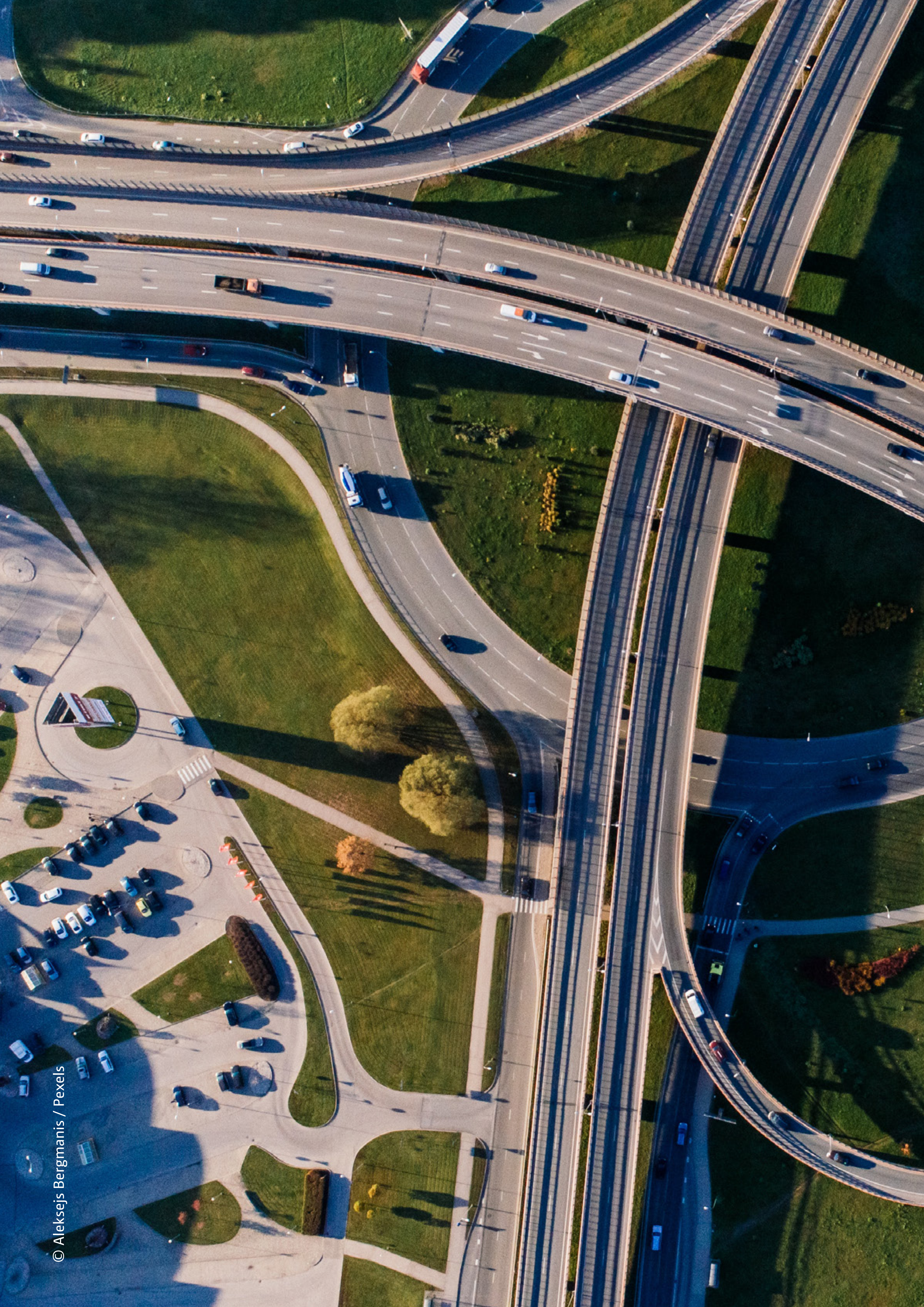


TABLE OF CONTENTS

1 Introduction

The concept of systems of innovation and national systems of innovation

Systems of Innovation (SI) is an established conceptual framework for studying innovation processes while that takes into account their systemic nature and which can generate insights for policymakers.[1] "The elements and relationships which interact in the production, diffusion, and use of new, and economically useful, knowledge" comprise a system of innovation.[2] The process of technological development and innovation facilitated by "components, relationships, and attributes":[3]

- **Components** are the 'operating parts' (actors, organizations, and institutions);
- **Relationships** are the market and non-market interlinkages between the components (feedback mechanisms; technology spillovers, transfer, acquisition, etc.);
- **Attributes** are the properties and capabilities of the components which characterize the system (systems' robustness, flexibility and ability to generate change and respond to changes).

The concept of systems of innovation has been defined and understood at different complementary analytical levels, such as the national systems of innovation (NSIs), regional systems of innovation, sectoral systems of innovation (SSIs), and technological innovation systems (TISs). In practice, these systems are interconnected, which means that when looking at an initiative aiming to foster innovation for climate action at the national level (NSI), this may cover different technologies and sectors (TISs and SSIs). Importantly, actors, institutions, technologies and interactions may come from the international level or through global innovation systems and interact with those at the national level, for example crossing the boundaries between different NSIs.

TEC Brief #7[4] on strengthening NSI defines it as "a network of actors, institutional contexts and linkages that underlie national technological change". As defined in the TEC Brief, an NSI consists of:

- **Actors:** Organizations that participate in technology development and transfer e.g. technology firms, universities and financiers;
- **Institutional context:** Norms, cultural practices and laws that shape actor efforts e.g. government policies that affect how the private sector invests in a particular sector;
- **Linkages**: Interactions and relations between the actors and the institutional context e.g. flows of information and knowledge, and collaboration between firms, universities and research institutes.

1 Blanco, G., H. de Coninck, L. Agbemabiese, E. H. Mbaye Diagne, L. Diaz Anadon, Y. S. Lim, W.A. Pengue, A.D. Sagar, T. Sugiyama, K. Tanaka, E. Verdolini, J. Witajewski-Baltvilks, 2022: Innovation, technology development and transfer. In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.018.

2 Lundvall, B. Å. (2016). National systems of innovation: towards a theory of innovation and interactive learning. *The Learning Economy and the Economics of Hope, 85.*

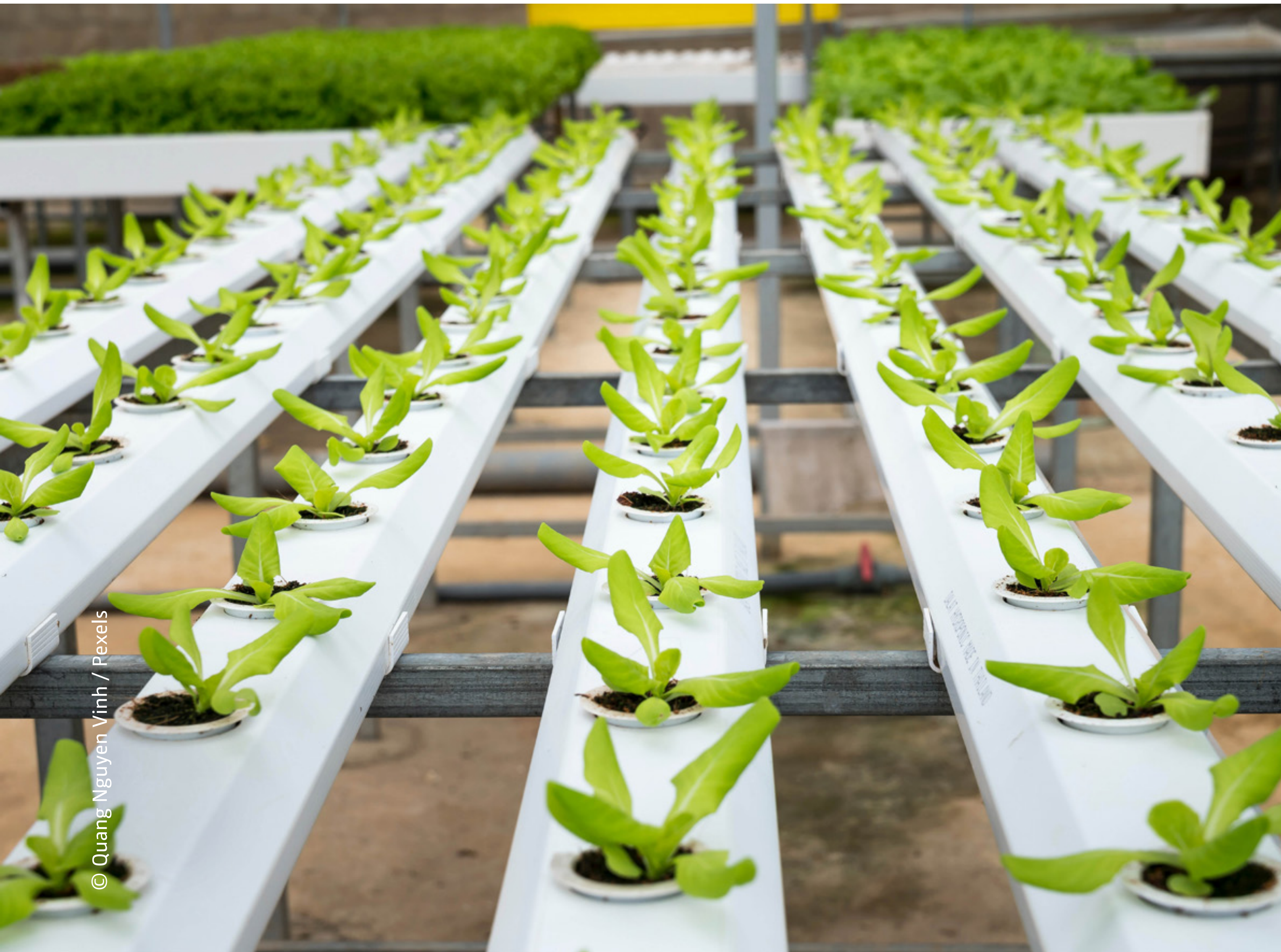
3 Carlsson, B.; Jacobsson, S.; Holmén, M.; Rickne, A. (2002). Innovation systems: analytical and methodological issues, Research Policy, v31(2), 233–245.

4 TEC. (2015). TEC Brief #7, Strengthening National Systems of Innovation to Enhance Action on Climate Change, UNFCCC Technology Executive Committee, Bonn.

The effectiveness of a national system of innovation is important for scaling up development and deployment of climate action

Article 10, paragraph 5, of the Paris Agreement states that accelerating, encouraging and enabling innovation is critical for an effective, long-term global response to climate change and promoting economic growth and sustainable development. A country's capabilities in driving and enabling climate technology innovation are crucial in this regard and are determined in part by the effectiveness of its NSI.

The primary aim of this summary for policymakers is to synthesize the findings and recommendations from the Technology Executive Committee (TEC) compilation of good practices and lessons learned on the set-up and implementation of NSI for developing country policymakers looking to strengthen their NSI in the context of climate action. The analysis of NSI aims to deepen the understanding of selected parts of the systems and identify measures and approaches that have improved the effectiveness of the national systems in specific cases and translate them into good practices that can be replicated in other countries or sectors. The recognition of good practices, even though implemented in specific country or sectoral contexts, can lead to cross-learning, including exchange of knowledge and experience. This report presents a two-step approach to analysing NSIs and provides recommendations on setting up an NSI. From the policy perspective, an enhanced understanding of NSIs can help a country to identify the 'leverage points' for strengthening its innovative performance and overall competitiveness.



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2 An approach to analysing parts of national systems of innovation

Within the current scope it is not possible to evaluate entire national innovation systems, given their size and complexity. Therefore, the assessment looks at selected parts of NSI.

Step 1. Assess the delivery of functions of the innovation system

The effectiveness of an NSI depends on its ability to fulfil key functions

In general, innovation outcomes depend on the overall functioning of the innovation system. There are different approaches for assessing such performance. These can range from the use of relatively simple indicators to an analysis of existing barriers and enablers or based on the functions that a technology innovation system aims to perform. As discussed in TEC Brief #7, the indicator approach aims to measure a country's effort spent to stimulate innovation, a barrier approach focuses on what can hinder innovation from taking place, while a functional approach aims to assess the overall functioning of the innovation system, in terms of how well key processes are being carried out.[5] The TEC compilation of good practices and lessons learned on the set-up and implementation of NSI applies the functional approach to assessing their performance.

An innovation system's overall aim is to produce, diffuse, and use innovations.[6] To achieve this goal, some specific activities should be undertaken with a view to facilitating the innovation process, for example the diffusion of knowledge. These activities are referred to as the functions that an innovation system can perform. Functions explain 'what happens' in an innovation system, that is:

- The activities of the actors and/or organizations pursuing innovation;
- The role played by institutions in promoting or impeding innovations;
- The impacts of the interactions between the various elements of the system.

Based on empirical evidence, innovation studies identify seven main functions as described in table 1.

Table 1. Functions of systems of innovation[a]

#	Function	Description
F1	Knowledge development and diffusion	Expansion and intensification of the knowledge base of the innovation system, dissemination of knowledge among actors in the system, creation of new combinations of knowledge
F2	Entrepreneurial experimentation	Designing business models for emergent technologies and knowledge, practices of uncertainty reduction through experimentation with new technologies, applications and strategies
F3	Market formation	Creation of a space or an arena in which goods and services can be exchanged between suppliers and buyers. Includes processes related to definition of demand and choices, positioning (pricing, segmentation) of products, regulation of standards and the rules of exchange
F4	Influence on the direction of search	Processes that influence the direction of research of firms and other actors; that is, which technologies they explore, which problems or solutions they choose to invest in, where they channelize their resources from, etc.
F5	Resource mobilization	Processes by which the system acquires the resources required for innovation, which could be financial and human resources (workforce and capabilities), complementary assets such as infrastructure, etc.
F6	Legitimation	Mechanisms by which an emergent technology, its developers and the TIS in question attain regulative, normative and cognitive legitimacy as viewed by the stakeholders concerned
F7	Development of positive externalities	Creation of system-level utilities (or resources), such as pooled labour markets, complementary technologies and specialized suppliers, which are also available to system actors that did not contribute to building them up

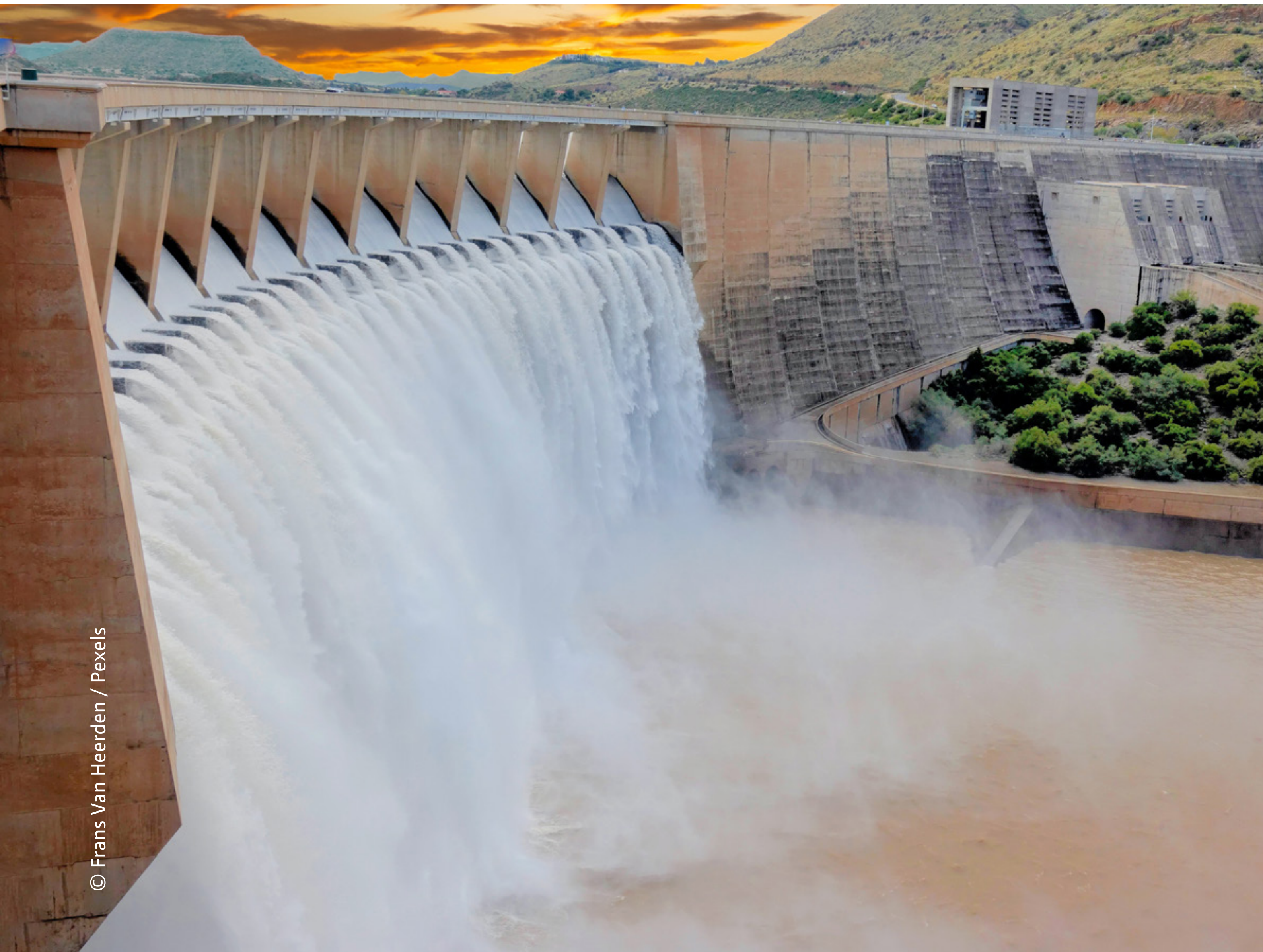
[a] Adapted from Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. Research policy, 37(3), 407–429.

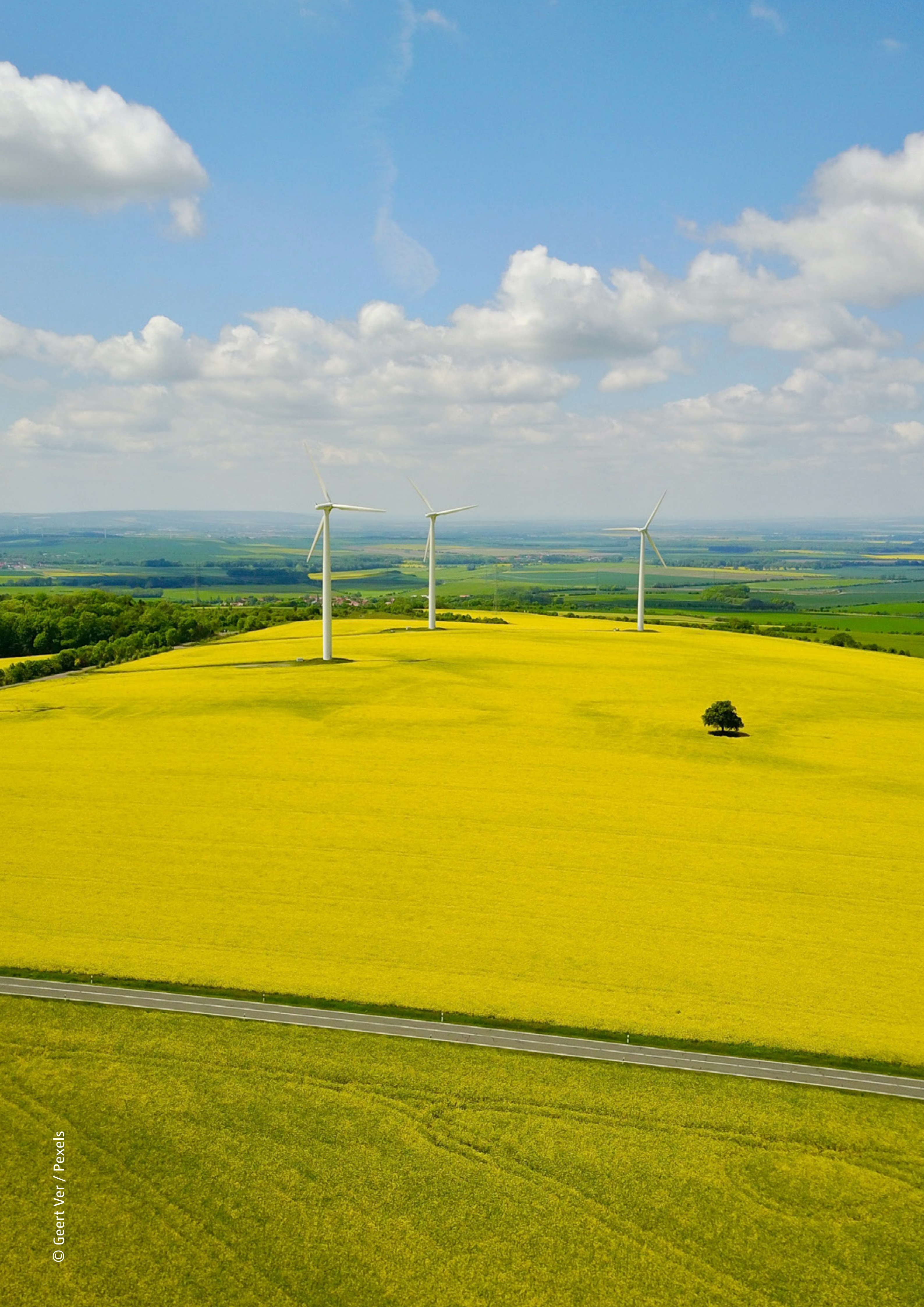
5 Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. Research policy, 37(3), 407–429.

6 Edquist, C. (2001, June). The Systems of Innovation Approach and Innovation Policy: An account of the state of the art. In *DRUID conference, Aalborg* (pp. 12–15).

Evaluating to what extent an innovation system can perform these functions is necessary to identify and assess the innovation system's achievements, failures and gaps or barriers. Such a 'functional analysis' enables the development of a comprehensive view of an NSI's operations, either retrospectively to identify lessons learned and strengthen existing NSIs, or prospectively as a guide to systematic action when putting in place policies to achieve specific climate objectives.

The extent to which the various functions can be performed effectively depends on whether '**structural components**' are present and of sufficient quality. These components include actors, institutions, interactions or networks and technologies, including infrastructure. A system's underachievement can be directly related to absences or weaknesses in these structural components.





Step 2. Assess the systems's contribution to addressing innovation barriers and gaps

A 'structure–function coupled analysis' can help the understanding of how to improve the NSI's effectiveness

Improving an NSI's effectiveness requires looking at its functional performance (*what* is going well and *what* is not?), as well as at the reasons behind the observed performance (*why* it is going well or not going well?). This is done by coupling the evaluation of the overall functional performance of the system with an analysis of its structural components. This type of '**structure–function coupled analysis**' facilitates the identification of situations where, for example, insufficient actor capabilities or inadequate policy environments are the main cause behind an ill-functioning system. It also allows the identification of situations where the opposite is the case, that is, where specific actors or policies play a key role in strengthening the functions of the system. Functions, therefore, cannot be influenced without changing the structural components of the system; they are interrelated. In the TEC compilation of good practices and lessons learned and on the set-up and implementation of NSIs, such a structure–function analysis has been applied to six case studies to identify lessons learned and good practices.

Table 2 illustrates how the functional analysis of an innovation system mentioned above in the light of its structural components reveals the system's strengths and deficiencies (or missing links).

Table 2. Structure–function analysis[a]

Structural component and functions of NSI[b]	Systemic problem (weakness)	Type of problem (weakness)
Actor (for F1 to F7)	Absence of relevant actor/s	Presence/absence
	Absence or inadequate capabilities of the actor/s	Capability
Institutions (for F1 to F7)	Absence of required/relevant institutions	Presence/absence
	Absence or inadequate capabilities of institutions	Capability
Interactions (for F1 to F7)	Absence of interactions between relevant actors and organizations (due to distance, lack of trust, lack of capabilities, divergent goals, etc.)	Presence/absence
	Inadequate quality or intensity of interactions (too strong, too weak)	Quality or intensity
Technology (including physical artefacts, knowledge set-ups, financial infrastructure, etc.) (for F1 to F7)	Absence of technology, infrastructure	Presence/absence
	Inadequate quality of the infrastructure	Quality

[a] Wieczorek, A. J., and Hekkert, M. P. (2012). Systemic instruments for systemic innovation problems: A framework for policy makers and innovation scholars. Science and public policy, 39(1), 74–87.
[b] See table 1 for the definition of F1 – F7

The absence or deficiency of functions or lack of synergy between functions denote 'weaknesses', or also understood as 'barriers', 'systemic failures', 'blocking mechanisms', etc., and pose challenges for innovation.

3 Lesson learned and good practices identified through case studies

The TEC compilation of good practices and lessons learned on the set-up and implementation of NSIs undertakes an analysis of a selection of (parts of) innovation systems as case studies. The selection was made with the aim of highlighting initiatives or systems which have successfully addressed some of the challenges to climate technology innovation, leading to a well-functioning system.

Six case studies were selected across a range of countries, covering both mitigation and adaptation initiatives, with an appropriate representation across regions and country income groups as well as sectors. The case studies also cover different innovation system perspectives (national/sector/technology-focused, top-down/bottom-up). The selection was made keeping in mind the need for the initiatives to be sufficiently mature to facilitate meaningful evaluation and have the potential to provide good practices and/or useful lessons learned and sufficient availability of information. The case studies are as follows:

- The Indian Bureau of Energy Efficiency (BEE);
- The Kenya Climate Innovation Center (KCIC);
- Haiti's Disaster Risk Reduction strategy (DRR);
- Brazil's bioethanol transport fuel activities;
- Jakarta, Indonesia's urban flood management activities;
- Denmark's wind energy sector.

For a comprehensive analysis and recognition of good practices for knowledge-sharing, the case studies cover the following broad steps:

- First, the delivery of the initiative's functions is assessed (see annex on the main NSI functions performed across case studies). Here it should be noted that not every innovation system or initiative can be expected to deliver on all the functions.[7] Initiatives (or systems) could focus specifically on particular stages (knowledge creation, absorption and application) or actors of the overall innovation system.
- Second, an analysis is made of the contribution of the initiative in addressing the barriers to climate innovation or the missing links and strengthening the core areas in the overall innovation system (a structure–function analysis). Recognizing that the design and implementation of the initiatives would suit national objectives, the analysis aims to pinpoint factors that made them successful that are based on the common principles for improving innovation systems at the country level. Specifically, the analysis looks at how initiatives in the innovation system contributes to:
    - Enhancing the capabilities of the relevant actors;
    - Strengthening the institutional context in which the actors operate;
    - Enhancing linkages between actors, and between actors and the institutional settings;
    - Catalysing changes for knowledge production and its wider implementation in order to achieve co-evolving goals of climate mitigation and adaptation, and sustainable development.

7 Although it can be supported or complemented by other initiatives or systems.

The case studies have been synthesized into the following generic lessons learned and good practices (see also table 4 for a summary of the characteristics and lessons learned by each case study):

1. **Take a systemic perspective towards the establishment/strengthening of the NSI, integrated with host country development objectives**
   The build-up of an NSI needs to be aligned with the country's development priorities for legitimation and long-term support. Once climate policy goals have been defined in the context of national socioeconomic objectives, the interactions between mitigation, adaptation and sustainable development become clear. Such a systemic perspective makes it possible to define with some specificity the strategic prioritization of sectors and overall innovation needs. At the same time, such a perspective also requires some long-term visioning and planning. In addition, actions to strengthen (relevant parts of) the NSI could be mentioned in countries' nationally determined contributions. A country's national designated entity or technology needs assessment coordinator could potentially play a role in this process at the national level, while also providing connections to the international level, opening up possibilities for international cooperation on innovation.

2. **Yet a tailored approach to bridging sector- and innovation phase-specific gaps**
   Notwithstanding the required systemic perspective described above, a tailored approach to the development of an NSI is needed, given that innovation needs vary from sector to sector. This, in turn, requires a comprehensive understanding of gaps and barriers related to specific sectors and specific phases of the innovation cycle. Such an approach is underpinned by a systematic focus on innovation system functions that need to be addressed as well as the structural elements (actors, institutions, interactions and infrastructure) that can help in specific sectors.

3. **Leadership with a collaborative attitude and an understanding of local context**
   One common and significant feature of the case studies is the importance of initiatives being led by people and/or organizations with a broader and nuanced understanding of the local innovation system. This helps in engaging the right kind of actors, marshalling the right kind of resources, identifying and addressing the gaps in the innovation process, and tapping into the complementary structures and processes of the overall innovation system to advance the climate initiatives. If the capabilities and decision-making in a project are dominated by actors that are not locally grounded, such processes may stall (see also #4 below). Specific organizations that are able to take the lead can play a key role as 'integrators' or 'coordinators' of the various structural and functional aspects of the innovation system. The overarching and interactive functioning of the leading organizations can not only facilitate coordination among actors but also address gaps such as financial resources, enabling policy frameworks or human and institutional capacity.

4. **Participation of/interactions among local actors facilitates innovation and alignment**
   Participation of and interactions among domestic actors (at the national and subnational level) is key since they have the best understanding of local context and institutions, they often have the largest stake in the outcome and therefore are best placed to help to fill gaps in, and advance the functions of, the innovation system. Therefore, promoting such interactions is critical, whether among knowledge institutions such as universities, between knowledge institutions, firms and government agencies, between firms and communities, or among government agencies, etc. In the case studies on first-mover countries for specific technologies (Brazil, Denmark), networks between actor groups were key for moving the technology along the innovation cycle and the formation of markets. In the case of India, the Bureau of Energy Efficiency drew upon existing networks, expanding them to facilitate the flow of knowledge (such as international best practices) as well the implementation of programmes.

5. **Engage with international institutions and collaborations to help build local institutions and networks**
   International institutions can play an important role in strengthening NSI by bringing in global best practices, assisting with the development, adaptation and diffusion of new technologies, helping to mobilize financial and technical resources and building the capabilities of local actors and institutions. Such innovation cooperation can also pave the way for more than one-way technology transfer. It also broadens the scope from the often-narrower focus on hardware in technology transfer activities to various elements relevant to effective innovation (such as effective institutional forms) and to cooperation and mutual problem-solving. But engagement with such institutions is likely to be most effective when based on an understanding of local innovation needs and gaps. In the Kenya case study, international actors combined forces with local actors to create KCIC and generate capabilities and knowledge, which was subsequently shared again internationally, among others in the network of climate innovation centres. Haiti benefited strongly from the activities of the Sahana volunteer network, applying internationally developed tools and knowledge locally, which in turn improved multilateral agencies responses. As shown in the figure below, all cases have international linkages, although their motive, extent and direction differs for each case. This confirms the importance of international exchanges for the development and diffusion of climate technology.

6. **Ensure that innovation and organizations are evolutionary and able to adapt to new circumstances through continuous monitoring and review**
   The innovation context, capabilities and resources change over time and therefore so do innovation needs. At the same time, analysis of the functioning of the NSI may also yield insights as to how to strengthen the NSI and make it more effective. Adapting to the changed circumstances and emerging knowledge so as to remain relevant and effective may mean engaging with new actors or addressing new functions of the NSI, for example with different types of interventions. It may also mean that organizations themselves evolve over time. Therefore, continuous monitoring and evaluation of innovation needs and outcomes, and the ability to adapt in response, takes on great importance. The insights from such monitoring and review can be used to improve the set-up and implementation of the NSI, thereby creating a dynamic situation where the NSI is able to evolve in response to the new knowledge and understanding. It can provide a better understanding of long-term policy goals to innovation actors, allowing for course correction, when and where needed.

7. **Portfolio of solutions**
   The scale and complexity of climate change adaptation and mitigation challenges in the context of sustainable development as well as the diversity of a national system of innovation means that the intervention cannot be contained in a single measure. It requires a portfolio of measures to strengthen the relevant functions across the innovation cycle and to build capacity with a variety of actors. Different sectors, innovation cycle phases and actors will have different needs, benefiting from a range of tailor-made approaches, including in many cases a combination of top-down and bottom-up approaches used interactively and iteratively.

8. **Deal with structural problems**
   In some cases, the underlying problems of poverty, lack of influence and voice and environmental or social challenges are not acknowledged when designing the intervention, or only become clear during the intervention. Focusing on broader development goals, NSI's functions and including all stakeholders usually addresses this, but structural problems may rebound. Even when solving them is beyond the capacity of a climate action project, attention for such structural problems needs to be part of an integrated approach.

Figure 1. International interactions each case study[a]

Case study	International		National		
India BEE	Expertise Collaborative Labelling and Appliance Standards Program (CLASP)	→	Development of standards for appliances in S&L programme, adopted by the Bureau of Indian Standards		
	Funding from United States Agency for International Development, United States Environmental Protection Agency and United Nations Foundation via CLASP	→			
Kenya KCIC	Concept development, funding by UNIDO, UK Department for International Development, World Bank infoDev	→	Establishment of KCIC	←	Kenya Industrial Research and Development Institute KIRDI
	International consortium partners	→			
	International expertise, information sharing, networking	←	Operation of KCIC		
	Other Climate Innovation Centers	→			
Haiti DRR	Funding to DRR (e.g. UNDP) and DR financing strategies (EU's Caribbean Regional Resilience Building Facility), cooperation platforms	→	National early warning system		
	International insurance pool	←	SNGRD, International Coop. Support Group, NGO Forum, UNDP Civil Society Adv. Comm., DRF strategy		
	International funders	←	Requirement to include DRR as conditionality for international cooperation project		
	International programmes like World Food Programme, aid organizations	←	Establishment of information portal, platforms		
	Sahana Software Foundation/ community of volunteers	→			
Brazil bioethanol	Reduced sugar demand; Increased oil prices; Increased bioethanol demand	→	Policies to stimulate local bioethanol market, technologies		
	International car manufacturers	↔	Increased market for bioethanol production	←	Local technology suppliers
	Concerns re climate change, sustainability, energy dependency; International technology suppliers	→		→	
	International R&D cooperation, funding , information exchange	↔	Local R&D initiatives, researchers	→	
Danish wind sector	Concerns re climate change, sustainability, energy dependency; Increased oil prices; Increased wind technology demand	→	Policies to reduce energy dependency, promote renewable energy, increase prosperity in rural areas		
	International technology suppliers	←	Increased market for wind technology		
	International R&D cooperation, funding , information exchange			←	Local R&D, technology suppliers
Jakarta flood management	Funding from international agencies (World Bank, Japan International Cooperation Agency), governments, NGOs, private sector for awareness raising, capacity building, cooperation platforms	→	Policies to drive, regulate government flood management activities; Plan Indonesia; Build up know how local private sector		
	International flood management companies provide private funding, expertise	→	Local market opportunities through competitive procurement processes; Project-related mini innovation systems; Increased resilience		

[a] Note that concerns regarding e.g. energy dependence or climate change that are shown here on the international side can also exist at the national level (not shown here because of space limitations).

Funding sources for the various case study initiatives

An overview of the financial resources for the activities covered in the case studies, although not included as a lesson learned or a good practice, may provide an insight into the variety of resources that can be tapped into, both internationally and nationally, from both public and private sources. Non-financial resources can also be involved, such as recruiting human resources from volunteers. Table 3 shows the various sources, as well as the use of resources in terms of activities and beneficiaries across cases. Government funding was used in all cases, either as part of the general budget or generated by energy or environmental/carbon taxes, a tax on oil and gas exploration in Brazil or, in the case of Haiti, labour taxes. For KCIC, only indirect government funding is involved, through the participation of the government body Kenya Industrial Research and Development Institute in the original project consortium. KCIC demonstrates a successful evolution in a funding model, from (mostly) international funding leading to the establishment of KCIC; KCIC and international funding establishing Kenya Climate Ventures; and Kenya Climate Ventures funding Early-stage Finance Mechanism (ESFM), which funds projects. In addition to traditional funding instruments (e.g. subsidies, grants, tax incentives), financial resources also come from price guarantees and public service obligations (Brazil, Denmark) or revenues from tradeable credits/certificates (India, Brazil).

Table 3. Funding sources for the various case study initiatives

Case	Source of funding	Use/beneficiaries
India BEE	• Government budget • Funding opportunities through Collaborative Labeling and Appliance Standards Program (USAID, USEPA, UNF) • Carbon credit revenues • Energy saving certificate revenues	• Awareness-raising campaign, capacity-building with retailers/end users to create a market for energy efficiency products • Definition of standards, labels • Creation of testing/servicing infrastructure, training of energy managers, auditors and verifiers • Discounted prices for end users of energy efficiency products • Pilot installation for energy efficiency products (street lighting) • Funding for industrial energy efficiency to meet perform, achieve and trade targets
Kenya KCIC	• Initially international funding (UK Aid, DANIDA through World Bank) • World Bank funding to launch Kenya Climate Ventures (KCV) • KCV, with KCIC convertible debt investment • Early-Stage Finance Mechanism, with KCV and other funding	• Awareness-raising programmes on technologies, markets, knowledge/research updates • Mentorships, technical assistance and customized training to entrepreneurs • Funding of projects and ventures in early stages of innovation cycle by private sector parties[a] • Government lobby, policy advocacy, policy advice to businesses • Increased access for entrepreneurs to facilities
Haiti DRR	• Government budget, Emergency Fund (funded by tax on salaries) • International donors, e.g. United Nations Development Programme, World Food Programme, Green Climate Fund, bilateral agencies (Swedish Agency for Development and Cooperation, USAID, etc.) • Risk financing instruments, supported by the World Bank and the European Union (Caribbean Catastrophe Risk Insurance Facility, Contingency Emergency Response Component) • International non-governmental organizations, crowdsourcing	• Strengthening government institutions, building capacity of local communities • Analysis, development of national plans, response strategies • Awareness campaigns • Educational programmes and training sessions at schools and universities • Reconstruction programmes • Data collection and tool development

[a] Such as proof-of-concept grants, seed funding, early-stage risk financing.

Table 3 (continued). Funding sources for the various case study initiatives

Case	Source of funding	Use/beneficiaries
Brazil bioethanol	• Government funding, including from the National Oil Agency 1% clause,[b] ProÁlcool, national incubator policy • Minimum sales prices • Public funding via National Bank for Economic and Social Development, National Council for Scientific and Technological Development, innovation funding agency Brazilian Agency for Innovation • Private funding (companies and associations) • Decarbonization credits	• Funding R&D, pilots and demonstration projects for ethanol production as well as use in e.g. flex-fuel vehicles • Technology parks and incubators • Governmental ethanol-fuelled vehicle fleet • Financial incentives for sugarcane producers (to increase sugarcane production, expand/adapt ethanol processing plants) and automobile industry (to develop ethanol-fuelled vehicles) • Subsidies for ethanol fuel consumption • Trust building and awareness campaigns for end users
Jakarta, Indonesian urban flood manage-ment	• Bilateral donors and multilateral agencies (World Bank, Japan International Cooperation Agency, African Development Bank) • National government • Private sector investments (national and international) • International non-governmental organizations	• Development of master plans, feasibility studies • Infrastructure investments (sea walls, dykes, floodgates, canals, reservoirs), as well as dredging and normalizing rivers • Capacity-building and funding for operation and management of floodgates • Technical assistance for project management, contract management, engineering design reviews, monitoring, supervision, social safeguards, resettlement plans • Knowledge generation, diffusion • Strengthening community preparedness, via implementation of early warning systems, flood control systems, capacity-building, awareness-raising
Denmark wind energy	• Government, using energy/environmental tax revenues • Pension funds • Private funding (entrepreneurs, cooperatives, companies) • Consumers (via Public Service Obligations)	• Funding R&D programmes • Subsidies for wind energy industry, association for wind energy • Support for local cooperatives for local experimentation and deployment • Financing for grid connection, grid balancing

[b] Requiring oil and gas exploration companies exploring in Brazil to invest 1 per cent of their gross revenue from these activities in research and development projects “to the interest of the national energy sector”.

Table 4. Summary of case studies and key lessons learned[a]

Case	Source of funding	Use/beneficiaries

India Bureau of Energy Efficiency	• Focus: Mitigation
	  ◦ Energy demand
	• Top-down Approach
	• Main innovation system functions:
	  ◦ F1 Knowledge development and diffusion
	  ◦ F2 Entrepreneurial experimentation
	  ◦ F3 Market formation
	• International support received:
	  ◦ Some of the initiatives tapped into international technical expertise, e.g. Standards and Labelling Programme drew on the expertise of CLASP
	  ◦ Engagements with CLASP also facilitated funding opportunities with USEPA, USAID, etc.
	  ◦ The standards used in the UJALA programme (Unnat Jyoti by Affordable LEDs for All) were devised by an international expert group
		• A tailored approach is required as innovation needs vary from sector to sector
		• Bridging sector-specific gaps is key
		• Innovation activities need to be strategic, iterative and evolutionary
		• Coordination and integration of NSI elements is crucial
		• Strategic prioritization of focus sectors improves efficiency, credibility and legitimacy

Kenya Climate Innovation Centre	• Focus: Mitigation and adaptation
	  ◦ Scope: Energy, agriculture, water, waste management
	• Top-down approach
	• Main innovation system functions:
	  ◦ F1 Knowledge development and diffusion
	  ◦ F2 Entrepreneurial experimentation
	  ◦ F3 Market formation
	  ◦ F5 Resource mobilization
	• International support received:
	  ◦ International support and collaborations (consortia) to build local technical and innovation capacity, project management capacity, etc. For instance, the Climate Technology Centre and Network is working with KCIC to help Kenyan small and medium-sized enterprises to adopt efficient technologies
	  ◦ International support to generate funds for R&D, innovation, projects, etc.
	  ◦ International support to mobilize policy and market action to create an enabling environment for climate action
		• Organizations need to evolve and diversify with time to achieve their goals
		• Collaborative, multi-actor partnerships are crucial for effective climate action
		• Funding model design needs to be sector/ innovation cycle phase-specific
		• Full integration with host country development objectives is needed for effective outcomes
		• Local actors' engagement in the design is crucial for effectiveness
		• Effective interaction among local actors is vital for peer-to-peer learning
		• International institutions and collaborations can help to build local institutions and networks

Haiti Disaster Risk Reduction	• Focus: Adaptation
	  ◦ Scope: Disaster risk reduction in all sectors
	• Top-down and bottom-up approach
	• Main innovation system functions:
	  ◦ F1 Knowledge development and diffusion
	  ◦ F4 Influence on the direction of search
	  ◦ F5 Resource mobilization
	  ◦ F6 Legitimation
	• International support received:
	  ◦ Technical cooperation and capacity-building for elaborating the national plan from e.g. the United Nations Environment Programme
	  ◦ Funding from bilateral donors for educational and training programmes
	  ◦ Financial support for disaster recovery from multilateral and bilateral institutions, including the Caribbean Catastrophe Risk Insurance Facility
	  ◦ Contribution from volunteers, e.g. Sahana
		• Taking a systemic perspective is important
		• Local knowledge and needs must be taken on board
		• Strong networks are crucial in coordination
		• Combined top-down and bottom-up efforts can create synergies
		• Multi-stakeholder partnerships, including international collaboration, is important
		• Systemic change requires time
		• Long-term planning and continuous review are important

[a] See table 1 for definitions of F1 – F7.

Table 4 (continued). Summary of case studies and key lessons learned

Case	Source of funding	Use/beneficiaries
Brazil bio-Ethanol activities	• Focus: Mitigation ◦ Scope: Transport, energy, and agriculture • Top-down and bottom-up approach • Main innovation system functions: ◦ F1 Knowledge development and diffusion ◦ F2 Entrepreneurial experimentation ◦ F3 Market formation ◦ F5 Resource mobilization ◦ F6 Legitimation ◦ F7 Development of positive externalities • International support received: not applicable, although international developments resulted in economic opportunities by creating international markets	• For successful innovation, both technology push and technology pull policies are needed • Innovation policies and coordination are needed across the value chain • A mix of bottom-up and top-down measures facilitate innovation • Coordination between knowledge producers and users accelerated diffusion • Aligning technological development to societal goals facilitates formation of coalitions that provide political support and legitimacy • Innovation takes time and is uncertain and highly dynamic • International aspects can influence the development of local innovation systems, whether intentionally or not • Local support for technology innovation and early market formation increased the country's ability to compete in international markets • Capacity-building is needed across all stakeholders • Multi-stakeholder partnerships, including international collaboration, is important
Indonesia's urban flood manage-ment	• Focus: Adaptation ◦ Scope: Urban flood management • Top-down and bottom-up approach • Main innovation system functions: ◦ F1 Knowledge development and diffusion ◦ F5 Resource mobilization • International support received: ◦ Support/collaborations for scientific studies on vulnerability and risk assessments, potential solutions ◦ Capacity-building, awareness generation, knowledge diffusion and projects ◦ Building project consortia/public–private partnerships to create investment opportunities for various stakeholders ◦ Funds for R&D, innovation, projects, etc.	• Integrated and collaborative governance is crucial • Complex problems require a portfolio of strategies • Focus on chronic problems and root causes is essential • Adaptive governance and continuous learning are crucial • Building capacities of local governments and agencies is important • Future risk assessment and long-term planning is indispensable • Convergence of disaster risk reduction, climate change adaptation and development processes is crucial • Risk governance needs to go beyond technical strategies, requiring a people-centred approach • Community preparedness is key • Context specificity of knowledge has implications for knowledge and technology transfer outcomes • Engaging local communities in developing early warning systems increases capacity to respond during emergencies
Denmark wind energy	• Focus: Mitigation ◦ Scope: Energy supply • Top-down and bottom-up • Main innovation system functions: ◦ F1 Knowledge development and diffusion ◦ F2 Entrepreneurial experimentation ◦ F3 Market formation ◦ F4 Guidance of the search ◦ F5 Resource mobilization ◦ F6 Legitimation ◦ F7 Development of positive externalities • International support received: not applicable, although international markets resulted in economic opportunities by creating international markets	• For successful innovation, both technology push and demand pull policies are needed • A dynamic interaction and synergy between bottom-up and top-down measures facilitates innovation • Coordination between knowledge producers and knowledge users accelerates technology development and diffusion • Multi-stakeholder partnerships, including international collaboration is important • Aligning technological development to societal goals can facilitate formation of coalitions that provide political support and legitimacy • Participatory approaches increase ownership and public acceptance • International aspects can influence the development of local innovation systems, whether intentionally or not • Local support for technology innovation as well as early market formation increased the country's ability to compete in international markets

4 Overall conclusions and recommendations

The analysis in the compilation underlines the value of a systematic approach to strengthening relevant parts of an NSI that can support and advance climate action through scaled up development and diffusion of climate technology for both adaptation and mitigation. **NSI functions and the structure–function framework used can serve to guide the systematic approach to implement the NSI to advance climate action.** Specifically, the objective would be to help to ensure that the NSI is organized and resourced suitably to perform the functions required for successful innovation. But since many of the details are sector-specific, it is recommended that the process begin with an identification of sectoral priorities aligned with national policy goals and socioeconomic objectives. This can subsequently guide and facilitate, as needed, the process of strengthening NSI functions, marshalling resources and addressing weaknesses and gaps in structural elements in NSIs.

An important distinction exists between the direction of such actions and their scale. Meeting the challenges of climate change requires transformative change, which means in part developing and implementing different technologies (captured by the innovation system function "influence on the direction of search") as well as developing and implementing climate-resilient technologies in an accelerated manner and at a much larger scale. The latter is not captured by the innovation system functions but is determined by choices made outside of the NSI in terms of political and societal priorities and the scale of resources provided to the NSI. While the focus of the TEC compilation has been on how to organize the NSIs in a way that enables it to achieve its objective effectively and efficiently, the conclusions and recommendations highlight the need to align climate action plans and their objectives with national priorities. If implemented (and sufficiently resourced), this would in effect provide such a signal from the political/policy domain to the NSIs about both the direction and the ambition of the search.

Good practices for potential replication that have been identified in the various case studies lead to the specific recommendations set out below. Here, a distinction is made between the preparation for actions to align the NSI with climate action, recommendations to design and implement efforts to strengthen the NSIs contribution to climate action and the monitoring/evaluation/revision of that contribution. This is done, however, on the understanding that the boundaries between these phases are not strict.

Recommendations on preparing actions to align the national system of innovation with climate action

- **Develop the climate action plan in alignment with the national long-term policy framework and socioeconomic priorities:** It is essential to ensure that climate actions are in synergy with the overall policy framework of the country, including that defined in the nationally determined contribution, and that it facilitates the country's overall development and climate objectives. This has two benefits:

    1. It allows for clear articulation of priority areas/sectors, which will help efforts to suitably strengthen the NSI;

    2. Synergies with local objectives (such as livelihoods, gender parity) will also help to enhance buy-in and participation by stakeholders.

- **Map the NSI before designing and implementing strategie**s: Such mapping helps to create the necessary understanding of the existing structural elements and functions of the innovation system, barriers and missing links in the innovation ecosystem, crucial actor groups, state of resources and capabilities, potential synergies and trade-offs between other initiatives and policy structures, and the role of international collaborations. This knowledge can inform and guide subsequent efforts to strengthen the NSIs and make them more effective. The mapping can be done at different levels, and is likely to involve more aggregate mapping (e.g. at the national level) and more detailed mapping (at the level of specific sectors or technologies).

- **Look for win-win measures:** It is important to design win-win strategies (through, for example, an appropriate choice of focus area, innovative governance and market models) to ensure participation and acceptance by all relevant stakeholders and minimization of risk factors.

- **Engage both public and private sectors:** Ensure the participation of diverse stakeholders to address the complexities and uncertainties associated with innovation processes. This will also help in tapping into the capabilities and skill sets of a range of actors. It should be noted that, while the above, preparation actions, are crucial in the preparatory phase, it is important that they continue to be applied during the implementation phase.

Recommendations on designing and implementing efforts to strengthen the contribution of the national system of innovation to climate action

- **Establish a clear role for a coordinating agency:** In situations where diverse stakeholders need to come together to make an intervention/innovation effective, the role of coordinating agencies or 'system operators/integrators' becomes important. Coordinating agencies with a holistic understanding of the strengths and shortcomings of the NSI can organize and coordinate the actions of different stakeholders, tap into the resources and strengths of various actors, and address other system gaps to maximize impact. This can be, for example, the national designated entity or technology needs assessment coordinator at the national level, and more specialized agencies with domain expertise at the sector or technology level.

- **Explore innovative, customized and flexible funding frameworks:** Explore funding models to suit the stage, scope and risk perception of the innovators/firms. Complement funding schemes with enabling policy and financial regimes for effective and sustained outcomes.

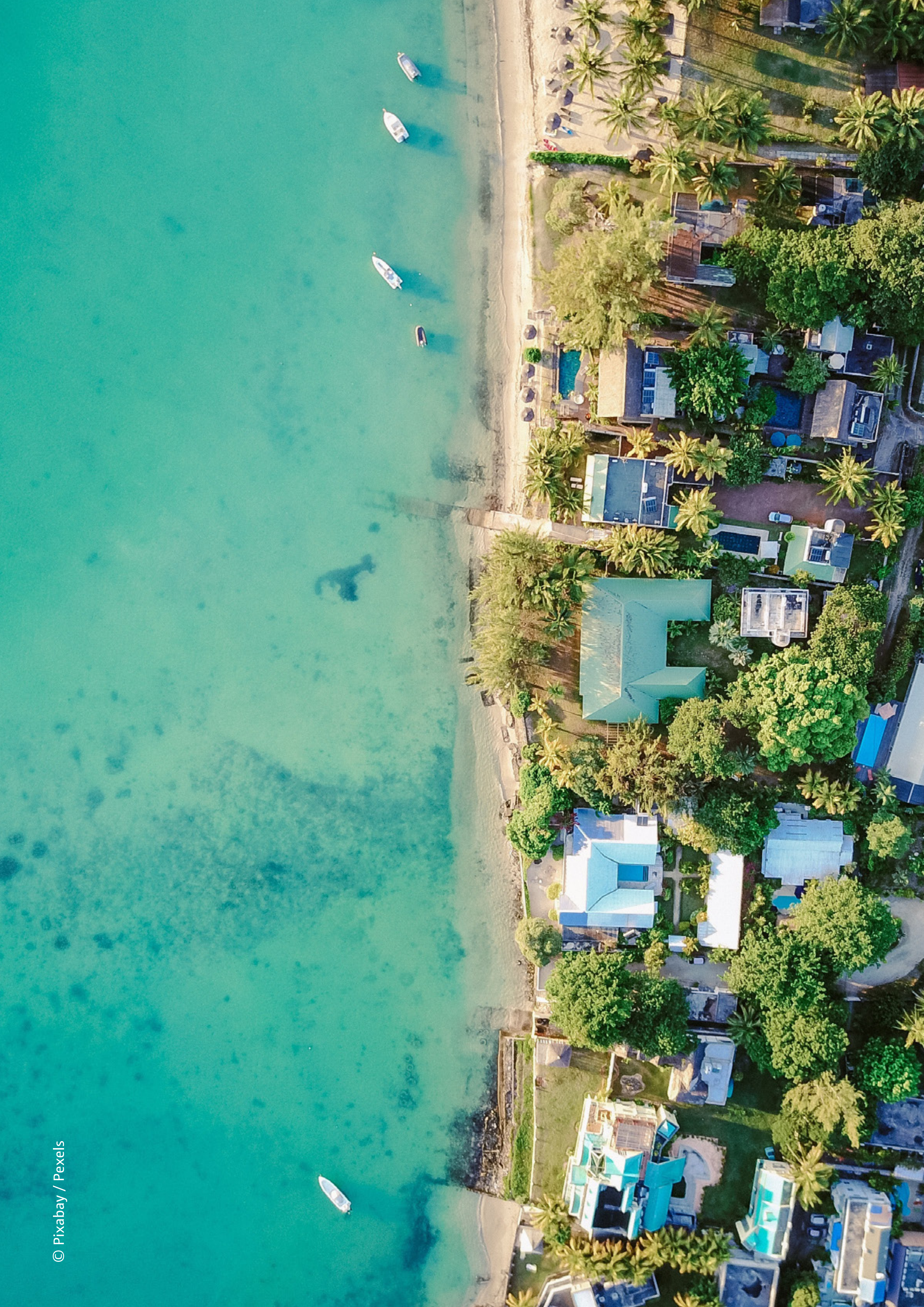
- **Put together a suitable mix of actors and policies:** To accommodate the wide range of actors and innovation phases, a mix of policies is needed, providing both technology push and technology pull type incentives, and engaging both bottom-up and top-down actors.

- **Allow flexibility in how policy goals are met:** This is particularly relevant in a developing country context. Where possible, the policy goals and aspirations should be defined, with the stakeholders given the flexibility to adopt the technology/means that suit them best to achieve those goals (e.g. be technology-neutral). This will generate credibility for policy implementation, manage risk perceptions of stakeholders and facilitate faster attainment of policy goals.

- **Pay attention to market creation for climate technologies:** For a mature and effective ecosystem for green innovation, policies, market structures and actor capabilities should be directed towards creating sustained demand and supply dynamics for clean technologies.

- **Focus beyond hardware innovation:** Technological hardware can provide an important contribution to mitigation and adaptation goals. However, this should be combined with building the capacity of local actors, creating the right communication channels for sharing knowledge and information, and establishing the right regulatory framework for an effective strategy to scale up the implementation of climate technology.

- **Strengthen local capabilities, while ensuring coordination:** Strengthening local capabilities is crucial for effective action. However, there is also a need for harmonization of curricula, protocols and information management mechanisms. Finding the right balance between bottom-up and top-down processes can be challenging, but can contribute to more effective strategies.



- **Create complementary knowledge and servicing infrastructure:** In order to promote and implement technological innovations effectively and consistently (in the long term), the creation and retention of complementary knowledge, skill sets and a trained human resource base must be facilitated. This will also aid in monitoring, evaluating and upgrading technological innovations.

- **Maximize productive engagement with international actors and opportunities:** International partnerships and exchanges can be very useful in learning from others' experiences and best practices. They also can help to develop local technological, financial, political and human resources. Therefore, international engagement can help to strengthen the NSI in many different ways but this also requires local actors actively shaping and driving this engagement. Furthermore, the international arena may well offer market opportunities that could be very productive.

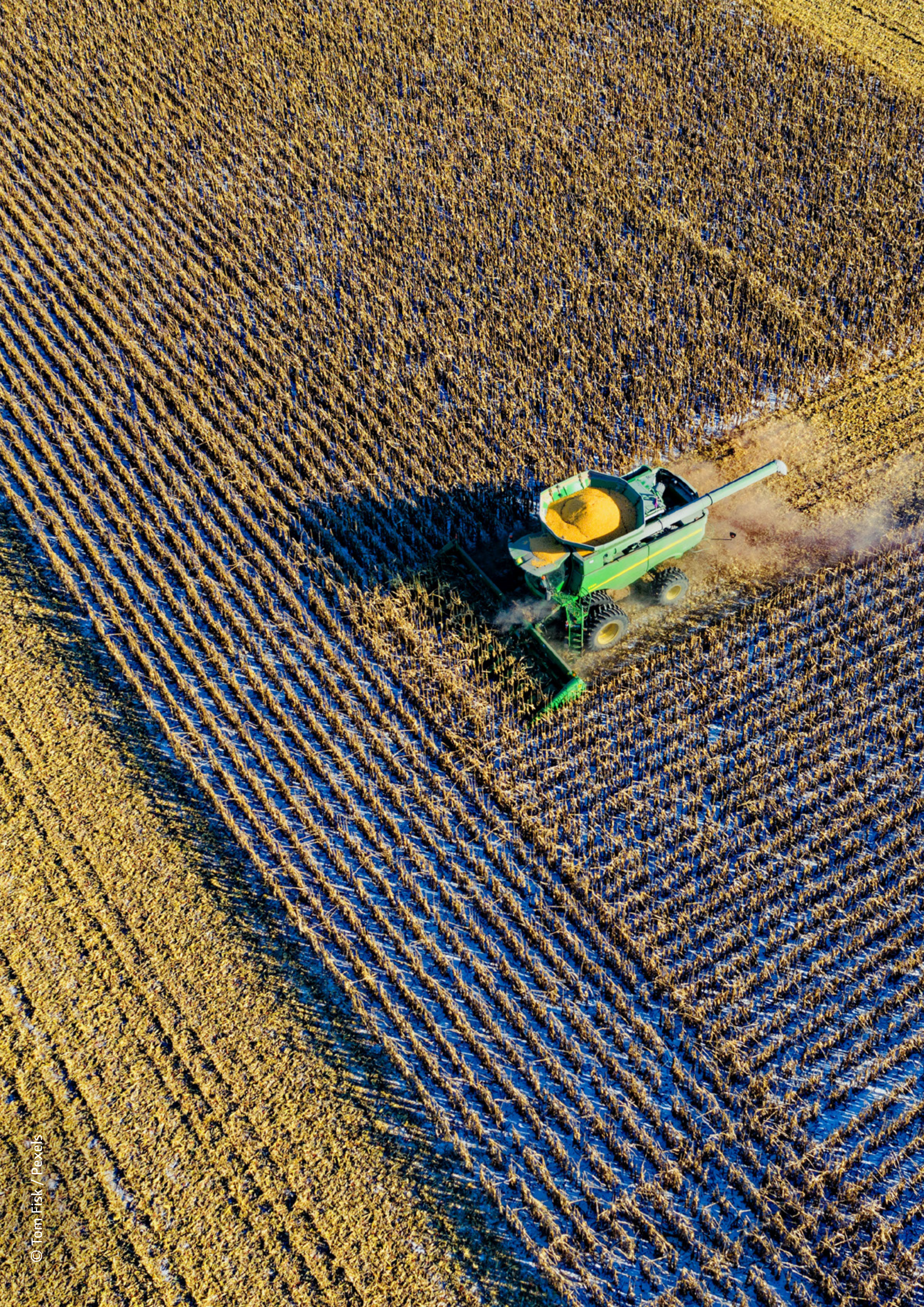
Recommendations on monitoring, evaluation, learning and revision of the contribution of the national system of innovation to climate action

- **Ensure there is adequate and systematic monitoring, evaluation and revision:** Since systemic change requires time, short-term planning (with too short time frames covering only a few years) will only be effective to a limited degree in achieving objectives. It is therefore important to plan according to longer time frames, while continuously taking account of progress made, and to review where necessary.

- **Evolve and improve through learning by doing and learning through analysis:** Learning comes both from evaluation and review-based analysis and from experimental learning by doing. These are complementary forms of learning and both should be utilized as the basis for constant enhancement of the NSI through the strengthening of functions and structural elements.

- **Adapt to evolving context and needs:** Climate actions will be ongoing activities, and the social, economic and political context and needs are likely to evolve over time. Therefore, NSI actors and institutions will also need to adapt and evolve over time in line with these changes. This responsiveness and dynamism has to be part of the institutional design from the early stages so the NSI continues to be relevant and useful in helping to deliver successful climate action over time.

Most of these recommendations will be operationalized through the appropriate government entities that are tasked with planning, implementing or monitoring and evaluating. But many are also relevant for other audiences. Multilateral and bilateral organizations can use them in the design of their support activities for national governments and other stakeholders. Civil society organizations, citizens and communities can use them to strengthen their public engagement activities, particularly during the preparatory stages to ensure that the prioritization is robust. They often also have knowledge to offer. The private sector is a critical stakeholder, although their role varies according to the issue at hand, for instance between adaptation and mitigation. Their engagement is important in the preparatory, design and implementation phases. Therefore, many of the recommendations directly pertain to them, such as those relating to entrepreneurial opportunities, how to address barriers for development and deployment of their technologies, routes for successful ways to engage with local partners and stakeholders, and the importance of using appropriate impact assessment, forecasting and risk management tools. And lastly, academic/research organizations can use the lessons learned to help in directing their research and educational activities to increase their relevance and effectiveness. They can potentially also play a role in the evaluation phase mentioned in the recommendations on monitoring, learning and revision.



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Annex: Main national system of innovation functions performed across case studies

The table below shows the **main NSI functions** observed in each of the cases. This shows that in all cases, the innovation system performs the function of knowledge development and diffusion, even though the primary audience may be different (end users, entrepreneurs, manufacturers, research and development actors, local communities, governmental actors). The innovation systems in Brazil and Denmark have a narrower focus (bioethanol, wind energy), but carry out all (or almost all) functions. In these cases, as well as for Kenya, the functions of entrepreneurial experimentation, market formation and resource mobilization are particularly well represented, given the importance of the private sector and market demand/supply as drivers. Market formation has also been important for India, creating demand and supply for energy efficiency products and services. Legitimation has been important for the adaptation cases in Haiti and Indonesia, for the necessary support for interventions with local communities. For India, Brazil and Denmark, this function focused more on legitimation of technologies or processes, to create confidence for investors and buyers. The development of positive externalities is especially clear for bioethanol in Brazil and wind energy in Denmark, where reduction of national dependency on international (sugar, oil) markets coincides with the development of new business opportunities and sectors, as well as – in the case of Denmark – increased opportunities and energy access for rural communities. The function “influence on the direction of search” can be fulfilled by a variety of actors and interventions, as the cases show: from national to local government and from international standards to local policy plans.

Main national system of innovation functions performed in each case study

Case	F1 Knowledge development and diffusion	F2 Entrepreneurial experimentation	F3 Market formation	F4 Influence on the direction of search	F5 Resource mobilization	F6 Legitimation	F7 Development of positive externalities
India BEE	• Awareness-building programmes to create an informed user base for energy efficiency • Interactions facilitated by the Bureau of Energy Efficiency to promote knowledge diffusion, peer-to-peer learning, best practice promotion • Knowledge exchange platforms • System to monitor, evaluate, adapt set-up	• Technology-neutral nature of programme for flexibility for entrepreneurs • Evolutionary approach to promote experimentation • Innovative funding designs based on stakeholder capabilities to de-risk investments	• Awareness-raising to create demand for energy efficiency • Innovative business models to incentivize actors, sustain demand • Phased approach, PPPs to support market transformation • Actor exchanges to create competition • Energy manager, verifier capabilities, protocols/standards to create trust in the market • Pilot programmes for early market development	• Technology-neutral nature of programme for flexibility for manufacturer to innovate • Interaction among industry actors to spread best practices, steer innovation/R&D • Definition of energy saving targets to promote innovation, R&D	• Ensured market demand, regulatory obligations to encourage manufactures to invest • Innovative funding models (PoAs, ESCerts, demand aggregation, auction mechanisms) to mobilize resources	• Evolutionary approach, increasing ambition over time • Flexibility for industry to meet targets (credits, ESCerts) • Start with low-hanging fruit to show feasibility • Creation of labels, testing infrastructure • Ensuring market demand	• Development of local manufacturing eco-systems • Development of insti-tutional infrastructure for effective implementation • Flexibility for manufacturers to meet targets • Interactions resulting in trust to enable implementation, scaling up • Incentives increasing actors' motivation • Increased human capabilities
Kenya KCIC	• Training, capacity-building, mentorships for entrepreneurs • Funding innovation, diffusion of clean technology • R&D collaboration, knowledge-sharing networks and events • Access to R&D facilities, incubator hubs • Market intelligence, policy advice to business	• Innovative engagement/business models/funding mechanisms for different stakeholders, innovation cycle phases • Facilitation of interactions to promote development of green businesses and uptake of projects • Policy advocacy to promote uptake and implementation of green business projects • Physical infrastructure for actor engagements	• Capacity-building of actors to engage in the market • Creation of awareness of merits of technologies, developing market demand • Funding for green projects in different phases, developing market supply side • Risk management to encourage business participation • Policy advocacy to promote market creation, reduce risk • Creation of market infrastructure (skills, funding mechanisms, facilities)	• Recognition of priority sectors for support and funding • Support/funds businesses/innovations aligned with overall policy goals • Advocacy for enabling policy for green RD&D • Facilitation of interactions between actors to guide the direction of research, learn from best practices	• Use of different business models/funding models and management of risks across the innovation cycle • Building actors' fund-raising capacities • Connecting potential funders/project developers • Government engagement to facilitate resources mobilization	• Due diligence on clients, investors, collaborators • Engaged in mainstreaming the Sustainable Development Goals, climate change • Mediating discussions between actors to enhance credibility of project/process	• Capacity-building to implement projects, fundraise, negotiate with collaborators, procure technologies • Development of networks, institutions and infrastructures for R&D, innovation, enhancement of value chains • Establishment of pro green business environment

Note: shading indicates the more important functions, as summarized at the start of each case study

Main national system of innovation functions performed in each case study (continued)

Case	F1 Knowledge development and diffusion	F2 Entrepreneurial experimentation	F3 Market formation	F4 Influence on the direction of search	F5 Resource mobilization	F6 Legitimation	F7 Development of positive externalities
Haiti DRR	• Committee to coordinate awareness-raising campaigns • Communication campaigns by government, non-governmental organizations • Network of local Disasters Reduction (DR) committees to develop/share knowledge, data, build capacity • Platforms, mechanisms for institutional/ intersectoral coordination • National databases, data tools, data gathering by many actors • Training, courses	• Adaptation of Sahana Open Source Disaster Management software to local context • Use of Sahana by volunteers and local actors to create new databases, consolidating DRR data management		• National system for coordination of the management National Disaster Risk Management System • Strengthened networks (government, teaching, communities) to provide plans, guidance, protocols • Plans, guidance, protocols, improved information provision re geospatial data to influence building practices, more resilient infrastructure • Improved coordination under several thematic committees	• Funding from government, international donors, crowdsourcing • Human resources (volunteers) for disaster response, tool/knowledge development • Dedicated budget lines for emergency response/ preparedness, tax revenues • Development of disaster reduction finance strategy • Participation in regional insurance mechanisms	• Integration of DRR in strategic documents • Sectoral committees to develop standards, codes • Codes and protocols for more resilient infrastructure • Guidelines for interaction, communication in case of a natural disaster	

Main national system of innovation functions performed in each case study (continued)

Case	F1 Knowledge development and diffusion	F2 Entrepreneurial experimentation	F3 Market formation	F4 Influence on the direction of search	F5 Resource mobilization	F6 Legitimation	F7 Development of positive externalities
Brazil bioethanol	• Multiple RD&D projects conducted via multi-stakeholder collaborations, including producers and users across the value chain • Policies to promote knowledge development, diffusion • National Oil Agency requirement to use 1% of oil and gas revenues for R&D • Local industry learning from imported technology	• Experimentation initially led by sugarcane producers, then by other private sector actors such as technology suppliers • Policies to incentivize experimentation, including the ethanol industry's status as an 'industry of national interest' • Collaboration between universities and government on early experimentation • Multi-stakeholder collaborations for exchange between knowledge producers/users, accelerating incorporation of lessons learned	• Policies to stimulate demand, including public procurement • Government coordinating with the sugar, automobile, and oil and gas industries to align expectations to create trust in the market and coordinate action for ramping up • Automobile industry development of flex-fuel vehicles • Increased international environmental concerns, resulting in demand for sustainable biofuels	• Presence of a strong sugarcane industry, industry lobby • Policies and institutions aligned expectations for future ethanol technology (and market) development, including standards and regulations • Designation of ethanol industry as an industry of national interest • International agreements, policies to reprioritize between first-generation ethanol and second generation ethanol	• Government subsidies, R&D funding from research and innovation public funds, national development bank • National Oil Agency requirement to use 1% of oil and gas revenues for R&D • Private funding via private R&D institutes, technology suppliers, manufacturers and joint R&D projects with universities and government	• Sugarcane producers supporting ethanol to reduce dependency on international markets • Early mandatory blending requirements for ethanol • Recognition of ethanol as an industry of national interest • Public campaigns on ethanol vehicles to increase acceptance • Scientific meetings to share best practice • Benefits from reduced dependency on international markets	• Recognizing ethanol as an industry of national interest, creating opportunities for industrial development • Economic benefits for sugarcane, automobile and energy sectors • Job creation • Economic efficiency for consumers in flexibility in choosing fuel through flex-fuel vehicles • Technological routes with lower environmental impact • Benefits leading to support for technology, policies
Jakarta, Indonesia urban flood manage-ment	• Subsidies, surveys to understand/ assess causes, risks, impacts and potential solutions for floods • Flood forecast studies • Capacity-building, awareness-raising programmes to develop capabilities of stakeholders and communities	• Project partnerships formed in consideration of required resources, skills for specific projects • Public–private partnerships in large investment projects • Competitive tendering to select project participants in large-scale projects	• Government authorities and agencies are active participants to create an enabling environment for investments	• National, regional legislations steered search • Interactions with international innovation system/ expertise also a key driver	• Internal partnerships, collaboration to generate funds • Public–private partnerships to address funding gaps	• Capacity- and awareness-building activities, stakeholder consultations to build trust, transparency, and ownership • Engagement of local communities in developing and implementing early warning systems	• Interactional partnerships for new resources, knowledge, technologies • Development of more aware, capable stakeholders, including youth • Capabilities, infrastructure for flood management with spillover effects for other sectors

Main national system of innovation functions performed in each case study (continued)

Case	F1 Knowledge development and diffusion	F2 Entrepreneurial experimentation	F3 Market formation	F4 Influence on the direction of search	F5 Resource mobilization	F6 Legitimation	F7 Development of positive externalities
Denmark wind energy	• R&D funding lines, promoting knowledge development at universities • MSc, PhD, technical education programmes to develop wind energy capabilities • Individual scientists diffused knowledge in rural areas • University–industry feedback between knowledge producers and users, diffusing knowledge among actors • Planning procedure, public hearings diffusing knowledge at different levels and local communities	• Champions with a key role in early bottom-up experimentation • Rural companies promoted experimentation with manufacturing process, learning 'on the go' • Early rural experimentation to form a wind Technology Innovation System with strong community ownership	• Strong government role to set conditions for a competitive market position for wind energy • Policies to reduce barriers (grid access, integration) and generate funds for wind energy RD&D and deployment (taxes) and incentives for wind turbine manufactures, local cooperatives, end users • Leveraging the international market for the wind power industry in Denmark	• Societal resistance to e.g. nuclear energy to meet energy/ environmental goals • Government R&D funding, especially for large-scale wind energy • Local cooperatives, small manufacturers, scientists in a community-owned, small-scale system for rural development • International agreements, national energy plans' long-term wind energy targets to align expectations around the technology as a solution for existing challenges • Publications, meetings to set standards, share best practice for wind energy	• Energy/ environmental taxes to fund wind energy R&D • Consumers contribution to TIS through energy taxes, public service obligation • University–industry interaction to fund R&D where public funding is limited • Multi-stakeholder partnerships e.g. to reducing risks for private companies • Feed-in tariff, subsidies for building, operating wind parks, replacing aging turbines	• Independent experts, environmentalists viewing wind as alternative to nuclear, fossil fuels • Wind energy as key in national energy plans, i.e. as a legitimate energy supply technology • Publications highlighting Danish wind technology's good performance • Local actors, cooperatives increasing awareness regarding benefits for rural areas • Effective public hearings to ensure meaningful stakeholder engagement	• Financial support for local cooperatives, strengthening their capabilities and roles • Strong community ownership to ensure wind energy helps to meet local community goals • Actors, networks with environmental and rural development concerns increasing political support for wind energy • Formation of a local renewable energy system, reducing energy dependency and decarbonizing electricity production without nuclear power • Establishment of an internationally leading industry

About the Technology Executive Committee

The Technology Executive Committee is the policy component of the Technology Mechanism, which was established by the Conference of the Parties in 2010 to facilitate the implementation of enhanced action on climate technology development and transfer. The Paris Agreement established a technology framework to provide overarching guidance to the Technology Mechanism and mandated the TEC and CTCN to serve the Paris Agreement. The TEC analyses climate technology issues and develops policies that can accelerate the development and transfer of low-emission and climate resilient technologies.

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