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Technology Executive Committee

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Technology roadmaps for scaled-up implementation of climate technologies in developing countries

Scoping paper

I. Background

1. Joint work programme of the UNFCCC Technology Mechanism for 2023–2027 includes a joint activity A.1. on technology roadmaps, including planning tools, catalysing the development and use of technology roadmaps, at international, regional and national levels to support the implementation of NDCs, NAPs and LT-LEDS.

2. With regard to the TEC–CTCN joint activity on technology road maps, the TEC and the CTCN Advisory Board considered a draft concept note prepared by their secretariats and requested the joint task force, taking into account the guidance provided, to produce a draft paper for scoping further work on the topic for consideration at the next joint session of the TEC and the CTCN Advisory Board.

3. At the joint session, the joint taskforce on the technology roadmaps, with support from the secretariats and a consultant, will report on progress in the development of a scoping paper on technology roadmaps.

II. Scope of the note

4. The annex to this note contains a draft scoping paper on the technology roadmaps for scaled-up implementation of climate technologies in developing countries.

III. Expected action by the Technology Executive Committee

5. The TEC and the CTCN Advisory Board will be invited to consider the scoping paper on technology roadmaps and provide guidance for further work on this matter.

Annex

Scoping paper: Technology roadmaps for scaled up implementation of climate technologies in developing countries

Executive Summary

1. This paper examines previous work by the CTCN and the TEC and other processes under the Convention, and beyond, to better understand the concept of Technology Roadmaps (TRMs). For that, the paper analyses TRMs, including those supported by the CTCN, technology needs assessment (TNAs) and national adaptation plan (NAP) documents produced during approximately the past ten years have been analysed. Good practice experience with these technology road mapping in developing countries have been identified, including coping with challenges encountered. Based on this, the paper offers inputs for TEC and CTCN to define a scope for TRMs climate technology development and transfer in developing countries.

2. The evaluation in this paper shows that the scope for TRMs can cover individual technologies or whole sectors, countries, or regions, and can yield relatively advanced implementation plans or future envisions for the development of a concept through scenarios and policy recommendations.

3. From this paper, it can be extracted that TRMs performed with the support of the CTCN often do not have formal links to other processes under the Convention, such as TNAs. In case interlinkages emerge, this is often due to the initiative of the TRM elaboration team. Hence, some TRMs are aligned with other processes while others are mainly developed as stand-alone processes. Another finding is that there is often not a clear shortlisting and prioritisation process, with some documents featuring detailed analyses on the criteria used to identify the selected actions, and other documents tackling sectors or technologies without describing the mechanisms used for its selection.

4. TEC and CTCN could therefore consider the TRM as an overarching concept that supports countries in conducting a full cycle of technology prioritisation for achieving national goals for climate and development, thereby efficiently combining elements of already existing processes. This information could then be communicated with multilateral development banks (MDBs), and other private and public bodies offering financial and technical support.

5. As such, the TRM concept under the Technology Mechanism would not necessarily be a new trajectory with additional needs for country resources and reporting commitments. Rather would TRM support developing country decision makers in binding available support together into a coherent decision making and implementation package.

6. Other possible directions for scoping the TRM concept are:

(a) **TRM guidebook**: The impact of TRMs could be improved by extended the existing TRM format, as used by CTCN, towards a guidebook. This could help developing countries requesting assistance through the CTCN to improve their TRM report and align this work with other supporting mechanisms under the Convention and elsewhere;

(b) **TRM as reference document**: The database of, for instance, TNAs is extensive and provides valuable information for other countries. Amalgamating this information across countries, *e.g.*, within a region or with similar climate and development needs and characteristics, could result in TRM reference documents with generalised challenges and solutions for climate and development. These could form valuable reference documents for other countries that are facing similar challenges and that could tap in proven solutions developed elsewhere;

(c) **TRM for new and proven technologies in developing country contexts**: In line with the above reference document suggestion, the bulk of knowledge gathered through CTCN-supported TRMs, TNAs, NAPs, etc., can be used to draft technology-level TRMs for technology options in the stage of RD&D and already proven solutions. This would help countries to follow a roadmap for implementing a particular technology, *e.g.*, battery storage or climate-resilient crops, based on good practice examples gathered elsewhere in developing country contexts, including where financial and capacity building support can be acquired.

Acronyms and abbreviations

CMA	Conference of Parties serving as the meeting of the Parties to the Paris Agreement
COP	Conference of Parties to the UNFCCC
CTCN	Climate Technology Centre and Network
EU	European Union
GCF	Green Climate Fund
GEF	Global Environment Facility
	Greenhouse gases
GST	Global stocktake
IGO	Intergovernmental organisations
IEA	International Energy Agency
LANDMARC	Land use based mitigation for resilient climate pathways
LPG	Liquefied petroleum gas
LT-LEDS	Long-term low emission development strategies
MDBs	Multilateral development banks
MOI	Mean of Implementation
NAP	National adaptation plans
NDC	Nationally determined contributions
NGO	Non-governmental organisations
NOx	Nitrogen oxides
PCCB	Paris Committee on Capacity Building
PSP	Poznan Strategic Programme
RD&D	Research, development and demonstration
SBSTA	Subsidiary Body for Scientific and Technological Advice
SBI	Subsidiary Body for Implementation
SCF	Standing Committee on Finance
SDGs	Sustainable development goals
SSC	South to South Cooperation
TAP	Technology action plan (part of TNAs)
TEC	Technology Executive Committee
TNA	Technology needs assessment for climate change
TRMs	Technology roadmaps
UNEP	UN Environment Programme
UDP	UNEP DTU Partnership
UNFCCC	United Nations Framework Convention on Climate Change

I. Introduction

A. Background

7. The United Nations Framework Convention on Climate Change (UNFCCC) is the focus of the political process to address climate change. Its secretariat supports the Convention, Kyoto Protocol, and Paris Agreement, aiding meetings of the Parties for these arrangements.

8. The UNFCCC's Means of Implementation Division (MoI) aids in resource mobilization, tech cooperation, capacity-building, and awareness for effective climate action. The Technology sub-division promotes collaboration on tech for adaptation and mitigation, backing the Technology Executive Committee's (TEC) functions and the Technology Mechanism, established in 2010 by UNFCCC Parties. The TEC and the Climate Technology Centre and Network (CTCN) are, respectively, the policy and implementation arms of the Technology Mechanism.

9. The UNFCCC's 2023-2027 Technology Mechanism joint work program features a collaborative effort on Technology Roadmaps (TRMs). This involves creating planning tools and promoting the adoption of TRMs globally, regionally, and nationally. The goal is to assist in implementing NDCs, NAPs, and LT-LEDS.

10. Regarding the TEC-CTCN joint effort on TRMs, the TEC and CTCN Advisory Board (AB) reviewed a concept note prepared by the secretariat. They asked the joint task force to draft a paper outlining future work based on given guidance. This draft will be discussed at the next TEC and CTCN AB joint session.

B. Objectives

11. This scoping paper's goal is to help the TEC and the CTCN AB use the TRM concept to help countries to make decisions about climate technologies and effective implementation planning. The paper will evaluate current procedures that support the road mapping of climate technologies in developing countries, both inside and outside the Convention. It will discuss the difficulties these processes face and investigate whether TRMs can provide solutions.

12. More specifically, the paper aims to:

(a) Identify success stories and lessons learned from experiences with technology road mapping, including from work by the TEC, CTCN technical assistance and other international organisations, to further develop the concept of TRMs under the Technology Mechanism;

(b) Analyse steps to prepare TRMs for mitigation and adaptation, thereby considering already existing actions for country-driven prioritization and planning of climate technologies. The latter include technology needs assessment (TNA) with its technology action plan step (TAP), national adaptation plans (NAP), long-term low-emission development strategies (LEDS) and nationally determined contributions under the Paris Agreement (NDC);

(c) Identify challenges related to climate technology prioritization, planning, implementation, and evaluation, and assess how joint TEC/CTCN action on TRMs could address these challenges. This includes exploring financial resources for that and links to existing financial mechanisms under and beyond the Convention and programmes of the multi-lateral development banks (MDBs).

C. Scope of the paper

13. The scope of this paper ranges from TRMs at the level of a major technology, a sector, the national or even international, such as a regional context. With that the paper acknowledges that TRMs can focus on innovative approaches for progressing a specific climate technology in multiple countries but could also take a national or sector policy perspective by exploring how a prioritized portfolio of climate technologies can be successfully scaled up in the sector or country.

14. This paper crucially examines the entire decision-making cycle of technology roadmap processes, as outlined in the TEC background (2013). It proposes linking effective existing processes

within the Convention to create a comprehensive framework for technology road mapping, encompassing initiation, prioritization, monitoring, and evaluation.

15. The intention is thereby not to suggest a new process under the Convention with reporting mandates for countries, but to offer support to the TEC and the CTCN to connect existing successful element for improved practical support to developing countries and strengthened policy advice to the COP.

16. Work to be considered for that is, i.a.:

(a) Earlier work by the TEC on Technology Roadmaps (TEC, 2013);

(b) Lessons learned from work on TNAs and its main product, the TAPs;

(c) Case studies carried out by the CTCN on Technology Roadmaps in developing countries;

(d) Case studies of mitigation, adaptation and cross cutting Technology Roadmaps, and other relevant documents and literature.

Box 1
Overview of existing climate technology planning processes

This paper will analyse and consider links between TRMs and existing practice with climate technology planning, with a specific focus on developing countries. These are briefly introduced below:

Technology needs assessment (TNA) has been a process under the Convention since 2001, followed by the Global TNA project which started in 2009. The latter is backed by the GEF and managed by UNEP Copenhagen Climate Centre (UNEPCCC). TNAs aid developing countries in prioritizing climate technologies, by involving stakeholders in a process where the country aligns sustainable development goals with emission reduction and climate resilience through technology selection.

Following the prioritization of climate technologies in a TNA, with technology action plans (TAPs) implementation plans are constituted. TAPs often feature specific actions, timelines, cost information, and potential funding mechanisms, and are ideally ready for consideration by financial institutions.

In their national adaptation plans (NAPs), countries define solutions for increasing their climate resilience, such as natural disaster early monitoring systems, actions in key sectors to shield them against future climate disturbances, policy recommendations and training programs, etc. NAPs are usually elaborated through a top-down approach, and they generally do not define implementation plans.

Long-term low emission development strategies (LEDS) are documents to be formulated and communicated by countries, as decided in the Paris Agreement (UNFCCC, 2016, pp. 7, Art.4.19). As concluded by (UNFCCC, 2022), LEDS generally provide a “clear development perspective and integrated climate change related aspects and objectives with development visions, priorities, principles or economic, social and environmental objectives.” LEDS do not feature specific action plans and submissions after COP21 include explicit references to NDCs, which are often reported to have been built on previous LEDS submissions, whereas recent LT-LEDS are largely based on NDCs.

Work on technology roadmaps (TRM) has been supported by, i.a., the CTCN at the request of developing countries (see elsewhere in this paper). TRMs can adopt a variety of forms as no standardised format for it exists yet under the Convention (e.g. when compared to the detailed TNA and TAP guidance). There are similarities with TAP steps, in terms of its focus on actions for implementation of climate technologies in a country (sector).

II. The initial scoping for climate technology roadmaps by the TEC

17. In its rolling workplan for 2012-2013 the TEC included the preparation of an inventory of existing climate technology roadmaps (TRMs). This resulted in a background paper published by the TEC (2013) with an analysis of existing TRMs, including good practice examples.

18. The paper adopted the following working definition of a TRM: "A Technology Roadmap serves as a coherent basis for specific technology development and transfer activities, providing a common (preferably quantifiable) objective, time-specific milestones and a consistent set of concrete actions; developed jointly with relevant stakeholders, who commit to their roles in the Technology Roadmap implementation." (TEC, 2013)

19. Hence, a TRM is an action-oriented pathway centred around climate technologies for realising a vision for a desired future situation. For example, a TRM for hydrogen would contain a vision on how this technology option can replace conventional fossil fuel use in transportation. It could also focus on how the option can serve as an energy carrier by converting renewable energy into hydrogen or synthetic gas, so that electrons generated through solar, or wind energy are used to generate molecules for heating, industrial and transport services.

20. This vision is usually based on trends and drivers (TEC, 2013) within the relevant sector, as well as technology innovations, cost developments, energy resources in a country and the existing infrastructure and capacity. These aspects together determine how stakeholders in the country see a potential for the technology option. After determining this future, concrete actions can be identified for a technology implementation plan.

21. A potential limitation of TRMs is that their scope can easily become too wide. Taking the above example of hydrogen, it can have multiple applications and for each a separate vision with an action plan can be formulated. Let alone, applications of a technology can differ strongly between countries. This can be the case because of different country contexts and countries' differing abilities to adopt the technology in existing (energy) market systems or modify these systems as needed for hydrogen diffusion.

22. The above framework for TRMs, i.e., an action-oriented pathway towards a desired future, has in practice been applied at different levels, such as that of a company/industry, a sector, or a country. According to TEC (2013), at corporate level a TRM can identify, *e.g.*, what research and development (R&D) activities a company needs to undertake for successful implementation of a technology option and how to organise these activities internally. TEC (2013) concludes that "private sector Technology Roadmaps are primarily focussed on R&D," with a "focus on product innovations (achieving new functionality and performance of technologies)."

23. At the level of the sector, a TRM could fulfil the function of binding preferences of sectorial stakeholders together into a vision for the sector with a (set of) prioritised technologies for realising this vision. Such a TRM process is likely to be more complex though than a technology-level TRM as for a sector-level roadmap multiple and possibly conflicting interests need to be considered and combined. The scope of sector-level TRMs is mostly on a generic class of technologies (TEC, 2013).

24. National and international level TRMs are likely to be most complex as they tap into interests and development of multiple sectors, national strategic processes, and policy processes. TEC (2013) concludes that public TRMs "are predominantly concerned with technology diffusion (implementation, deployment)" with a "focus on organisational innovations ... implementing technologies new to a specific field, organisation, country, *etc*. to achieve desirable societal, economic and technical outcomes."

25. Concerning (inter)national policy dimensions, TEC (2013) identifies the following possible contributions of a TRM to:

(a) Providing a coherent basis for (inter)national technology RD&D policy;

(b) Forming a basis for national policies in support of climate technology diffusion;

(c) Catalysing innovations, in particular in developing countries, to allow existing climate technologies to enter new markets;

(d) Mobilizing private and public entities' interests in climate technologies, as they partake in a Technology Roadmap process;

(e) Providing a structure for enabling the implementation of results of technology needs assessment (TNA) processes in developing countries, including via the implementation of technology action plans (TAPs);

(f) Integrating technology-related activities carried out by different ministries within countries, so that these activities form "a coherent strategy supported by all ministries and donors engaged" (TEC, 2013).

26. Building further on IEA (2010), TEC (2013) highlighted that TRMs are developed based built upon data and information provided by experts, which is then processed through four phases:

(a) Planning and preparing the process of TRM formulation;

(b) Formulating a vision with identification of long-terms goals and objectives;

(c) Roadmap development, with expert workshops;

(d) Roadmap implementation and revision.

27. Of key importance in the process of designing a TRM are key experts who bring in their expert knowledge and partake in "consensus-building activities [that] form the core of an effective technology road mapping process." (IEA, 2010) Another key aspect is the continuity of the process once implementation of the technology (portfolios) has taken place. According to TEC (2013), TRMs are commonly seen as "'living documents' that require regular revision," thereby checking their credibility, desirability, utility, and adaptability.

28. As of 2013, most TRMs analysed by TEC (2013) were focussed on technologies for mitigation (95%; mainly renewable energy or other energy-related technologies), whereas TRMs for adaptation were mostly about sustainable management of water resources. Moreover, TRMs were mostly authored by developed country analysts, with "a clear lack of Technology Roadmaps authored by or relevant to Non-Annex I countries." (TEC, 2013)

29. On adaptation, TEC (2013) concluded that TRMs aimed at both 'soft' technologies such as practices for climate resilience, management strategies and behavioural patterns, and 'hard' technologies such as dams and infrastructure investments, or a combination of soft and hard technologies.

30. In terms of vision development, TRMs for adaptation generally focussed on coping with a country's climate change vulnerability. At the same time, the TEC (2013) noticed that uncertainty about this vulnerability, due to uncertainty about climate change impacts for a region or country, complicates TRMs' prioritization of solutions for adaptation and determination of the scale of their implementation.

III. Practice with road mapping for climate technology implementation in developing countries

A. Review of practice with CTCN-assisted technology roadmaps

31. The Climate Technology Centre and Network (CTCN) has provided technical assistance to developing countries in designing TRMs for the implementation of climate action plans within their national contexts. These TRMs are often additional to other processes, e.g., carried out in countries that have not participated in the Global TNA Project or in sectors not covered by these other processes. CTCN-supported TRMs could also have a specific focus, such as on the circular economy.

32. In this section, eleven of the CTCN-supported TRMs in developing countries, conducted since 2013, are analysed according to their:

a) Alignment with NDCs, past TNAs and NAPs;

b) Involvement of the private sector;

c) Technology selection and prioritization process;

d) Results and outcome;

e) Scope covering single technology, technology sector or national policies.

33. The CTCN assisted TRMs generally follow a standardized template. In this, a description of the alignment of TRMs with NDCs, as well as sustainable development goals, is suggested. Most TRMs take into consideration the NDC process in the country concerned, although to differing extents. While the template asks to define the contribution of the TRM activity to a country's NDC, the descriptions of this contribution differ in terms of level of detail. For instance, resulting TRMs do not necessarily quantify its contribution to emission reduction, making it difficult to directly feed emission reduction estimates into NDC action plans.

34. It is noted that this standardized template has only been used in those processes that have been directly coordinated by the CTCN. In other processes, while these may receive technical support from CTCN, the process steps have been less standardized. Consequently, the degree of alignment of these processes with national mitigation goals described in NDCs varies strongly.

35. As for TNAs and NAPs, the CTCN template does not foresee an explicit elaboration on alignment with a TRM, although alignment with these processes is sometimes defined by the TRM elaboration team itself. It is noted that of the eleven countries analysed, two conducted a TNA since 2013 (Uruguay and Tanzania). However, no alignment (neither explicit nor in content) was found between the processes.

36. Regarding the involvement of private sector stakeholders, it has been found that some reports explain how stakeholders have participated in the TRM drafting process, but others provide less information about that. The consideration of the private sector in these TRMs is generally focussed on describing their role as stakeholders in technology development and transfer.

37. The standardized template for the CTCN TRM process does not include a process for prioritising strategic sectors for climate and development, nor technology options. While some documents briefly describe the rationale behind the sector and/or technology choice, these descriptions do not necessarily link the technology choice to any specific process or NDC goal.

38. In terms of identifying climate technology solutions, the analysed TRMs therefore show different approaches, ranging from a detailed shortlisting process of technology options (similar to a TNA) to a pre-determined technology solution for which a TRM is drafted for its market deployment. Analysed TRMs of the first type also tend to include stakeholder consultations and assessing technology options against socio-economic criteria within the country context.

39. In line with the above observation, also the results of the analysed TRMs differ. Some TRMs result in prioritised climate technology portfolios and scenarios while others deliver detailed implementation plans for a specific technology.

40. In terms of scope, analysed TRMs supported by the CTCN generally address a whole sector but they can also be focused, as explained above, on a single technology. In general, through the TRM advice developing country governments have strived for acquiring the in-depth knowledge of technology development and transfer issues that they desired within their country context.

41. Box 2 show two illustrations of TRM conducted with support from CTCN; one example shows a regional initiative culminating in a joint roadmap focussing on the circular economy; the second example show a TRM featuring a technology prioritization process.

Box 2
Examples of TRMs with support from CTCN

Technical Assistance Closure Report – Assessment of the current status of the Circular Economy for developing a Roadmap in Brazil, Chile, Mexico, and Uruguay

While facing vulnerability for natural resource exploitation, Brazil, Chile, Mexico, and Uruguay collaborated on a forward-looking assessment of circular economy implementation. Identifying key stakeholders and addressing circularity gaps and deficits, this effort culminated in a joint roadmap for sustainable resource use. Circular economy emerges as a solution to natural resource depletion and vulnerability to exploitation in the region. Conducted between July 2019 and August 2021 under the CTCN, this innovative initiative intertwines circular economy with climate action. This report concluded with a proposed pilot

project that could be used to secure funding from international collaborations, such as the Green Climate Fund.

Technology Roadmap Implementation Report – Technology Roadmap for the Implementation of Climate Action Plans in Palestine

The State of Palestine anticipates greater water scarcity, decreased agricultural productivity, decreased food and water security, and saline water intrusion as severe impacts of climate change to its economy and development. Unlike most technology assistance requests sent to the CTCN, this TRM includes a prioritization process to create a shortlist of technologies based on a certain criterion. A short list of climate change adaptation and mitigation technologies was formulated based on rating a long list of technologies through the completion of a scoring process using six criteria. The short list of technologies delivered in this TRM will create synergies between the Green Climate Fund Country Programme and the implementation action plan of Palestine's NDC. The TRM specifies how the technologies will benefit Palestine's most vulnerable communities – women, youth, and persons with disabilities. The technologies are prioritised from easiest to implement to the most challenging to implement.

42. Considering the contributions by TRMs to national climate technology development and diffusion, as per the criteria formulated by the TEC (2013) (see elsewhere in this paper), the following lessons can be drawn from the CTCN experience with conducting TRMs as discussed above:

(a) **Providing a coherent basis for (inter)national technology RD&D policy:** CTCN TRMs are directed to targeting specific national issues primarily through the implementation of known technologies. Hence, their focus is not on elaborating RD&D policies. However, some CTCN TRMs recognise that policies supporting RD&D should be implemented to ensure the continuity and improvement of the actions in the mid and long-term;

(b) **Forming a basis for national policies in support of climate technology diffusion:** CTCN TRMs acknowledge the necessity of implementing policies that enable the implementation of the addressed technologies and allow for future developments in the mid-to-long term. However, no specific policy recommendations are suggested;

(c) **Catalysing innovations in developing countries to allow existing climate technologies to enter new markets:** CTCN TRMs emphasize the application of existing climate technologies in developing countries, also encouraging their adoption by the private sector to promote their development aside from public intervention;

(d) **Mobilizing private and public entities' interests in climate technologies, as they partake in a Technology Roadmap process:** the elaboration of CTCN TRMs always involves the public sector of the beneficiary country. While mentioned, it is not always specified how and where private sector stakeholder partake in the process. However, many CTCN TRMs recognise the necessity of involving the private sector to achieve large-scale implementation and foster further developments;

(e) **Providing a structure for enabling the implementation of TNA results in developing countries:** In general, CTCN TRMs are not aligned with other processes such as TNAs. Therefore, the stepwise technology prioritization structure as in TNA is often absent. Yet, implementation of TNA-prioritised technology options could benefit from TRMs work on enhancing deployment of climate technologies;

(f) **Integrating technology-related activities carried out by different ministries within countries, so that these activities form "a coherent strategy supported by all ministries and donors engaged":** CTCN TRMs involve different relevant ministries within the beneficiary country, strengthening the process with multidisciplinary support and building consensus among governmental institutions and other participating parties.

B. Review of practice technology roadmaps not coordinated by the CTCN

43. Following the same criteria as applied in the discussion above, ten TRM processes are briefly discussed which have been conducted without the coordination of the CTCN (see Annex II). These TRMs have been supported by international organisations, such as the International Energy Agency (IEA) and the Green Climate Fund (GCF), private industry entities, and regional and national governments. Box 3 shows examples of these TRMs.

44. It has been found that these TRMs vary considerably in terms of structure but also in terms of alignment with, for instance, NDCs. Some of the TRMs are aligned with NDCs, especially in case of support from IEA and GCF, but alignment with TNAs and NAPs was only found in one TRM.

45. Most of the analysed TRMs in this category address a sector, instead of specific technologies. Linked to this, it was found that the result of most of these TRMs is not a detailed implementation plan with explicit timeframes and funding mechanisms, but rather the identification of a specific desired scenario for technology transfer.

46. The shortlisting and prioritization of actions in this category of TRMs varies strongly, with those supported by public international institutions often including stakeholder consultations for assessing the most suitable options. TRMs developed by national and regional governments and industrial entities rely more on top-down scenarios or focus on a pre-determined technology option. This is particularly true for TRMs produced by private companies, which often envision a future based on the endorsed technology without considering other options.

47. As most TRMs in this category use different formats and also often have different scopes, it is difficult to draw overarching conclusions on the differences between the processes supported by the CTCN and those elaborated by different institutions. However, some key differences can still be observed:

(a) Despite not being (seemingly) compulsory for CTCN TRMs to be mainstreamed with other UNFCCC processes, the mention to "contribution to NDC" in the CTCN TRM template encourages the creation of this linkage, with most documents defining this alignment. In the case of non-CTCN supported documents, the establishment of links to UNFCCC processes is up to the elaboration team, with some documents being well aligned with NDCs, NAPs and even TNAs, and many others completely omitting these alignments;

(b) CTCN-TRMs are more action-oriented, even without stablishing detailed plans, than many non-CTCN supported TRMs. The results of the latter can range from relatively elaborate action plans to the envision of a broad desired future, with few action plans to achieve it.

Box 3
Examples of Technology Roadmaps without the support of the CTCN

Cambodia's E-mobility roadmap (supported by the GCF)

Cambodia is one of the most vulnerable countries to the effects of climate change in Asia. Transport sector in Cambodia accounts for 53.1% of emissions in the energy sector, and 45% of the total fuel consumption, which is mainly imported petroleum, contributing to a poor energy security. Therefore, Cambodia decided to analyse their current policies (including their NDC), socio-economic barriers (through stakeholder workshops), and technical and infrastructural capacity, to assess how to foster sustainable mobility, with the goal of avoiding emissions and reduce energy dependence. With these findings, they created a strategy with supporting policies, funding, and institutional mechanisms to foster the implementation of sustainable mobility technologies.

Fostering Autogas in Europe (European LPG Association)

In this technology roadmap, the European LPG Association describes how LPG can contribute to the climate transition and energy security of the European Union in a cheaper and faster way than other options, given its technology-readiness. The report presents emission-reduction scenarios based on the penetration of LPG-powered vehicles in the car fleet. The authors point out that LPG-powered vehicles are compliant with most cities' low-emissions areas, and they provide with a policy package that practitioners can use to increase the share of LPG-powered

vehicles to meet environmental targets, along with compromises from the LPG industry to facilitate this.

Marshall Islands Electricity Roadmap

In this technology roadmap, the government of the Marshall Islands looks at their emissions reduction targets for the electricity sector as defined in their NDC. Then they assess the islands characteristics to define a set of technology actions that could be taken to meet the NDC goals based on technology readiness and appropriateness. This results in a set of implementation goals for specific technologies (such as wind and solar energy) for different time frames. This TRM creates a baseline for policymaking to meet the NDC targets.

LANDMARC – EU-research project on pathways for nature-based negative emissions

The EU-funded LANDMARC (www.LANDMARC-project.eu) project uses a bottom-up approach to study land-use solutions that contribute to climate change mitigation. After consultation with land-users and experts from fourteen countries, the project shortlists solutions for application in these countries. Through monitoring and computer simulations, the project assesses the effects on mitigation of these solutions, including their mitigation potential if applied on a global scale.
However, upon more detailed observation of these techniques, it can be concluded that not only they contribute, to variable extents, to climate change mitigation, but most of them also excel at improving the resilience of the system against climate change. This is because the bottom-up approach allowed the project identifying the most advantageous solutions from the land-user perspective.

48. From the review of TRMs elaborated with and without the support of the CTCN, a set of good practices can be identified:

(a) The collaboration of local authorities and international institutions (as the CTCN) generally results in more complete documents that align and feed from other processes (such as NDCs) and count on specific local insights regarding institutional support, social aspects, capacity and available funding mechanisms, better mainstreaming them within national planning;

(b) Documents including a shortlisting process when addressing a sector, assessing aspects such as impact, cost, and capacity needed of different options tend to be better at identifying specific actions plans, resulting better quality reports;

(c) The support from international financial institutions, such as the GCF, in the elaboration of the documents results in better links to potential financial mechanisms. Also, the definition of links between macro-financing (*i.e.* the CGF allocating budget for a country to improve their electricity distribution system) and micro-financing (*i.e*. a country providing subsidies for homeowners to implement rainwater collection systems in their rooftops) for the identified actions facilitates the development of technology deployment plans;

(d) Given the open scope of TRMs, some (non-CTCN) supported documents can be understood as a support to NDCs for countries that don't count on very exhaustive documents. In these cases, a top-down a strategic plan is drawn to meet the targets defined by the NDCs. These documents can include the use of models and calculations to justify that the proposed plans are compatible with NDCs and can serve as a basis for policymaking and future elaboration of implementation plans.

C. Technology Needs Assessments as good practice of TRMs

1. Lessons learned from the Global TNA Project

49. TEC (2013) considered that TRM could "provide a structure for enabling the implementation of results of [TNA] processes in developing countries, including via the implementation of [TAPs]." Furthermore, TEC (2013) concluded that by 2013 experience with TRMs in developing countries had been limited, especially in comparison with road mapping activities in developed countries. This section analyses TNAs conducted under the Global TNA Project as possible good practice information for TRMs in developing countries.

50. Following the Poznan Strategic Programme on Technology Transfer, the Global TNA Project started in 2009, with support from the GEF and managed by the UNEP Copenhagen Climate Centre (UCCC) (TEC, 2022b). Initially, TNAs originated from a decision at COP-7 that "developing country Parties are encouraged to undertake assessments of country-specific technology needs" (UNFCCC, 2001).

51. As argued below, TNAs could be considered good practice TRM examples in developing countries, especially for the sector and country-level TRMs. This is because of TNAs objective to prioritise climate technologies in light of developing countries' sustainable development objectives, and to identify technology action plans for implementation. This means that, through a participatory approach with stakeholders, a country first considers its sustainable development goals and then selects technologies that help realise these goals with low emissions and strong climate resilience.

52. Considering TEC's (2013) characteristics of TRMs the following commonalities with TNAs can be identified:

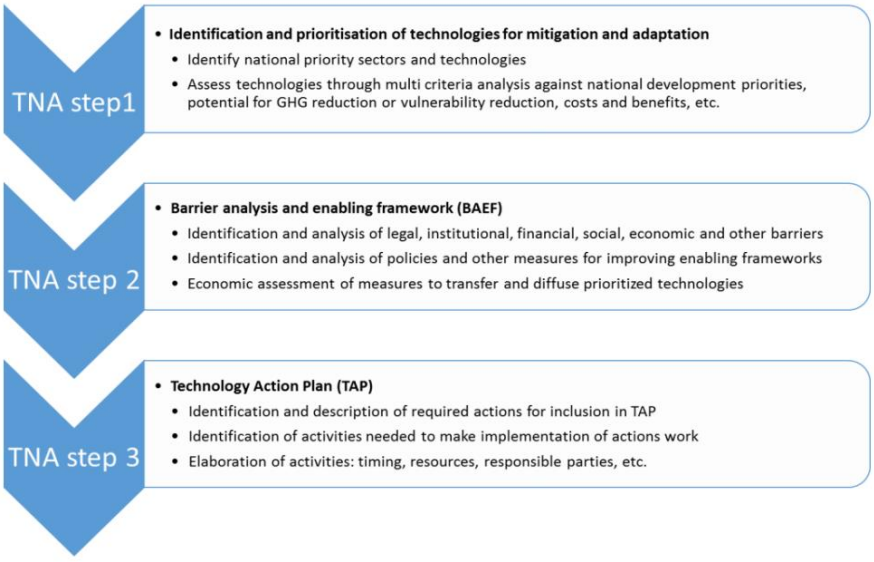
(a) Vision: both Technology Roadmaps and TNAs start from a vision or desired future for the country;

(b) Stakeholders: in both processes, an active role is foreseen for stakeholders in sectors or other relevant areas, to provide professional hands-on knowledge to the process, and to partake in participatory decision-making on pathways towards the desired future;

(c) Focus on stepwise process: both in TRM and TNA the process of assessment and mapping are considered of key importance for knowledge gathering, capacity support, awareness building and societal acceptance of the process results.

53. In terms of possible differences, it could be noted that TEC (2013) sees TRMs as normative documents with needed steps and actions towards successful technology implementation. The TNA process, on the other hand, has always been promoted as non-normative in the sense that the steps for each country are the same (see Figure 1), but countries decide themselves about the outcome of each step.

Figure 1
Key steps and components of the TNA process (TEC, 2022b)



54. The difference between sector or national-level TRMs and TNAs may, in terms of being normative or not, be negligible. After all, both processes are foreseen to be country-driven (desired future/vision), participatory (with country stakeholders) and with a focus on a structured process (stakeholders determining the actions for roadmap implementation). Therefore, the TNA experience could be considered as illustrative practice of technology road mapping in developing countries.

55. Concerning implementation, TEC (2013) concluded that the TNA-stage of developing TAPs is 'very similar to a Technology Roadmap approach.' After all, both a TRM and TAP contain actions

to address identified barriers to upscaled implementation of prioritised climate technologies.

56. At the same time, TEC (2013) concluded that, across developing countries, early TAPs (i.e. constructed during the first round of the Global TNA Project) differed widely in scope, detail and readiness for implementation. This conclusion was also drawn by SBSTA (2013), in particular regarding cost data whereby "the [estimated action] budgets of Parties differed significantly in terms of their magnitude and detail." In particular, details were lacking "about ways to secure funds…and monitoring, reporting and verification requirements." (SBSTA, 2013)

57. In response to a similar observation by the TEC (2015b), SBSTA (2015) suggested a more structured approach for developing TAPs for:

(a) identifying barriers to scaled-up technology implementation in a country;

(b) actions to clear these barriers;

(c) assigning responsibilities for these actions to public and private stakeholders within a certain timeframe;

(d) identifying cost items per action and funding sources for these. SBSTA (2015) suggested minimally required cost information for potential funders to be able to consider funding an action.

58. As a result, TEC & UDP (2016) published an improved guidance document for preparing TAPs. TEC (2019b) concluded that "updated TAP guidance has significantly improved the quality of the TAP reports, with clear and consistent information on for example stakeholder roles and responsibilities, timelines, budgets, and potential funding sources."

59. Box 4 summarizes the TNA results in light of the characteristics of TRM as analysed by the TEC (2013).

Box 4
Overview of TNA results (2022b)

Since 2001, over 90 developing countries have conducted TNAs (some countries have renewed earlier conducted TNAs) in four rounds of the Global TNA Project. SBI (2020) derives the following overarching, generic conclusions on TNAs:

(a) The majority of TNAs are **coordinated** by the government, with the Ministry of Environment being in the lead in most of the cases. TNAs are generally strongly participatory with the engagement of stakeholders from national government bodies, ministries, academia, the private sector, NGOs, independent consultants and IGOs.

(b) Most TNAs take national **development priorities** and GHG emissions and/or climate vulnerability as a starting point for their assessment. This enables the identification of technologies for realising national development goals with low emissions and strengthened climate resilience.

(c) Energy is most frequently identified in TNAs as a **strategic sector** for mitigation (in 94 per cent of the countries), with a particular focus on energy industries and transport. Agriculture (87 per cent) and water (79 per cent) are key sectors for adaptation.

(d) Within the energy sector, solar PV, hydroelectricity and biomass or biogas electricity generation technologies are the most **prioritized technologies**, followed by wind turbines, efficient lighting, and improved cook stoves. Within agriculture, prioritised options for stronger climate resilience are sprinkler and drip irrigation, followed by biotechnologies for crop improvements.

(e) In terms of **barriers** to technology implementation, most TNAs refer to obstacles of economic, financial, or technical nature, such as inadequate access to financial resources and high capital costs. In the TNAs for adaptation policy, legal and regulatory, institutional and lack of human skills are barriers to the implementation of prioritised solutions.

(f) As **enabling actions** for implementation, TNAs mostly contain suggestions to increase the availability of financial resources, including subsidies, new financial mechanisms, and a larger allocation of government budgets for prioritised technologies.

(g) Based on the budget information provided in TAPs, Parties request a cumulative **budget** of USD 20.1 billion for technologies for mitigation, while the estimated budget for prioritised technologies for adaptation amounts to USD 4.4 billion.

2. TNA 'fitness' for TRMs for developing countries

60. TEC (2013) defined TRMs as action-oriented processes starting from a vision for a desired future situation, identifying the envisaged contribution of a technology or a set of technologies to that, and formulating a set of actions forming a pathway towards the desired future. Considering TNA and TAP experience, the similarities between TNA-TAP and TRM are substantial. When considering the criteria as formulated by TEC (2013) for improved TRMs in light of TNA and TAP practice, the following can be concluded:

(a) **Providing a coherent basis for (inter)national technology RD&D policy**: Most TNAs focus on proven climate technologies that are prioritised for meeting a country's climate and development goals. This implies that prioritised technologies are usually already in the stage of market deployment or diffusion. Hence, TNA usually do not focus on technologies that are still at the stage of RD&D, unless a proven technology needs to be adapted to a country's conditions. Should other countries in a region face similar issues, TEC (2020b) suggested a supporting role for a regional technology incubator or accelerator;

(b) **Forming a basis for national policies in support of climate technology diffusion**: In particular, the content of TAPs can support developing countries in formulating policies for diffusing climate technologies. TAPs contain information about country-specific barriers to technology deployment and diffusion with actions to clear these. This (synthesised) information can form input for national policies for climate technology diffusion;

(c) **Catalysing innovations, in particular in developing countries, to allow existing climate technologies to enter new markets**: The TNA-TAP process offers insights on a range of innovative actions that countries can undertake for scaled-up implementation of climate technologies. In this sense, TNA-TAPs promote innovations in a broad sense, not only technical but also in terms of, *e.g*., organising responsibilities and mitigating technology investment risks for potential investors. As such, the implementation of a TAP or multiple TAPs can contribute to an innovative ecosystem for enabling proven technologies to enter new developing country markets;

(d) **Mobilizing private and public entities' interests in climate technologies, as they partake in a TRM process**: TNAs and TAPs are drafted with input from sector or national-level stakeholders. This helps, first, to tap into their tacit, hands-on knowledge, but also trigger their willingness to take responsibility during the eventual technology implementation stage. From the TNA's good practice of stakeholder engagement, the role of 'champions' can be highlighted as an emerging approach (TEC, 2019b). Champions are stakeholders who advance a sectoral or national technology option.

61. Another lesson learned during over ten years of TNA experience is that it pays off to engage financial experts as early in the process as possible (TEC, 2019b). Their expertise is instrumental as it contributes to the 'bankability' of TAPs and supports access to funding sources. The example of XacBank's involvement in the TNA for Mongolia is illustrative in this context as it shows how a private funder combined the output from a TNA with a funding proposal to the GCF (TEC, 2019b).

(a) **Providing a structure for enabling the implementation of TNA results in developing countries**: This characteristic of a TRM is inherent in a TNA through the step of TAP development. Initially, TAPs were criticised for not being well structured and not providing sufficient information about the bankability of a technology plan . Since then, as explained above, the TAP guidance has been revised with a clearer structure for technology action planning, including what actions are needed to clear national barriers, when these need to be carried out, by whom, with what cost items and with potential funders (TEC & UDP, 2016);

(b) **Integrating technology-related activities carried out by different ministries within countries, so that these activities form "a coherent strategy supported by all ministries and donors engaged"**: A key point of attention in TNAs has been the determination of its 'ownership'. Most TNAs have been coordinated by a ministry responsible for climate change issues, but high-level political recognition of a TNA and its results is usually supported by the engagement of key planning ministries, e.g., via an inter-ministerial committee with experts from these ministries.

62. For a coherent national strategy for climate technology support, all TNA-TAP outcomes could be combined to form a national TRM. In this respect, a TRM could use the outputs of multiple TAPs (for each technology) for the identification of common elements (challenges and solutions)

across the technologies. These combined outputs could then form a national-level TRM aiming at a national facilitating ecosystem for climate technology development and transfer.

63. In conclusion, the TNA-TAP process has several similarities with the description in TEC (2013) of a sector- or even national-level TRM. If not a TRM on its own, a TNA-TAP process can provide valuable input for a sector and/or national-level climate policy roadmap.

D. National Adaptation Plans

64. In national adaptation plans (NAPs), countries define climate adaptation plans to increase their resilience towards climate change. These plans include elements such as natural disaster early monitoring systems, actions in key sectors to shield them against future climate disturbances, policy recommendations and training programmes. NAPs are usually elaborated through a top-down approach, and they generally do not consider detailed implementation plans. In this section, therefore, possible interlinkages between NAPs and national-level TRMs are considered, largely based on the synthesis of NAPs by UNFCCC (2018).

65. The report highlights an existing gap in most developing countries between identified adaptation needs in NAPs and existing implementation mechanisms for identified adaptation actions to meet these needs. To address that, UNFCCC (2018) recommends creating guidance on accessing funding mechanisms (such as the GCF) for the implementation of NAPs. Moreover, additional efforts have been suggested to strengthen developing countries' access to funding. Moreover, the synthesis report recommends that the alignment NDCs is improved by using NAP findings as the baseline for establishing countries' adaptation ambitions in their NDCs.

66. When considering the criteria as formulated by TEC (2013) for improved TRMs in light of NAPs the following can be concluded:

(a) **Providing a coherent basis for (inter)national technology RD&D policy;** NAPs identify gaps in national climate resilience and exposure to future climate disturbances, identifying exposed sectors and providing plans to reduce their future vulnerability. NAPs outline national-level policies that could be implemented to tackle the identified vulnerabilities. These policies sometimes include an implementation timeline and can also feature budget allocations, but do not define specific action plans;

(b) **Forming a basis for national policies in support of climate technology diffusion**: NAPs identify gaps in adaptation and outline plans to tackle them. Policies to enhance climate adaptation within the identified areas are often referred to as part of these plans;

(c) **Catalysing innovations, in particular in developing countries, to allow existing climate technologies to enter new markets**: NAPs are not generally focused on identifying gaps and addressing them through known technologies. This could give scope for innovative approaches to stimulate the uptake of identified solutions for adaptation within country contexts;

(d) **Mobilizing private and public entities' interests in climate technologies, as they partake in a NAP process:** Most NAPs include plans to increase overall societal awareness about climate adaptation through education programmes. Although mobilizing private entities is seldomly explicitly mentioned in NAPs, activities involving stakeholder participation (often mentioned in NAPs) could help mobilise private interest in climate technologies;

(e) **Providing a structure for enabling the implementation of TNA results in developing countries:** NAPs do not often mention TNAs, but there could be interlinkages with TNAs, in particular through connecting TNA's bottom-up participatory with NAP's top-down analytical approach;

(f) **Integrating technology-related activities carried out by different ministries within countries, so that these activities form "a coherent strategy supported by all ministries and donors engaged"**: Many NAPs explicitly address inter-ministerial integration of adaptation activities, citing ongoing programmes within different ministries and suggesting inter-ministerial collaboration to achieve greater levels of coherence in technology-related activities. However, more specific policies pursuing consensus-building and consistency among involved ministries and parts could bring benefits to adaptation and resilience programs.

IV. Towards consistent climate technology road mapping

A. Good practice lessons from ongoing climate technology planning processes

67. This paper has analysed experience with planning and decision-making towards the implementation of climate technologies in developing countries. From this, it can be concluded that considerable experience has been gained through ongoing processes such as TNA and NAP, as well as road mapping activities by the CTCN and other relevant activities, *e.g*., by research projects.

68. In recent years a wealth of learning material has thus become available on how to identify technologies for mitigation and adaptation, embedded in an overall country(-driven) vision for sustainable development. Such a vision can be either revisited from an existing sustainable development strategy or formulated with inputs from country or sector stakeholders in participatory processes.

69. Further to work by CTCN and TEC, improvements have been made in terms of how to identify technology implementation barriers in developing countries as well as enabling actions to move technologies forward. For instance, resulting technology action plans from a TNA have become increasingly informative, realistic, and thus 'bankable' for consideration by potential investors (TEC, 2019b).

70. While TNAs, NAPs and TRMs overlap significantly, though TRMs originated at the 'firm' level as an effort to align technology and product strategies, and they have in common the "the idea that the future can and should be created" so that processes are "not lead by technological determinism." (Laat & McKibbin, 2003) This approach is typically characterized by a strong consensus-building vision, which has been guiding, i.a., the work on TNA-TAP in the Global TNA Project and CTCN work on TRMs.

71. Yet, despite the similarities between the multiple processes for climate technology action planning and implementation, they tend to be carried out in their own 'silos', with identified interlinkages with each other and NDC processes, but mostly without structural, organized collaboration between national teams responsible for each process. Therefore, the processes limitedly feed into each other, nor are directly aimed at addressing the priorities set by the others.

72. Another observation is that activities on specific climate TRMs have been relatively small since the publication by the TEC (2013), particularly in developing countries, except for the assistance provided by the CTCN on climate TRMs (see elsewhere in this paper). Thus, the bulk of the work on climate technology road mapping has been done through a dedicated programme such as the Global TNA Project under the Poznan Strategic Programme. Such a programme has not existed for TRMs in support of developing countries.

B. Challenges and solutions for national level enabling environments

73. Above, relevance of ongoing practice for technology and sector-level TRMs has been discussed, including possible interlinkages with other activities under the Convention. This section focusses on national-level activities for stimulating climate technology uptake, for consideration in national-level TRMs.

74. Despite the improved climate technology prioritization and planning in developing countries, technology implementation is often hampered by constraints which are related to insufficiently enabling environments for climate technology uptake. Examples include limited funding for technology research in least developed countries, lack of incubators for deployment of technologies in developing country markets, (perceptions of) high technology investment risks and insufficient inclusion of private sector stakeholders in technology decision making (TEC, 2022c).

75. Over the years CTCN and TEC have worked on improving the understanding of these constraints and identifying solutions to clear or mitigate these. With these insights developing countries can be supported in creating an enabling environment for technological development and support. The TEC (2022c) furthermore suggested addressing the following challenges and solutions related to climate technology development and transfer:

(a) In international **RD&D collaboration** programmes, developing country researchers often find it difficult to participate on an equal footing with international colleagues, due to capacity limitations (TEC, 2020a, pp. 54-57);

(b) In many developing countries there is insufficient encouragement to undertake **entrepreneurial activities**, and a lack of (financial) support for entrepreneurs, leading to limited incentives to work on climate action (TEC, 2019a, p. 3);

(c) **Incubators and accelerators** are internationally proven concepts to support start-ups, but in developing countries and particularly for climate technologies, there are only a few of them (TEC, 2018b, p. 6);

(d) **Access to finance** by developing country innovators is in many cases restricted due to perceived risks and investment uncertainties, which restricts not only access to commercial funding but also to angel and venture capital (TEC, 2018a, p. 8);

(e) There is an **insufficient exchange of knowledge and experience** between countries on market uptake of emerging technologies, which prevents immediate efficiency gains and accelerated action (TEC & CTCN, 2021, p. 35).

76. TEC (2020a) illustrates how collaboration between research institutes from developed and developing countries helps the latter to align research activities with their national priorities, needs and capabilities. Early engagement of developing country researchers thereby enables them to collaborate with developed country colleagues on an equal footing.

77. Also, high-level policymaker engagement generally helps to sustain RD&D collaboration and keep programme goals aligned with sustainable development goals of the participating countries. The TEC (2020a) also concludes that putting in a broader ecosystem-level context enables a wider RD&D focus, not only on technology hardware but also on the software and orgware.

78. Entrepreneurs have a role to bring new and improved climate technologies into broad usage, but they need 'the right encouragement, guidance and support' to, *e.g*., develop innovative business models for scaled up implementation (TEC, 2019a, p. 7). However, such successful entrepreneurship on climate technology innovation is often lacking in developing countries due to, i.a., limited incentives to work on climate action, and limited access to funding.

79. As a result, potential entrepreneurs decide to work "in other professions since the risks associated with becoming an entrepreneur are too high." (TEC, 2019a) Aspects contributing to this challenge are, i.a., local culture, a lack of education and skills, weak integration into global value chains, lack of venture capitalists and angel investors, and additional hurdles, especially for female entrepreneurs. According to TEC (2018b, p. 8), this is particularly true for low-income entrepreneurs in developing countries who lack access to non-dilutive low-cost capital and financial instruments. Consequently, they have insufficient capacity to leverage loans and private capital.

80. For that, the TEC (2019a) (2018a) has recommended improving developing countries' entrepreneurial ecosystems, providing holistic, systemic support to whole groups of enterprises and entrepreneurs. In such ecosystems also societal recognition and prestige would be strengthened for entrepreneurs engaging in climate-friendly business activities.

81. In multiple publications, the TEC underscored the importance of incubators and accelerators focusing on climate technologies (TEC, 2018b) (TEC, 2022c), while noticing that currently few exist in developing countries. This is generally caused by a lack of effective models for climate technology incubation and acceleration in developing countries (TEC, 2018b). For example, in the Dominican Republic and India, successful accelerators have been established, based on experience-sharing and capacity-building collaboration between countries.

82. Concerning finance, the TEC (2018b) (2020b) has assessed the potential role of international development banks to support stakeholders from developing countries in obtaining better access to international funding for climate technologies. This could help clear financial barriers such as the long time for technologies to maturity and profitability, policy uncertainties due to political instability, and limited availability of public finance.

83. Examples of innovative financial products are the blending of public and private funds, the use of financial benchmarks that incorporate climate considerations and the use of classification schemes (TEC, 2021b, pp. 8-9). Moreover, while climate technologies may have longer payback

times, the broader array of environmental, social, and economic benefits in the short, medium, as well as long term could make an investment still attractive.

84. To address the challenge of insufficient international collaboration in support of market take-up of emerging technologies, the TEC (2018c) (2022c) has referred to, for instance, South-to-South Collaboration (SSC) between developing countries and triangular collaboration with developed countries. This can also be facilitated by, i.a., the Poznan Strategic Programme and the TNA training programme for Europe, Latin America, Africa, and South-East Asia.

85. This is often supported by Multilateral Banks or other international organisations and bodies under the Convention such as the Technology Mechanism, GCF, GEF, SCF, and the PCCB. Finally, technology decision-making in developing countries can benefit from international collaboration through the NDC Partnership (TEC, 2021c, p. 20).

V. Possible scope for joint work by TEC and CTCN on TRMs

86. TEC & the CTCN (2021, p. 38) foresee a role for TRMs for climate technology development and transfer, containing best available information on aspects of technology market uptake. Yet, the TEC & the CTCN (2021, p. 36) observe that for many technologies, in particular for adaptation, such roadmaps are not available, although this paper has identified several activities under the Convention and elsewhere that resemble road mapping for climate technologies in developing countries. This chapter focuses on possible future work by the TEC and CTCN on TRMs.

A. Technology-level roadmaps

87. For **technologies**, the TEC has published papers on specific technologies such as:

(a) Deep decarbonisation technologies for sustainable road mobility (TEC, 2022a);

(b) Emerging climate technologies in the energy supply sector (TEC, 2021a);

(c) Industrial energy efficiency and material substitution (TEC, 2017);

(d) Distributed renewable energy generation and integration (TEC, 2015a).

88. These papers contain generic pathways for research, development, and demonstration of the technology options, as well as recommended actions for their deployment and diffusion in markets, in particular in developing countries. While not dubbed technology roadmaps, these documents could form a basis for technology-level roadmaps for developing countries.

89. Furthermore, the experience of the CTCN on TRM (see elsewhere in this paper) and the work on TNAs and NAPs have resulted in a broad range of technology-level assessments in terms of:

(a) How they contribute to developing countries' sustainable development goals with lower emission and strongest climate resilience;

(b) What are barriers to their upscaled implementation within country contexts;

(c) What are enabling actions to clear these barriers;

(d) How these actions form a coherent pathway towards the desired future of the country and sector concerned.

90. Amalgamating this knowledge from the different processes and country reports can result in solid technology-specific roadmaps for use by developing country stakeholders (policymakers, entrepreneurs, universities and schools, investors, etc.).

91. As an illustration of a possible narrative of technology-level TRMs, the following could serve as an example. In its publication on emerging climate technologies for energy supply, the TEC (2021a, p. 49) has pointed out that both energy efficiency and most renewable energy technologies have relatively high initial capital expenditures, compensated by typically lower energy costs in the longer run. This reduces the value of the investment for private sector actors.

92. As these issues are particularly acute in developing countries, this calls for help to reduce the risk-weighted cost of capital in developing countries for investments in emerging climate

technologies. What such help could look like could form the core of a roadmap for these types of technologies.

B. Sector-level technology roadmaps

93. For sector-level TRMs, especially for developing countries, a range of activities have been undertaken with methodologies that resemble the TEC (2013) TRM description. First, the stepwise guidance on TNAs facilitates participatory processes with country or sector stakeholders to agree on a sustainable development vision to be realised with lower emissions and stronger climate resilience.

94. The subsequent work on TAPs supports countries in designing action plans for the implementation of prioritised climate technologies. The work on TNAs and TAPs in over 90 developing countries, as reviewed elsewhere in this paper, thus forms an important set of country-specific sectoral roadmaps to help country stakeholders realise their visions on climate and sustainable development.

95. Similarly, NAPs designed by developing countries form an extensive database with visions developed for options for adaptation. For these options, NAPs contain actions for policy making and implementation, with the ultimate objective to improve from countries' current vulnerabilities towards envisaged climate resilience. Also, the sector analyses carried out by NDCs could be considered as input to building knowledge of technology road mapping.

96. The knowledge base of TNAs and TAPs, as well as NAPs, could also be considered by the CTCN and TEC to support more generic sector-level TRMs for use by multiple developing countries. Should the focus be on stepwise guidance only, then the existing TNA-TAP guidance or CTCN's TRM format could, for instance, be used for that.

97. Should, however, CTCN and TEC consider sector-level TRMs with 'pre-filled' recommended actions or decisions for a range of climate technologies in developing countries, the existing databases with completed TNA-TAPs, NAPs and CTCN TRMs could be used. Such roadmaps could resemble technology-level TRMs though, as these would also include actions to clear common barriers in developing countries.

C. National-level technology roadmaps

98. Finally, for the third type of TRM as defined by TEC (2013), *i.e.* national-level roadmaps, the focus could be on creating an overarching enabling environment for accelerated uptake of climate technologies in developing countries.

99. The basis for this work could be the challenges and solutions as formulated by the TEC (2022c), such as:

(a) Creating ecosystems for intensified entrepreneurial activities on climate technologies;

(b) Enhanced access to finance for climate investments by securing revenue streams and de-risking investments;

(c) Participation of developing country research institutes in international RD&D projects on an equal footing with international colleagues;

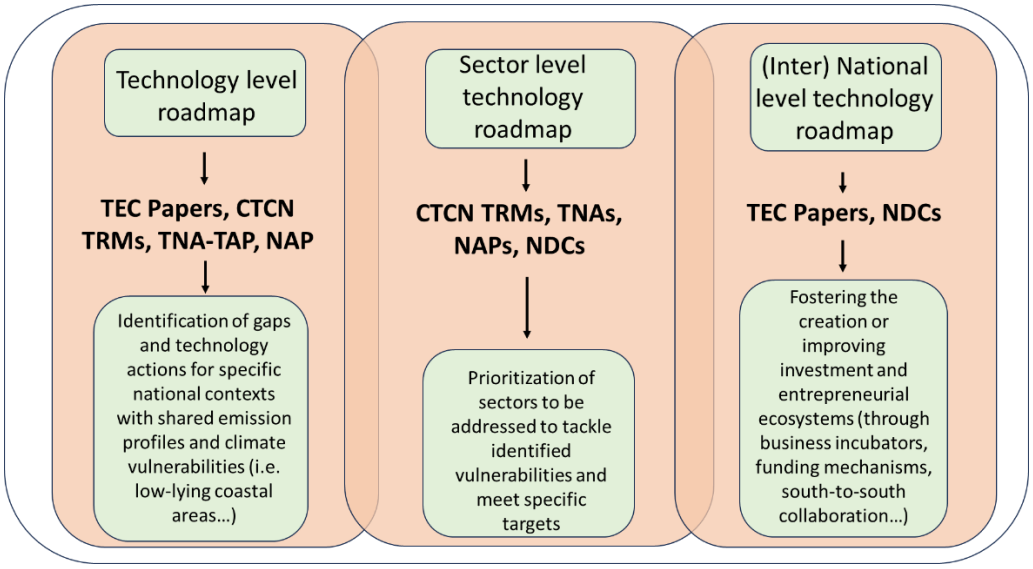
(d) Setting up incubators and accelerators for climate change technologies in developing countries;

(e) Intensifying international (south-to-south or triangular) collaboration between countries, regionally and possibly with help of international organisations and bodies under the Convention.

100. The knowledge base for this work could be earlier publications by the CTCN and the TEC (see elsewhere in this paper), in particular the synthesis report on the work of the TEC as input for the Global Stocktake (TEC, 2022c). Based on this, a national-level TRM could contain steps for a national government, possibly specified for different categories of developing countries (*e.g.*, specified per income per capita category, continent, vulnerability to climate change or sources of

GHG emissions), on ways forward with enabling actions for a low emission and high resilience future within the country.

Figure 2
Overview of possible scope for climate Technology Road Mapping



101. Figure 2 illustrates the three levels of Technology Roadmaps for consideration by the CTCN and the TEC. It is important to mention that the three levels, in line with TEC (2013), are instrumental for an improved focus on a country's specific problem and pathways with solutions for that. Yet, it is acknowledged that the levels do not form isolated silos and, in terms of content, are likely to overlap.

102. For example, when a country is focused on addressing specific issues related to, e.g., energy efficiency options, then a TRM may be the best applicable document to consult, but this document may also contain steps to, *e.g.*, establish public-private collaboration for de-risking private capital investments. The latter may also be a prominent topic in the national-level TRM for improved climate technology investment conditions.

VI. Way forward

103. The objective of this scoping paper has been to help TEC and CTCN AB use the TRM concept to support decisions about climate technologies and effective implementation planning. Current procedures have been analysed that aim at planning and implementing climate technologies in developing countries, such as, i.a., work on technology road mapping, supported and/or coordinated by the work of the TEC and the CTCN technical assistance and other international organisations, achievements of the technology needs assessment (TNA) process, and national adaptation plans (NAPs).

104. These processes and their results have been analysed based on the description of the concept of TRM by the TEC (2013). This contained a first scoping analysis for possible actions by the CTCN and the TEC to address technology development and transfer challenges at the level of a specific technology, a sector, or the country.

105. Based on the overview of these ongoing processes under the Convention and elsewhere, it can be concluded that technology road mapping as such is already taking place in support of developing countries on a large scale. Yet, harmonisation of these activities could be improved. For example, TNA is focusing on technology prioritisation and action plans, but the actual implementation of technologies and its monitoring and evaluation is beyond this process. Dedicated TRMs, such as those coordinated by the CTCN, focus often on implementation planning, but not always contain participatory decision-making steps for technology selection. NAPs often have a national-level perspective with less focus on detailed implementation planning.

106. TEC and CTCN could therefore consider the TRM as an overarching concept that supports countries in conducting a full cycle of technology prioritisation for achieving national goals for climate and development, thereby efficiently combining elements of already existing processes. This information could then be communicated with other relevant stakeholders, including financial actors, multilateral development banks, and other private and public bodies offering financial and technical support. As conclusion of the TRM concept, implementation of technology plans is evaluated by the countries for improved follow-up actions.

107. As such, the TRM concept under the Technology Mechanism would not necessarily be a new trajectory with additional needs for country resources and reporting commitments. Rather would TRM support developing country decision makers in binding available support together into a coherent decision making and implementation package.

108. TRMs can thus help synchronise actions undertaken in developing countries under other processes. For that, linking TRMs to the CTCN knowledge portal is suggested. This can help facilitate knowledge sharing and information exchange, as well as help (developing) countries share success stories and best practices.

109. Other possible ways forward, for consideration by the CTCN and TEC, are the following:

(a) **TRM guidebook**: Since the analysis of TRMs coordinated by the CTCN showed that the resulting roadmaps differ across countries, the impact of TRMs could be improved by extending the existing TRM format towards a guidebook. This could help developing countries requesting assistance through the CTCN, and other relevant organizations, including those that do not take part in the Global TNA Project, to improve their TRMs and align this work with other supporting mechanisms under the Convention and elsewhere. Such a guidebook could be directed towards the implementation of existing technologies in developing countries, providing a more action-oriented perspective, and e.g., fostering the creation of a local business environment around these technologies;

(b) **TRM as reference document**: The database of, for instance, TNAs is extensive and provides valuable information for other countries. Amalgamating this information across countries, *e.g.*, within a region or with similar climate and development needs and characteristics, could result in TRM documents with regional and sectoral findings (challenges and solutions) for climate and development. These could form valuable reference documents for other countries that are facing similar challenges and that could tap in proven solutions such as fostering south-south cooperation, mitigating climate finance risks, setting up or making use of climate technology accelerators and incubators;

(c) **TRM for proven and new climate technologies in developing country contexts**: In line with the above reference document suggestion, the bulk of knowledge gathered through CTCN-supported TRMs, TNAs, NAPs, etc., can be used to draft technology-level TRMs for technology options in the stage of RD&D and already proven solutions. This would help countries to follow a roadmap for implementing a particular technology for hard-to-abate sectors such as steel, cement, chemical, battery storage or climate-resilient crops, based on good practice examples gathered elsewhere in developing country contexts, including where financial and capacity building support can be acquired. This would address the observation that TRMs for several technologies exist, but these often focus mainly on developed country markets.

VII. Key findings

110. The TEC (2013) defined a TRM as process to form a coherent basis for specific technology development and transfer activities "providing a common (preferably quantifiable) objective, time-specific milestones and a consistent set of concrete actions; developed jointly with relevant stakeholders, which commit to their roles in the Technology Roadmap implementation." The CTCN supports developing countries in drafting TRMs for climate technologies. Several of these CTCN-supported TRMs have been analysed in this scoping paper.

111. As per 2013, most of the TRMs published globally were focussed on technologies for implementation in developed country markets and mainly about technologies for mitigation. Since then, although not labelled TRM, in developing countries a range of TNAs have been conducted under the Global TNA Project. TNAs, by their set-up, have some similarities with road mapping

processes for climate technologies. Other road mapping activities on climate solutions have been carried out in developing countries through NAPs with links to Long-term low emission development strategies, and NDCs.

112. It was mentioned, also by the previous work of the TEC, that interlinkages between TNAs, NAPs, NDCs and LDCs processes are often not harmonised, or could be established in a more systematic way. Hence, opportunities to efficiently use the output from one process (e.g., TNA) as input in another process (e.g., NAP or NDC) could be more effectively utilised. It is suggested that TRM as a concept could support developing countries in establishing efficient interlinkages between processes under the Convention, so that countries are better supported in technology planning and implementation.

113. The TEC and CTCN could consider scoping their work on TRMs at the level of specific technologies, sectors, and national policies. Technology-level TRMs could contain information on how a specific technology of interest for a developing country might need to be, e.g., researched for modification to country conditions, integrated within existing market systems, or how to improve these, and viable ways to mitigate investment risks and attract funding and capacity needs for that.

114. For that TRMs could, for instance, tap into the existing and growing knowledge base of TNA reports to amalgamate general findings for successful market transformation within a sector for accelerated climate technology deployment and diffusion.

115. These could form valuable reference documents for other countries that are facing similar challenges and that could tap in proven solutions such as fostering south-south cooperation, mitigating climate finance risks, setting up or making use of climate technology accelerators and incubators.

116. As such, a TRM would form a guidebook for sector policies based on good practice obtained elsewhere. Thus, work on TRMs enables more efficient utilisation of developing country resources for climate technology planning and implementation.

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Annex I - Overview of CTCN-supported TRMs

Document	Supporting institution	Countries	Alignment with TNAs, NDCs and NAPS	Year of Submission	Prioritization/ shortlisting processes	Degree of scope (single technology, sector, national)
Preparation of a national roadmap for the use of low-enthalpy geothermal energy for thermal conditioning in the residential, industrial, and commercial sectors in Uruguay	Climate Change Division of the Ministry of Environment Uruguay	Uruguay	Aligned with NDCs	2022	No	Single technology
Sustainable Land Transport Strategy and Proposed Actions for Nauru	Ministry of Commerce, Industry, and Environment	Nauru	No	2020	No	Sectoral
Technical Assistance for Supporting Jakarta's Transition to E-Mobility	Institute for Transportation and Development Policy	Indonesia	Contributes to NDC	2021	No	Sectoral
Technology Roadmap for the Implementation of Climate Action Plans in Palestine	Environmental Quality Authority of Palestine	Palestine	Aligned with NDC and NAP	2019	Yes	Sectoral
Development of an action plan to improve the circularity of large household appliances in Kenya	Kenya Industrial Research and Development Institute	Kenya	No	2022	No	Sectoral
Assessment of the current status of the circular economy in the waste sector for developing a waste stream specific roadmap in Zambia	Ministry of Technology and Science	Zambia	Contributes to NDC	2022	No	Sectoral
Developing a National Framework for deploying and scaling up E-Mobility (EM) in Tanzania	Centre for Development and Transfer of Technology Tanzania Commission for Science and Technology	Tanzania	Aligned with NDC	2022	No	Sectoral
Development of a Framework and Roadmap for a National Innovation System to foster low-carbon and climate resilient economic development in Zambia	Ministry of Technology and Science	Zambia	Aligned with NDC	2022	No	National
Assessment of the current status of the circular economy in the waste sector for developing a waste stream specific roadmap in Malawi	National Commission for Science and Technology	Malawi	Contributes to NDC	2022	No	Sectoral
Assessment of the current status of the circular economy in the waste sector for developing a waste stream specific roadmap in Zimbabwe	Ministry of Environment, Climate, Tourism, and Hospitality Industry	Zimbabwe	Contributes to NDC	2022	No	Sectoral

Document	Supporting institution	Countries	Alignment with TNAs, NDCs and NAPS	Year of Submission	Prioritization/ shortlisting processes	Degree of scope (single technology, sector, national)
Assessment of the current status of the Circular Economy for developing a Roadmap in Brazil, Chile, Mexico and Uruguay	Brazil Ministry of Science, Technology, and Innovations Chile Agency for Sustainability and Climate Change Mexico National Institute of Ecology and Climate Change Uruguay Ministry of Environment	Brazil Chile Mexico Uruguay	Aligned with NDCs	2021	No	Sectoral

Annex II - Overview of TRMs supported by other bodies and entities

Document	Supporting institution	Countries	Alignment with TNAs, NDCs and NAPS	Year of Submisssion	Prioritization/ shortlisting processes	Single technology or sectorial scope
Pan-Arab Renewable Energy Strategy	IRENA	League of Arab States	No		Yes, literature review, SWOT analysis and stakeholder consultations	Sector
Renewable Energy Roadmap for Central America	IRENA	All Central American countries	Aligned with NDCs	Submitted in 2022	No, it follows a top-down approach. There are mentions to stakeholder workshops, but more as dissemination than consultation.	Sector
Plan de Accion Para el Desarrolllo de las Energ'ias Renovables	UNPD, GEF	Equatorial Guinea	No	Submitted in 2018	Technical analyses were performed to justify the plan	Sector
Renewables in Buildings: Roadmap in Changjiang River Region	REEEP	China	No	Submitted in 2013	Not detailed in the document	Single Technology
Decarbonisation Pathways for Southeast Asia	IEA	Southeast Asia and Indonesia	Aligned with NDCs	Submitted in 2023	Yes, both stakeholder consultation and top-down modelling	Regional
Climate Technology Deployment Roadmap for E-mobility Ecosystem in Cambodia	GCF	Cambodia	Aligned with NDC and past TNAs. NAPs mentioned to secure funding	2021	Thorough technology prioritization process, involving stakeholder workshops	Sector
Autogas in Europe, The Sustainable Alternative	AEGPL Europe	Europe	No	2013	Rationale for the support of the technology is provided, but no other options are considered.	Single Technology
Marshall Islands Electricity Roadmap	Government of the Republic of the Marshall Islands, New Zealand Ministry of Foreign affairs	Marshall Islands	Aligned with NDCs	2018	Yes, well detailed.	Sector
Clean BC; a roadmap to 2030	Regional Government of British Columbia	Canada	No	2022	It prioritises actions based on the level of technology readiness (top-down approach)	Sector
Clean Energy Transitions in the Sahel	IEA	Sahel countries	NDCs are mentioned in the text, but it is not consistently aligned	submitted in 2022	There are no specific suggested actions and no clear shortlisting	Sector