Visualising Technology Needs for Non-Annex I Parties of the Paris Agreement

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Abstract

The Climate Technology Centre and Network (CTCN), the implementation arm of the United Nations Framework Convention on Climate Change (UNFCCC), is a global network of technology institutions that aid countries requesting technical or non-technical assistance in meeting their contributions to the Paris Agreement. The CTCN analyses climate plans submitted by countries to the UNFCCC to understand trends in climate technologies being prioritised and tracks climate technology needs to ensure its network has the capacity to meet these changing technology needs. CTCN relies on synthesis reports to communicate vital information from countries' expressed needs and requests over time. This paper explores an interactive approach to visualising the prioritisation of climate technology needs and how these are connected between countries. First, climate technology prioritisation and needs were analysed for non-annex I countries. This information was then used to create an application that parses climate technologies to create an interactive network diagram, prioritising any subset of countries analysed and providing easy access to underlying data. The tool also highlights areas where countries require assistance and guidance from CTCN in determining their technology needs. Outputs from the tool were then used to analyse how climate technology needs in two regional case studies align with expected impacts of climate change to highlight how the tool fits in the wider ecosystem of climate technologies analysis. The team was invited to present the tool and analysis, and reflection on the team's involvement, at the Conference of the Parties 26 held in Glasgow, Scotland in November of 2021.

Keywords: Technology Needs, NDCs, Paris Agreement, Data Visualisation

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Abbreviations:

- CDM: Clean Development Mechanism
- COP: Conference of the Parties
- COP26: 26th Conference of the Parties (Glasgow, United Kingdom, 2021)
- CTCN: Climate Technology Centre & Network
- GHG: Greenhouse Gas
- INDCs: Intended Nationally Determined Contributions (Under the Paris Agreement)
- IPCC: Intergovernmental Panel on Climate Change
- LDCs: Least Developed Countries
- MCDA: Multi-criteria Decision Analysis
- NDCs: Nationally Determined Contributions (Under the Paris Agreement)
- Parties: countries who are members of the UNFCCC
- SIDS: Small Island Developing States
- TNAs: Technology Needs Assessment
- UN: United Nations
- UNFCCC: United Nations Framework Conference on Climate Change

Aim of this project

The goal of this work was to define an alternative method of collecting, viewing, and interacting with the constantly changing landscape of climate technology prioritizations and needs of countries across the world. The team focused on analysing the Nationally Determined Contributions (NDCs) and Technology Needs Assessments (TNAs) for non-annex I countries, and parsed climate technology-specific information from these documents. This information was then used to design a web application (tool), https://dash.ctc-n.org/, (Rathod, Collins, Kim, & Davis, 2021) to visualise parsed information in the form of an interactive network diagram and highlight the tool's ability to visualize how climate technology prioritizations connect at regional scales. The tool also allows users to view data as a network and download it in CSV file format. The tool was used to 1) analyse gaps between Climate Technology Centre & Network's (CTCN) technology taxonomy (CTCN, n.d.a) and what countries prioritise, and 2) demonstrate one of the ways this tool fits in the climate technology analysis framework through a case study.

Introduction

The United Nations Climate Change Conferences are annual conferences held in the framework of the United Nations Framework Convention on Climate Change (UNFCCC), called the Conference of Parties (COP). This serves as the yearly meeting of UNFCCC parties to assess their progress in reducing the impacts of climate change. The first UN Conference of Parties occurred in Berlin, Germany in 1995. Two years later, countries launched negotiations to strengthen the global response to climate change in the form of the Kyoto Protocol. In total, there are 197 parties to the Convention and 192 Parties to the Kyoto Protocol (UNFCCC, 2022).

In 2015, 196 Parties to the UNFCCC adopted the Paris Agreement with the intention of limiting global warming caused by anthropogenic greenhouse gas (GHG) emissions. The Paris Agreement was historical in nature because it not only built upon the Kyoto Protocol which was the first GHG emissions reductions agreement enacted by the UNFCCC, but also brought a large majority of Parties to the Convention together emphasising the need for urgent and binding legal action to address climate change (UNFCCC, 2020). Under the Paris Agreement, adopting countries are expected to put forth their intended contributions to mitigate and adapt to climate change within their boundaries, with the overarching goal of limiting GHG emissions to keep Earth's mean temperature rise well below 2℃ - preferably to 1.5℃.

The Paris Agreement is a landmark in multilateral climate negotiations because, for the first time, all signatories are required to undertake ambitious efforts to combat climate change and adapt to its effects.

Countries who are signatories to the Paris Agreement must submit their plans and goals to reduce their GHG emissions to the UNFCCC, called a Nationally Determined Contribution (NDC). and are renewed and reviewed by each country every five years to strengthen and assess actions and impacts thus far. Some submissions are classified as INDCs (Intended Nationally Determined Contributions) meaning these NDCs are not, yet government ratified national climate plans (Denchak, 2021). Overall, NDCs highlight climate actions including targets, policies, and measures that the government aims to implement in response to climate change as a contribution to the global effort to drive down GHG emissions. Specifically, these NDCs detail areas where countries need assistance (capacity, financial, and technical) and expertise for emissions reduction projects. A climate technology is a broad way of describing the methods of adaptation and mitigation that countries undertake conditionally or unconditionally to meet the global temperature target and personal emissions reduction targets outlined in their NDCs (*National climate action under the Paris Agreement*, n.d.) In the case of mitigation technologies, these can include renewable energy projects, such as solar, hydropower, or wind power projects, energy efficiency projects, and so on. Adaptation to climate change involves climate technologies that "...reduce the vulnerability or enhance the resilience of a natural or human system to the impacts of climate change" (UNFCCC, 2010). Countries are expected to update their NDCs every five years with increasingly ambitious targets for reducing emissions.

One of the ways a country determines the climate technologies to target for implementation is through the process of Technology Needs Assessment (TNA) (Haselip, Narkevičiūtė, Rogat, & Trærup, 2019). This process consists of three steps:

1. Identification and Prioritisation of Climate Technologies
2. Barrier Analysis and Enabling Framework
3. Technology Action Plan

Each step in the TNA process allows a country to prioritise and implement its climate technology needs. The first step in the process involves the prioritisation of climate technologies that a country wishes to consider for implementation. This step urges relevant stakeholder engagement and consists of multi-criteria decision analysis (MCDA) as its main tool. The MCDA allows the comparison of different technologies under the same set of objectives by various stakeholders. The performance of each climate technology alternative against objectives is then scored based on a predetermined weight to determine an overall score representing the suitability of the technology. At the end of the TNA process, a TNA report is released which documents the process, outcomes, and any exceptions. Countries may also specify their 'climate technology needs' in the TNA report.

The clean development mechanism (CDM), a branch of the UNFCCC, aims to support developing countries in achieving a sustainable development path. Although there have been findings that indicate that the actual practice of CDM's technology transfers is focused more on reducing GHG emissions at a lower cost rather than on the development needs of the host countries (Gaast et. al., 2009), recently there have been more environmental justice-focused initiatives through the creation of different branches supporting the CDM. The CTCN was formed as a branch of the technology mechanism to support the CDM's effort. CTCN's main role is to facilitate the transfer of technologies that assist in climate change mitigation/adaptation at the request of developing countries.

The CTCN consists of two components: the coordinating centre, and a worldwide network of climate technology experts who help in the realisation of planned assistance. Therefore, the CTCN mobilises its worldwide technology partners to quickly provide climate technology solutions at the request of developing countries. Both NDCs and TNAs are submitted to the United Nations (UN) where they are then passed on to the CTCN. CTCN needs to understand the spatial and temporal aspects of climate technology needs manifested through TNAs, NDCs, and subsequent updates to these documents to properly mobilise and grow its technical assistance network. The centre also maintains a technology taxonomy, which represents a standardised list of climate technologies classified under various mitigation and adaptation sectors, and cross-sectoral approaches. Figure 1 shows the expansive network members

within the CTCN and how the NDCs analysed will further accelerate the understanding of climate technology needs for the coordinating centre, the technology experts, and the advisory board.

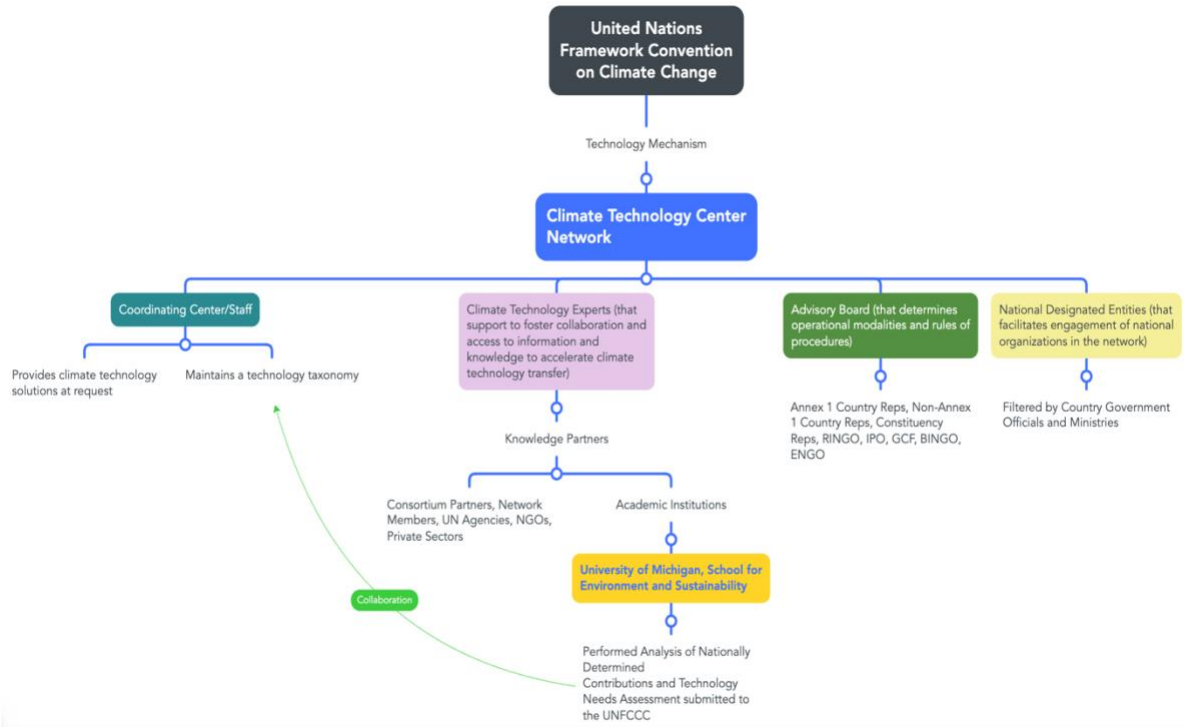

Figure 1: This diagram portrays how the CTCN operates and to whom its network members consist of.

Background

At present, a variety of online resources are available that consolidate and/or visualise Parties' commitments to adaptation and mitigation under the Paris Agreement in a methodical manner to inform policymakers, practitioners, and stakeholders who will oversee the implementation of these technologies goals after their requests are honoured. The information is either available in the form of reports, or interactive dashboards which show relevant information about a country on user actions. In the run-up to COP26, UNFCCC published a report synthesizing metadata and information necessary to provide information to provide transparency, clarity, and understanding of these documents (UNFCCC Secretariat, 2021). Other NDC synthesis reports include a tool that is meant to track the implementation of NDCs for selected countries in Africa through the development of an NDC implementation index (Ozor, Nyambane, Onuoha Dr., Makokha, & M'mboyi, 2020). The Stockholm Environmental Institute and German Institute for Development collaborated to develop an online platform that provides information on how climate technologies prioritized in NDCs connect with the 17 Sustainable Development Goals which are at the core of the 2030 Agenda for Sustainable Development German Development Institute also provides an interactive map which provides users with the ability to read information pertaining to a country's NDC by selecting it on a map (Pauw, Beck, & Valverde, 2022). A similar tool is available through the World Bank which is intended to provide information on INDCs by region, sector, category, and country (The World Bank, n.d.). The tool provides visuals that update with information on which technologies were prioritized by which countries, along with a count to give users an idea of how popular a technology is.

Additional tools available online include an analysis of 20 NDCs performed by Germany's Federal Environment Agency to determine if NDCs have increased in ambition (Casas, et al., 2021). The resulting information is presented as documents. The Institute for Global Environmental Strategies maintains its

own NDC database intending to provide information on NDCs along with relevant information such as technology needs expressed in NDCs (Hattori & Takahashi, 2021). The current offering of tools and synthesis reports focuses on NDCs and presents the information in form of documents, maps, or interactive tables for a country of interest. However, there is a lack of means to quickly determine how climate technologies across countries or across regions interact with one another or which climate technologies are mentioned together across a region. Extraction of information regarding connections between prioritized climate technologies would require a user to refer to multiple sources of information and perform their own data analysis. The tool described in this paper intends to fill this gap by providing its users with quick and easy means of interacting with climate technologies prioritized in NDCs and viewing how these technologies interact with one another.

Methods

The types of documents available for countries that are the focus of this work are presented in Figure 2 (ArcGIS Content Team, 2019) and are further detailed in Table 4 in Appendix 1. Data collection and analysis, prioritisation was determined by country category in the following order: Least Developed Countries (LDCs)/Small Island Developing States (SIDS), Africa, and Group of 77 (G77). All NDCs and TNAs submitted by LDCs, SIDS, and African countries were included for analysis and information pertaining to climate technology prioritisation and needs was parsed out of these documents while adhering to the CTCN taxonomy (Climate Technology Center and Network, n.d.a). For example, Solar PV technology was classified into the Solar category and within the Renewable Energy sector under Mitigation.

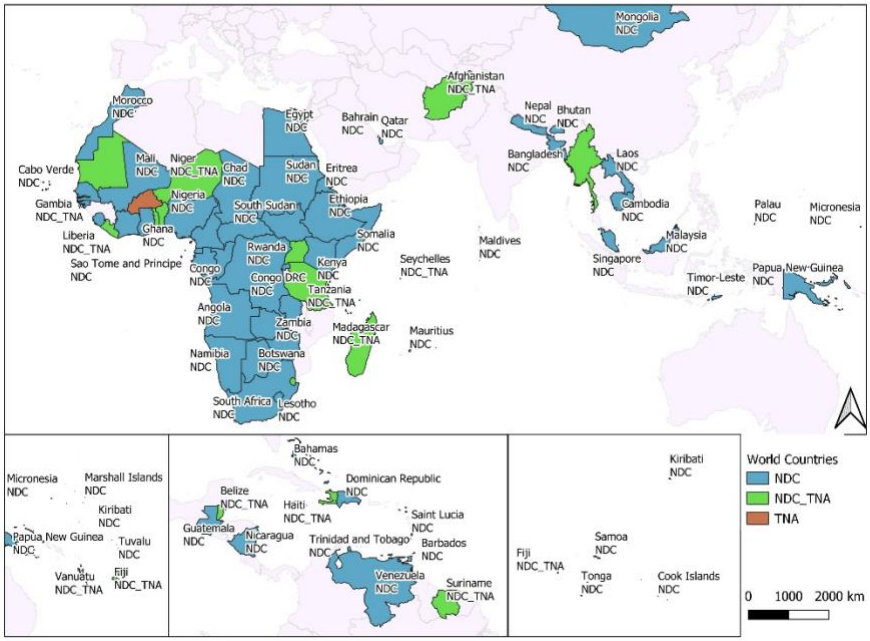

Figure 2: NDCs and TNAs were analysed from countries that can be categorized as SIDS and LDCs. This figure shows the countries analysed along with the kind of documents available for each country.

Data points collected for each parsed technology are presented in Table 1 along with information on the data's use and format. Each climate technology parsed out for a country either appeared in its NDC, TNA, or both. There were instances where a country was vague about which climate technology it wanted to prioritise. In these cases, the technology could not be fully mapped against the taxonomy (for example, a country could mention its desire to improve on energy efficiency, which is an entire technology category and not a specific technology). Alternatively, a country could be very specific in its climate

technology needs, in which case the need might not directly match a specific taxonomy value (for example rehabilitation of ageing hydroelectric plants). In both such instances, the technology was marked as UNDEFINED to capture its incompatibility with the existing taxonomy.

Table 1: Data points collected for each country along with their format, and anticipated usage.

Data point	Usage	Format
Parent category	To determine if a technology is for mitigation or adaptation	Value from the taxonomy
Category	A category value from the taxonomy	Value from the taxonomy
INDC sector	A sector value from the taxonomy, or undefined	Value from the taxonomy
INDC technology	A technology value from the taxonomy, or undefined	Technology from the taxonomy
Technology needs	Description of country's ambition with a technology	Free text
More information on INDC technology	Description of country's ambition with a technology	Free text
TNA technology prioritised	Priority of a technology in TNA document	Technology from the taxonomy
More information on TNA technology	Description of country's ambition with a TNA prioritised technology	Free text
Actions / project ideas	Description of any specific projects called out for a technology	Free text
Country	Country being analysed	List of valid countries

Once all eligible documents were analysed, the information was collected into a single CSV file, ready to be used programmatically. All programming was done in Python programming language and Plotly's Dash libraries were imported to allow for low-code web application development (Plotly, n.d.). The utilisation of Dash library allowed the tool to become interactive and filter data by countries and technologies on user actions. Due to its performance with substantial amounts of data and interactive capabilities, Dash_Cytoscape library was selected to render the network visualisation of climate technologies prioritised by countries (Plotly, n.d.). The following sections describe data processing performed when the tool is loaded, followed by an elaboration of tool layout and interactive capabilities, network diagram creation capability, and web hosting specifications. This section ends with a description of how the tool can be used to analyse a set of countries from a region.

Data pre-processing

Python-based Pandas library was used to read the analysed data for all countries. This superset of data was then used to generate lists of all unique countries analysed. This list was also used to create labels for LDCs, SIDS, and Africa which could retrieve data for all analysed countries under those categories (United Nations Conference on Trade and Development, n.d.), (United Nations, n.d.), (The Group of 77 at the United Nations, n.d.). All unique climate technologies mentioned by these countries were compiled into a list. The dataset was filtered for any instances of UNDEFINED climate technologies, which were moved into their own dataset to ensure the rendered network will only include technologies that matched the taxonomy.

Application layout and interactive capabilities

The application layout was divided into various parts to separate functionality on the page. Figures 3, 4, and 5 provide an overview of the application layout along with the functionality built into each section. The layout began with a header that described the purpose of the tool and explained how it should be used (see Figure 9 in Appendix 2).

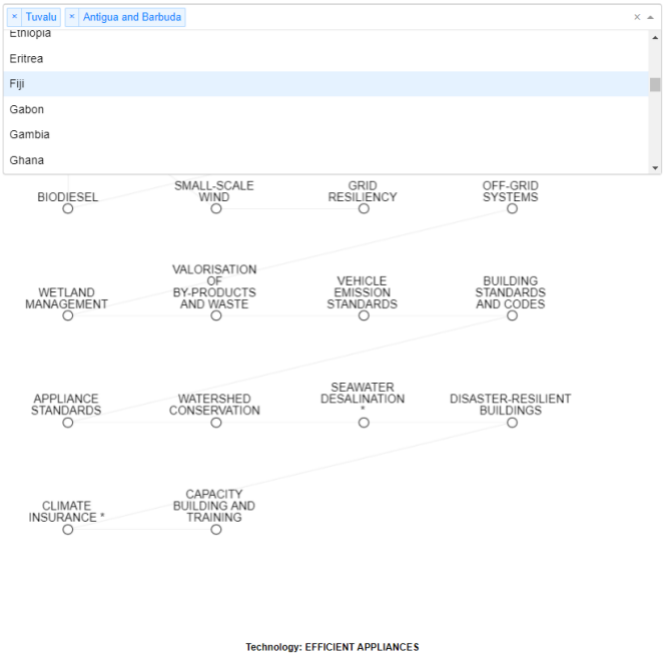

Figure 3: Screen Shot of the country selector and network diagram sections. The application introduction was followed up with a country selector and a section for the network diagram. The country selector dropdown allows a user to select one-to-many countries to view their prioritised climate technologies The list of countries from data processing was used to populate this dropdown. 'All,' 'LDCs,' 'SIDS', and 'Africa' were also added as options in the dropdown to allow for data retrieval by country categories. The section underneath the dropdown dynamically updates with a network diagram representing climate technologies for the countries selected. The bottom of this section also shows text which corresponds to the climate technology a user is hovering over in the diagram.

Figure 4: Screenshot of tables and links from the tool. The network diagram was followed up with many links and tables to provide users access to information as tables and CSV file. These links allow users to view and download information such as which climate technologies were mentioned, which UNDEFINED climate technologies were mentioned along with their sectors and technology categories, how the mentioned technologies were connected, which innovative technologies were mentioned, and how often a technology was mentioned.

Figure 5: Screenshot of technology selector from the tool. The last section of the tool was designed to allow users to select one-to-many climate technologies and download all mentions of selected technologies for all countries analysed. The list of unique climate technology from the data processing step was used to populate this dropdown. 'All' was also added as an option in the dropdown to allow for data retrieval for all technologies.

Network diagram creation

On initialization, the application defaults the country selector dropdown to Senegal and the technology selection dropdown to 'All' climate technologies. As depicted in figure 2, defaulting the country selector to a value triggers the application to filter the underlying data for Senegal and remove any UNDEFINED technologies. Next, the tool uses filtered climate technologies to create pairs between technologies in their order of appearance in underlying data. Lastly, climate technology for a country was paired with the first climate technology to ensure all technologies for a country were connected in a loop. These pairings are unique and the application tracks how often a pairing has been mentioned, and by which countries. The tool also creates a list of all unique climate technologies for selected countries. This information is then compiled into a data frame and then used to update the Cytoscape network diagram.

The tool represents all unique climate technologies as nodes, whereas all unique pairings are used to create edges between these nodes. Then, filtered data is processed to generate tables of innovative technologies, undefined technologies, and a count of all unique climate technologies to make this information available to users. The collection of nodes and edges is used to generate a new interactive

diagram. The diagram is formatted as a grid to ensure the visibility of all nodes. The tool was used to further highlight how climate technologies are connected to one another by adding the ability to view which technologies were mentioned together (i.e., appeared in order in the underlying data). Selecting a single node triggers the application to update its stylesheet to highlight the selected node and all nodes connected with that node through an edge. Lastly, the application shows which node a user may be hovering over. Figure 6 demonstrates this functionality using technologies prioritized in Kiribati's NDC as an example (Republic of Kiribati, 2016).

INDC technology	Country
Solar PV	Kiribati
Off-grid systems	Kiribati
Biodiesel	Kiribati
Advanced biofuels*	Kiribati
Mangrove conservation and rehabilitation	Kiribati
National adaptation programmes of action	Kiribati

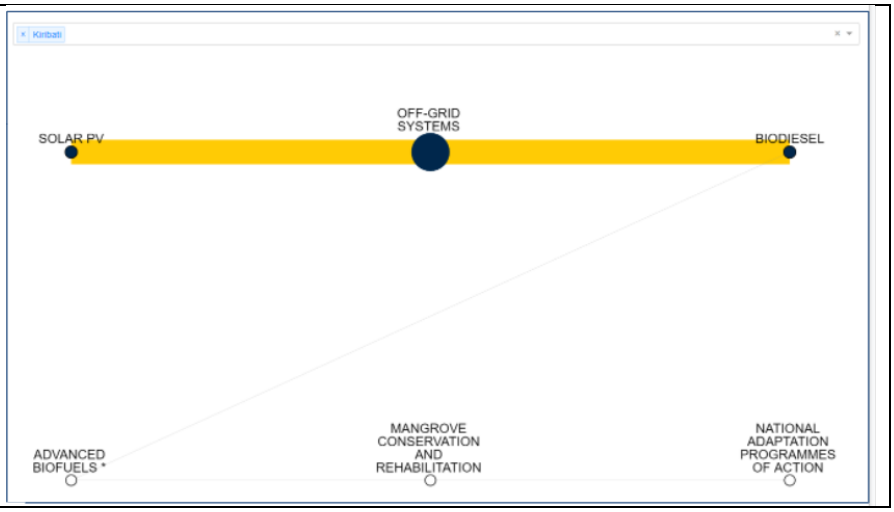

Figure 6: Network diagram creation depends on the order of underlying data. For example, data for Kiribati consisted of six technology prioritizations. The tool renders the network diagram for Kiribati where nodes (i.e., unique climate technologies) are rendered in order from Solar PV to National adaptation programmes or action. Selecting any node highlights technologies with whom it shares an edge. For example, selecting Off-Grid Systems in the above network highlights Solar PV and Biodiesel nodes, with whom it shares an edge. More complicated network diagrams provide the same functionality because the tool maintains a list of unique technologies as nodes, which are connected with one depending on how the underlying data was structured (see figure 7).

Web hosting

Initially, the application was hosted online using Google Cloud Run with guidance from (Tartarini, 2021). Immediately after COP26, the website hosting was moved to being hosted on CTCN's website (https://dash.ctc-n.org/) (Rathod, Collins, Kim, & Davis, 2021).

Tool capabilities and utilisation

As designed, the application allows its users to select one - to many countries and view a network diagram rendering all unique climate technologies prioritised in selected countries' NDCs as nodes, and ensures these nodes are connected in their order of appearance in underlying data. The tool also gives users the ability to download filtered data for further analysis and view relevant information on innovative and UNDEFINED technologies. Lastly, the tool allows users to see how prioritised technologies interact with each other for their selected countries by highlighting all climate technologies mentioned immediately before or after their technology of interest.

Findings

Climate technology landscape

The tool provides immediate access to information such as climate technologies mentioned in NDCs, frequency of mention for each technology, innovative technologies mentioned, and how these technologies connect with one another. By presenting this information as an interactive network diagram with easy access to underlying information, the application further enables its user to see how different technologies interact with one another for available data. By doing so, the tool provides its users with a high-level view of the underlying climate technology landscape for a selection of countries along with granular details in the form of tables and CSV files. This tool's ability to simultaneously provide the landscape and granular perspective on information is what makes it unique in comparison to alternative sources of similar information. By highlighting UNDEFINED sectors and categories, the tool further informs the user about the information gap between CTCN's taxonomy and what countries are prioritizing. Table 2 provides some key results from the global climate landscape.

Table 2: A summary of leading climate technologies and countries for various data points available via the tool.

Results metric for All countries	**Climate technologies/countries**
Top three mentioned innovative technologies	Seawater desalination, grid integration for renewables, climate insurance
Top three climate technologies by count	Solar PV, reforestation, capacity building and training
Top three Categories with UNDEFINED data	Water, renewable energy, transport
Top three Sectors with UNDEFINED data	Water efficiency and demand management, government and planning, wind*
Top three countries with UNDEFINED category data	Kenya, Sudan, Seychelles
Top three countries with UNDEFINED sector data	Seychelles, Sudan, Kenya

Analysis and Trends

Table 3 shows the technologies most cited across LDCs, SIDS, and Africa. Most highlighted technologies were similar in all country categories, such as the renewable energy sector, identified multiple times in all parties' documents. Solar PV technology was especially highlighted, as seen in the figure. The other technologies that were highlighted are Improved Cookstoves, within the energy efficiency and appliances category, Reforestation in forest management for mitigation, and Capacity Building and Training in the cross-sectoral sector.

*Table 3: Climate technologies with * are among the top 3 most mentioned technologies by countries by category. For countries which are in Africa, there was a tie for second-most mentioned climate technology, denoted by ^. Solar PV, improved cook stoves, and capacity building and training are among the most popular adaptation and mitigation technologies across country categories. Note how SIDS parties, which are surrounded by water, prioritize mangrove conservation instead of reforestation in their NDCs.*

Climate technology \ Country category	LDCs	SIDS	Africa
Solar PV	25*	12*	23*
Reforestation	18*	6	21*^
Mangrove conservation and rehabilitation	9	10*	10
Improved cook stoves	22*	2	21*^
Capacity building and training	15	10*	18*

To illustrate how the tool fits into the bigger ecosystem of climate change analysis, we compare the results observed from the tool with reports published in the Intergovernmental Panel on Climate Change (IPCC) Working Group AR6 report. The IPCC's Working Group 1 AR6 Physical Science report was released in August of 2021. This report reviewed over 14,000 studies to determine the physical science of climate change today to the best of our scientific knowledge. The team broadly evaluated the IPCC report's data that aligned with the technologies being requested by the countries they analysed. The team looked at two regions, West Africa, and the monsoon region in South-East Asia.

Case Study: West Africa

The team broadly evaluated the IPCC report's data that aligned with the technologies being requested by the countries they analysed. The team looked at two regions, West Africa, and the monsoon region in South-East Asia. We used Senegal, Burkina Faso, and Nigeria as a subset to represent this region. These countries are classified as African, G77 members and Senegal and Burkina Faso also represent LDCs. These countries also represent various aspects of the region, Senegal on the western coastline, Burkina Faso a landlocked country, and Nigeria on the Western coast and Western edge of the region and all are part of the Sahel region.

The AR6 report's regional fact sheet (2021) for Africa indicates that this region has observed increases in flooding, drying of agricultural land, and ecological droughts. Additionally, there are projected increases in meteorological droughts (in seasonal timescale), wind speed, heavy precipitation, and pluvial flooding. Additionally, when considering the Monsoon Region effects the report states that the increase in monsoon precipitation is directly linked to the human impact of increased GHG emissions and is further masked by aerosol emissions in Europe and North America (2021). The Monsoon precipitation is expected to increase but will have a change in when the precipitation season will occur.

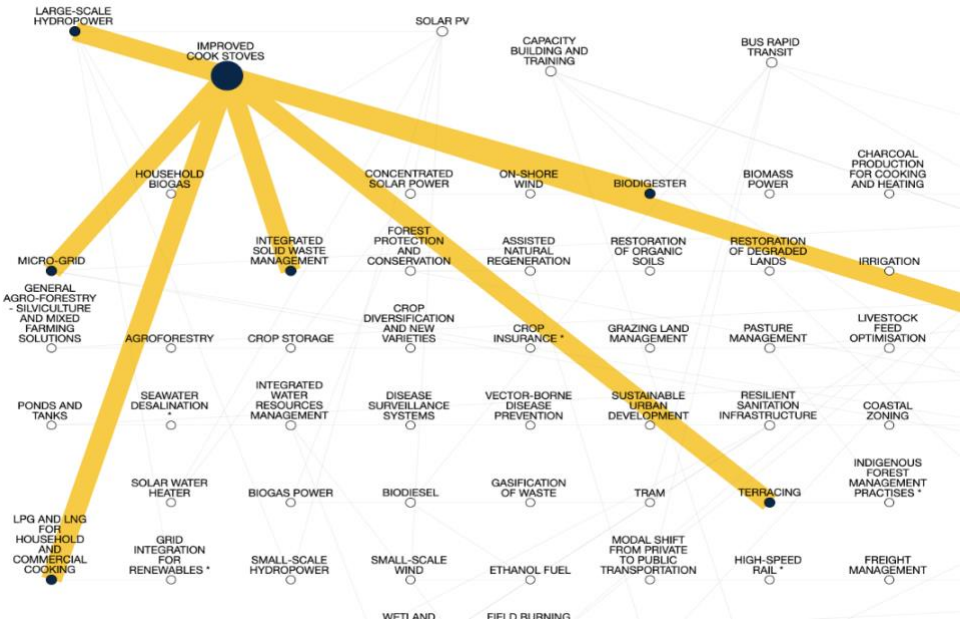

Figure 7: This image shows a snapshot of the tool in Senegal, Burkina Faso, and Nigeria's connected technologies.

In alignment with the AR6 report, seen in Figure 7, the tool shows us a snapshot of the visualisation of Senegal, Burkina Faso, and Nigeria's connected technologies. The tool allows users to evaluate which technologies are consistent across the region considering the impacts they are facing and will likely face in the coming years. It is important to note, however, that these technologies are not prioritised or weighted here, but a visualisation of their connection across country plans. All three countries determined that utilising large-scale hydropower and Solar PV can lead to a renewable energy approach to their continued development goals. Additionally, these countries were interested in providing their citizens with improved cook stoves, building capacities and training in sectors such as agriculture, water, and marine and fisheries, and providing reliable rapid bus transit. Their NDCs and TNAs indicate the need for their communities to have a sustainable livelihood and are at risk of losing them due to their high vulnerability to the impacts of climate change which is in alignment with the AR6 report's physical science findings. Water-related extremes of droughts and floods are particularly important to pay attention to in this region, as this has implications for infrastructure, human health, and agricultural production - influencing the population's sustainable livelihoods, poverty, and food security which are highlighted across these countries NDCS and TNAs. It is interesting then, that one of the only technologies that all three countries named, was large-scale hydropower when drought risk is a primary concern above flooding. Especially when Burkina Faso is landlocked, and Nigeria and Senegal have significant inland territories. While these countries address the relevant sectors to confront the changing climate, their approaches are highly individualised, as is appropriate for their set of circumstances. Important to note is that despite a lack of similar technology requests across this subset of countries, they all indicated significant financial, technical, and capacity support needs from the international community.

Case Study: Southeast Asia

The AR6 report's regional fact sheet for Asia indicates, with medium confidence in the long-term, South, and Southeast Asian monsoon and East Asian summer monsoon precipitation will increase. In high confidence, regional-mean sea level will continue to rise. Compound impacts of climate change, land subsidence, and local human activities will lead to higher flood levels and prolonged inundation in the Mekong Delta. The increase in flood levels will disrupt livelihoods

The three NDC/TNAs in Southeast Asia we analysed were Cambodia, Laos, and Malaysia. As mentioned above in the West African analysis, the tool aligns with the AR6 report (2021) as in Figure 8, it shows that groundwater extraction and monitoring technology needs were mentioned in all three NDCS, with additional mentions in integrated water resources management, flood forecasting systems, etc. There already have been at least 25 technical assistance requests made by the Southeast Asian region to the CTCN. Through the tool and further analysis, users will be able to perceive an increase in further technology assistant requests in the Water sector that the team analysed from the NDCs and IPCC report.

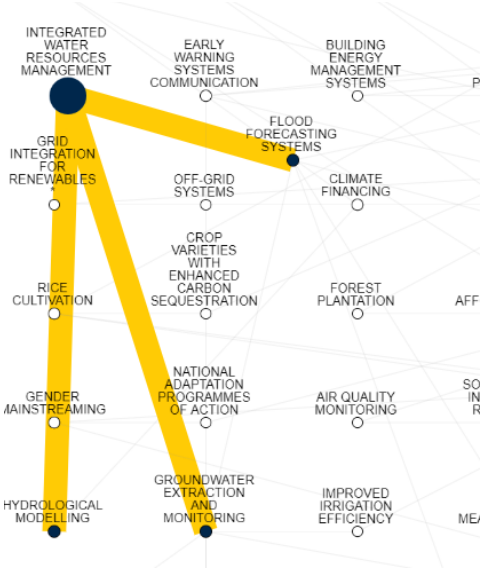

Figure 8: This image is a snapshot of the tool in Cambodia, Laos, and Malaysia's connected technologies.

Discussion

Our study aimed to define means to visualise technologies prioritised in NDCs and TNAs as a network diagram instead of more common methods (document synthesis and static maps) to highlight connections between climate technologies at the click of a button. To accomplish this goal, a Python-based web application was developed which utilised climate technology data from a subset of non-annex I parties' to better visualise these relationships between technologies, parties, and regional/party categories. The application developed not only allowed for a quick understanding of trends, patterns, and relationships among prioritised technologies over a selection of countries but also highlighted the gaps between what countries prioritised versus CTCN's technology taxonomy.

This tool can be used for two primary purposes. First, to quickly visualise relationships between technologies. Second, to aid in the development of private sector collaboration in delivering technology requests by looking at prioritized climate technologies as a landscape. This benefit of visualising technology relationships also helps organisations such as the CTCN to build a strategic plan for delivering comprehensive technology aid that drives the most impact.

A common theme called for at COP26 was that the world needs the private sector to become key collaborators in the global fight against climate change. By utilising the application, CTCN can begin to build relationships and networks with the private sector. Interested potential partners can work with CTCN to upload their data file to the application and receive a visualisation of how their technology matches with country needs and requests from a global to individual country scale. For instance, if CTCN was working with a solar company that wants to partner in projects in the West Africa region, they can see what other technologies related to solar are most requested. The application would indicate that related technologies in this region include improved cookstoves, solar PV, and capacity training for local workforce development. CTCN could then facilitate the delivery of a cohesive and strategic technology

package to the West Africa region optimising resource use to deliver greater impact. In an age of collaboration, this use would be particularly important for the rapid implementation required to meet global targets on time.

This application also offers CTCN a platform to help build a common language and understanding between CTCN, the private sector, and countries. This third, educational opportunity, aids in the global need for capacity building and training. In our analysis, it became clear that the classification of technologies used in the CTCN Technology Taxonomy often did not align with the technologies named in NDCs/TNAs. This tool helps CTCN review and adjust the taxonomy to meet the needs of countries and provide a baseline of understanding between all stakeholders. It also provides transparency between the public and private sector; particularly in how language is understood and used so that as new technologies become available and prioritised a central tool shows how parties understand the technology options available to them.

More importantly, as the team dove deeper into the data, presented our work and experienced COP26, a key, but hidden inequity became visible. Informational knowledge of the process, terminology, access, and support to identifying the best technology options are held by parties in different capacities. This compounds the existing constraints of many low- and middle-income parties as they grapple with climate impacts, resource depletion or availability, financial stressors, and/or conflicts. Without an apparent comparable visualisation tool such as the one presented here, transparency about what other parties' needs and plans are, all stakeholders must wade through the individual NDCs, UNFCCC, and party coalition documents to understand the information available and relevant to technology development and implementation.

International perception of a parties' worth is often a contributing factor as well. For example, Myanmar, a country in the LDC category and is in the lower ranking within the Human Development Index is currently going through many internal political challenges that have interrupted climate action. Azerbaijan, a G77 member, cannot access a considerable portion of its territory, rich in natural resources due to the occupation (Government of Azerbaijan, 2017). In Ethiopia, there is currently a civil war going on, or more so a devastating act of genocide against the Tigray group which is dividing the country and negatively affecting the economy (Mwai, 2022). The government of Ethiopia has previously blocked aid from the UN Human Rights office in assisting the famine situation for the Tigrayans creating a humanitarian crisis (Schlein, 2022). Yemen has yet to submit an NDC, needing to focus on meeting the needs of its starving population (Yemen Crisis, n.d.). Therefore, the UN as a general body is in a tight position in taking some of these country's NDCs to assist in climate technology and financial aid to meet their requests when some of these countries are violating human rights, and groups of people within countries of Myanmar, Azerbaijan, Ethiopia, and Yemen need aid. The UN needs to position all its branches and implementation mechanisms to work with these governments for a just and sustainable transition in climate mitigation and adaptation that is focused on justice for marginalized groups, indigenous people, and ethnic minorities.

Other parties, such as Fiji, a SIDS and G77 member, receive considerable support from the international community, they are politically situated in favour of the countries that hold the most funding resources. To note, SIDS are countries that are heavily impacted by sea-level rise. Other examples such as Barbados and Tonga, are extremely dependent on the actions of other countries, as they will be the first nations and communities without livelihoods due to the impacts of climate change (World Bank, 2021). Without equitable access to information, there will continue to be informational injustice that will impede progress toward carbon neutrality targets. By providing quick, free, and interactive access to climate change data, the tool offers an avenue to mitigate this informational justice for all countries.

Global climate action is dependent upon each country's individual contribution, however, with each passing IPCC report, our planet cannot afford any delay in implementing the interventions that each NDC lays out. High-income countries have an obligation to low- and middle-income countries to act and this action must include technology transfer. Throughout this project, it was evident that low and middle-income countries require significant support from the international, high-income country community to implement their NDCs predominantly through capacity, financial, and technical assistance. The Glasgow

Climate Pact (UNFCCC Authors, 2021) formed at COP26 requested that parties update their NDCs with strengthened, increased climate action by the end of 2022 at COP27, in Sharm El Sheikh, Egypt.

Limitations

Our data collection of party documents ended on July 31st, 2021, missing 61 updated NDCs submitted by parties to date (April 2022). These missing, updated NDCs are important for a clear picture of what regional and party categories need. To note, some parties are in more than one category, for example, Jamaica is in both LDC and SIDS categories. Additionally, this application can provide more meaningful insights by reorganising the input data. Currently, the technology relationships are determined by the adjacent position of the technologies around them as seen in Figure 6. The visualisation of relationships could become more meaningful if the technologies were ranked under a context (such as ease of implementation) or as they are in TNAs prioritisation tables. Our work lacked an understanding of which data would be most important to orient the technologies to and therefore the meaningfulness of the relationships can be improved with further prioritisation.

The tool could benefit from the addition of the ability to upload parsed NDC and TNA data rather than using a static data file. This capability can allow businesses, non-governmental organisations, countries, or other entities who analyse NDCs in the future to upload their analysis in the expected file format to use this tool as a service. Furthermore, if the uploaded data for each country is ranked prior to upload, the tool will highlight relationships between technologies by rank, and therefore enhance the value of network diagrams. Analysis of these new submissions will be a key part of continued research on the relationships between technology needs and climate crisis impacts. The tool could also show more information in the network. For example, the number of times two technologies are mentioned together can be used to determine edge thickness and locate technologies as clusters on the visualisation.

Conclusion

This project aimed to determine means of understanding and interacting with climate technology prioritization data from NDCs. Our team analysed data from NDCs for non-annex I countries and built a tool to visualize the parsed information as a network while providing easy access to information. The tool highlights key trends in data along with the most mentioned technologies by countries in various categories. The visualisation tool is intended to help the CTCN, and global stakeholders understand the technology needs landscape and assist in strategic planning and implementation of these technology requests. Through this tool, access to information is increased, supporting the necessary transition to equitable and just dissemination of information. The path forward requires a commitment to increased global collaboration and these authors beseech the reader to utilise tools such as this one to speed the needed technology transitions towards a carbon-neutral future.

Appendix

1. Country List of Work Completed

Table 4: County List of Work Completed. This list describes the country category, documents analysed, the year, if the document needed translation and in which language. If a country was not analysed an explanation is present.

Country Name	Category	Documents Analysed	Year	Translation	Language	Notes
Afghanistan	LDC, G77	INDC; TNA Adaptation, Mitigation	2015, 2020	N		
Algeria	Africa, G77					No qualifying documents
Angola	LDC, Africa, G77	INDC	2020	N		
Antigua and Barbuda	SIDS-UN Member, G77	NDC	2015	N		
Argentina	G77	NDC	2020	Y	Spanish	
Azerbaijan	G77	INDC	2016	N		
Bahamas	SIDS-UN Member, G77	NDC	2016	N		
Bahrain	SIDS-UN Member, G77	INDC	2016	N		
Bangladesh	LDC, G77	NDC, INDC	2020, 2016	N		
Barbados	SIDS-UN Member, G77	NDC	2021	N		
Belize	SIDS-UN Member, G77	NDC; TNA Adaptation, Mitigation	2016, 2017	N		
Benin	LDC, Africa, G77	NDC; TNA	2021, 2020	Y	French	
Bhutan	LDC, G77	NDC	2021	N		
Bolivia (Plurinational State of)	G77	INDC	2016	N		
Botswana	Africa, G77	NDC	2016	N		
Brazil	G77					Not analysed due to capacity
Brunei Darussalam	G77	NDC	2020	N		
Burkina Faso	LDC, Africa, G77	TNA Adaptation, Mitigation	2017, 2018	N		
Burundi	LDC, Africa, G77	NDC	2018	N		Data lost

Cabo Verde	SIDS-UN Member, Africa, G77	NDC	2017	N		
Cambodia	LDC, G77	NDC	2020	N		
Cameroon	Africa, G77	NDC	2016	Y	French	
Central African Republic	LDC, Africa, G77	NDC	2016	N		
Chad	LDC, Africa, G77	NDC	2017	N		
Chile	G77	NDC	2020			
China	G77					Excluded per client request
Colombia	G77					Not analysed due to capacity
Comoros	LDC, SIDS-UN Member, Africa, G77	NDC	2016	N		
Congo	Africa, G77	NDC, NDC	2021, 2017	Y	French	
Cook Islands	SIDS-Non-Member	NDC	2016	N		
Costa Rica	G77	NDC	2020	N		
Côte d'Ivoire	Africa, G77	INDC	2016	N		
Cuba	SIDS-UN Member, G77					Not analysed due to capacity
Democratic People's Republic of Korea	G77					Not analysed due to capacity
Democratic Republic of the Congo	LDC, G77	NDC	2017	N		
Djibouti	LDC, Africa, G77	NDC	2016	Y	French	TNAs not qualifying reports
Dominica	SIDS-UN Member, G77	NDC; TNA	2016, 2020	N		Not analysed due to capacity
Dominican Republic	G77	NDC, INDC	2020, 2017	Y	Spanish	
Ecuador	G77					Not analysed due to capacity
Egypt	Africa, G77	INDC	2017	N		
El Salvador	G77					Not analysed due to capacity
Equatorial Guinea, Republic of	Africa, G77	INDC	2018	Y	Spanish	

Eritrea	LDC, Africa, G77	NDC	2018	N		
Eswatini	Africa, G77	NDC; TNA Adaptation, Mitigation	2016, 2016	N		
Ethiopia, Federal Democratic Republic of	LDC, Africa, G77	INDC; NDC	2017, 2021	N		
Fiji	SIDS-UN Member, G77	NDC, INDC; TNA Adaptation, Mitigation	2020, 2016, 2020			
Gabon	Africa, G77	NDC	2016	N		
Gambia	LDC, Africa, G77	NDC; TNA	2016, 2017	N		
Ghana, Republic of	Africa, G77	NDC, INDC	2021, 2016	N		
Grenada	SIDS-UN Member, G77					Not analysed due to capacity
Guatemala	G77	NDC	2017	Y	Spanish	
Guinea	LDC, Africa, G77					No qualifying documents
Guinea-Bissau	LDC, SIDS-UN Member, Africa, G77	INDC	2016	N		
Guyana	SIDS-UN Member, G77			N		Not analysed due to capacity
Haiti	LDC, SIDS-UN Member, G77	NDC, TNA Adaptation, Mitigation	2016, 2020	N		
Honduras	G77	NDC	2021	Y	Spanish	
India	G77					Not analysed due to capacity
Indonesia	G77					Not analysed due to capacity
Iran (Islamic Republic of)	G77					Not analysed due to capacity
Iraq	G77					No qualifying documents
Jamaica	SIDS-UN Member, G77	NDC; TNA	2020, 2020	N		
Jordan	G77	NDC, TNA	2016, 2016	N		
Kenya, Republic of	Africa, G77	NDC	2020	N		

Kiribati	LDC, SIDS-UN Member, G77	NDC	2016	N		
Kuwait	G77					Not analysed due to capacity
Lao People's Democratic Republic	G77	NDC	2021	N		
Lebanon	G77					Not analysed due to capacity
Lesotho	LDC, Africa, G77	NDC, NDC	2018, 2017	N		
Liberia	LDC, Africa, G77	NDC; TNA Energy Agriculture Coastal Zone	2018, 2019	N		
Libya	Africa, G77					No qualifying documents
Madagascar	LDC, Africa, G77	NDC; TNA	2016, 2018	N		
Malawi, Republic of	LDC, Africa, G77	NDC; TNA Adaptation, Mitigation	2017, 2020	N		Not analysed due to capacity
Malaysia	G77	NDC, INDC	2021, 2016	N		
Maldives	SIDS-UN Member, G77	NDC	2020	N		
Mali	LDC, Africa, G77	NDC	2016	Y	French	
Marshall Islands	SIDS-UN Member, G77	NDC, NDC	2018, 2020	N		
Mauritania	LDC, Africa, G77	NDC; TNA Adaptation, Mitigation	2016, 2017	N		
Mauritius	SIDS-UN Member, Africa, G77	INDC	2016	N		
Micronesia (Federated States of)	G77	NDC	2016	N		
Mongolia	G77	NDC	2020	N		
Morocco	Africa, G77	NDC, NDC	2021, 2016	N		
Mozambique	LDC, Africa, G77					Not analysed due to capacity
Myanmar	LDC, G77	INDC; TNA Adaptation, Mitigation	2017, 2020	N		
Namibia	Africa, G77	NDC, NDC	2021, 2016	N		

Nauru	SIDS-UN Member, G77	INDC; TNA	2016, 2020	N		
Nepal	LDC, G77	NDC	2020	N		
Nicaragua	G77	NDC	2020	Y	Spanish	
Niger	LDC, Africa, G77	INDC; TNA Adaptation, Mitigation	2016, 2020	Y	French	
Nigeria	Africa, G77	Interim NDC, NDC	2020, 2017			
Oman	G77					Not analysed due to capacity
Pakistan	G77					Not analysed due to capacity
Palau	SIDS-UN Member	NDC	2016			
Panama	G77					Not analysed due to capacity
Papua New Guinea	SIDS-UN Member, G77	NDC	2020	N		
Paraguay	G77					Not analysed due to capacity
Peru	G77					Not analysed due to capacity
Philippines	G77					Not analysed due to capacity
Qatar	G77	NDC	2017	N		
Rwanda	LDC, Africa, G77	INDC	2020	N		
Saint Kitts and Nevis	SIDS-UN Member, G77	INDC	2016	N		
Saint Lucia	SIDS-UN Member, G77	NDC	2021	N		
Saint Vincent and the Grenadines	SIDS-UN Member, G77	NDC	2016	N		
Samoa	SIDS-UN Member, G77	NDC, INDC	2021, 2016	N		
São Tomé and Príncipe	G77	NDC, INDC	2021, 2016	N		
Saudi Arabia	G77					Not analysed due to capacity

Senegal	LDC, Africa, G77	NDC	2020	Y	French	
Seychelles	SIDS-UN Member, Africa, G77	NDC, INDC; TNA Adaptation, Mitigation	2021, 2016, 2017	N		
Sierra Leone	Africa, LDC, G77	NDC, INDC	2021, 2016	N		
Singapore	SIDS-UN Member, G77	NDC	2020	N		
Solomon Islands	LDC, SIDS-UN Member, G77					Not analyse due to capacity
Somalia	LDC, Africa, G77	NDC, INDC	2021, 2016	N		
South Africa	Africa, G77	NDC, INDC	2021	N		
South Sudan	LDC, Africa, G77	INDC	2021	N		
Sri Lanka	G77					Not analysed due to capacity
State of Palestine	G77					Not analysed due to capacity
Sudan, Republic of Sudan	LDC, Africa, G77	Interim NDC, INDC	2020, 2017	N		
Suriname	SIDS-UN Member, G77	INDC; TNA	2019, 2019	N		
Syrian Arab Republic	G77					Not analysed due to capacity
Tajikistan	G77					Not analysed due to capacity
Thailand	G77					Not analysed due to capacity
Timor-Leste	LDC, SIDS-UN Member, G77	NDC	2017	N		
Togo	LDC, Africa, G77	NDC; TNA Adaptation, Mitigation	2021, 2017	Y	French	
Tonga	SIDS-UN Member, G77	NDC	2020			
Trinidad and Tobago	SIDS-UN Member, G77	INDC	2018			

Tunisia	Africa, G77					Not analysed due to capacity
Tuvalu	SIDS-UN Member, LDC	INDC	2016	N		
Turkmenistan	G77					Not analysed due to capacity
Uganda	LDC, Africa, G77	INDC; TNA Mitigation, Adaptation	2015, 2019, 2020	N		
United Arab Emirates	G77					Not analysed due to capacity
United Republic of Tanzania	LDC, G77	NDC; TNA Mitigation, Adaptation	2021, 2016	N		
Uruguay	G77					Not analysed due to capacity
Vanuatu	SIDS-UN Member, G77	NDC, NDC; TNA Adaptation, Mitigation	2015, 2020, 2020	N		
Venezuela (Bolivarian Republic of)	G77	NDC	2018	Y	Spanish	
Viet Nam	G77					Not analysed due to capacity
Yemen	LDC, G77					No qualifying documents
Zambia	LDC, Africa, G77	NDC	2020	N		
Zimbabwe	Africa, G77	INDC	2017	N		

2. Figure 9 explains the header text used in the application.

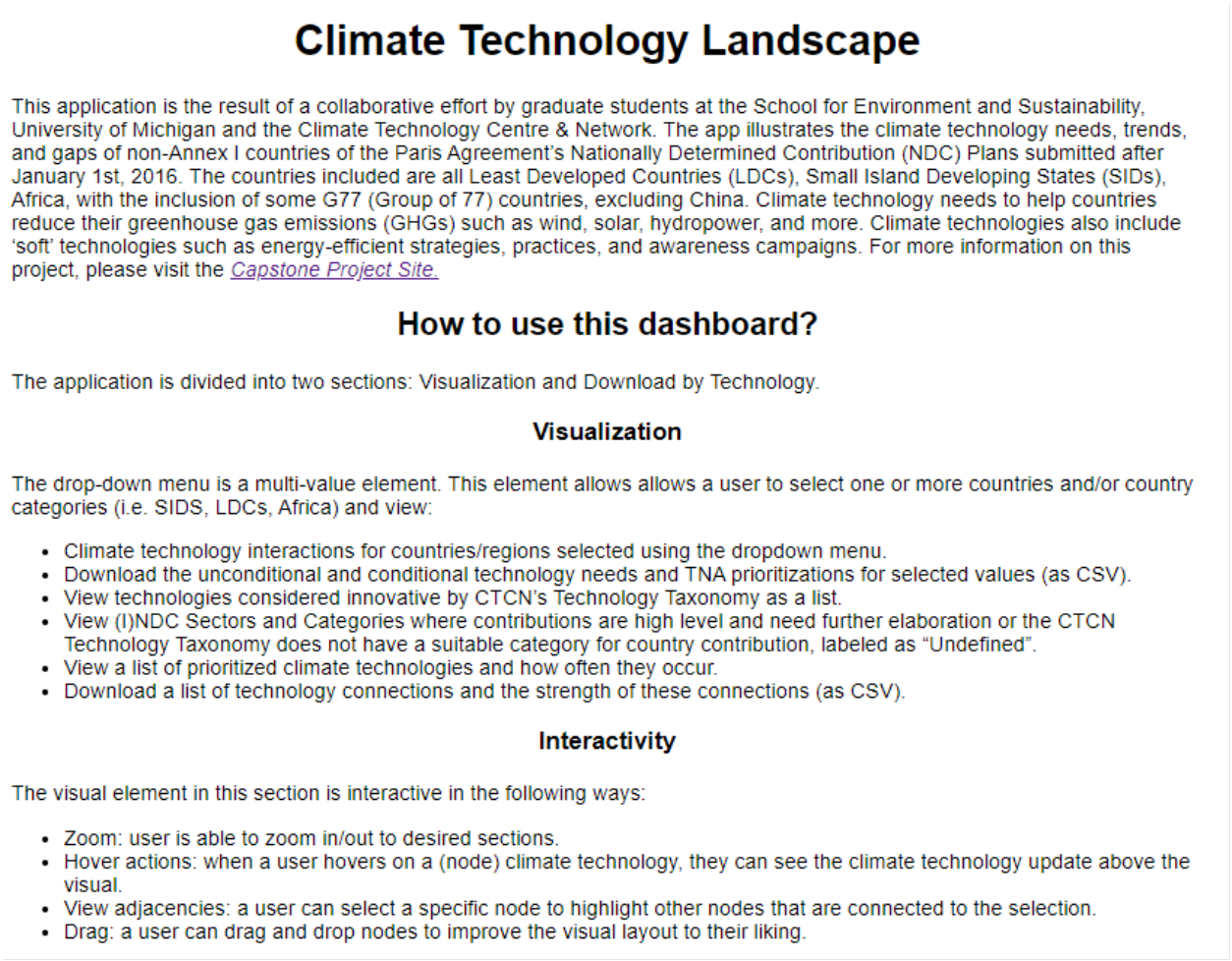

Figure 9: The first section of the tool details what the tool is and how to use it.

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