Connected Developments

The Governance of Formal Global Knowledge Networks in Sustainability Transformations

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Signed declaration

I, *Lucas Somavilla Croxatto* confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in this thesis.

Abstract

Climate change adds pressure to the international community to work cooperatively, find ways to govern technologies and expert knowledge, develop better policies, and mobilise resources, tools, and practices to deal with potential consequences and impacts. The institutional drivers underpinning current knowledge applications in globally connected spaces of sustainable development practice are increasingly complex, intertwined, and empirically understudied. In this context, this PhD thesis aims to advance our empirical understanding of why and how formal cooperation networks form, negotiate, mobilise and utilise particular technologies and expert knowledge and attempt to steer visions and pathways for change. This research combines multi-sited ethnography with social network analysis and policy analysis and investigates formal contexts of global connection. This thesis examines practices of science and technology policy through technology-driven networks in multiple locations in Europe and Southeast Asia. In particular, this thesis analyses the processes and conditions through which tools (e.g. modelling technologies), practices (e.g. climate negotiations, technology transfer activities, risk management, and environmental planning), and ways of dealing with climate-related uncertainties are implemented in a global knowledge network articulated under the UN system. The participant observation that is applied in the research is grounded in mobile contexts of project-based interactions, intergovernmental negotiations, international expert meetings, high-level advisory boards, technology assessments, implementation of technology transfer programmes, capacity-building workshops, expert discussions on anticipation and uncertainty, and the production of reports, climate policies, and procurement systems. This thesis examines how the artefacts of transfer interact in the implementation of the Technology Mechanism under the UNFCCC, drawing on cases of climate and hydrological modelling ranging from the Climate Technology Centre and Network (CTCN) to Thailand and Myanmar. It maps and analyses the global response of networked organisations, with special attention to persistent North–South power dynamics imposed by global environmental governance regimes and their emergent 'transformational claims'. This thesis delves into a critical evaluation of transformational change narratives in institutionalised knowledge systems, practices of technology transfer, and science–policy spaces inside the United Nations. It contributes to a better foundational understanding of knowledge governance relating to critical social and environmental challenges, and rethinks futures of collective climate action in light of sustainability transformations theory and practice.

Impact Statement

This PhD thesis is the product of four years of intensive research involving numerous interactions with experts around the applications of knowledge to solve complex problems relating to climate change. The development of this PhD study included a critical analysis of the practice of international development in the context of transformations to sustainability. The material contained in this doctoral work is part of an exhaustive inquiry that contributes to the advancement of knowledge about collective climate action and builds on a comprehensive assessment of those who practice sustainable development in formal global knowledge networks. First, this thesis contributes to rethinking epistemic problems of why and how particular forms of expert knowledge are used in the practice of technology transfer to try solving complex issues in sustainability. The thesis contributes to a better understanding of knowledge's conditionality as iterative practice and the debate between knowledge and action. In this sense, it contributes to scientific and academic knowledge regarding the praxis of sustainability expertise while informing sustainability policy and practice—this project involved experimentation with methodologies belonging to different problem domains and disciplines. Second, this thesis's development, outputs were produced in the form of one peer-review article published in the journal *Futures* in January 2020, with a second article published in *Earth System Governance* in January 2021. A third article is under review in *Global Environmental Change*. The research process also included my participation in various scientific advice contexts under the United Nations system, as well as providing written and verbal input to the Technology Executive Committee under the UNFCCC and to participants in the Technology Needs Assessments process in matters related to technology and innovation policy. Third, this doctoral work contributes to current debates taking place in diplomatic and scientific spheres on global sustainability policy. In particular, this thesis informs the practice of international organisations and the global response from stakeholders in matters related to climate change. More specifically, it informs several interest groups that work in the areas of expert knowledge, technological transfer, knowledge systems, innovation systems, sustainability transitions and paradigms of transformational change, and the governance of institutional systems dedicated to planning mitigation and adaptation efforts. Finally, this doctoral work contributes to those expert communities looking for new ways to understand and deal with uncertainties in environmental governance. This PhD study advances knowledge about future collective climate actions and provides critical insight to global institutions implementing programmes and projects aimed at tackling complex challenges in sustainability.

Table of Content

List of Figures

List of Tables

List of Acronyms

ADB	Asian Development Bank
ADPC	Asian Disaster Preparedness Centre
AIT	Asian Institute of Technology
AR2	Assessment Report 2
AR3	Assessment Report 3
AR4	Assessment Report 4
AR5	Assessment Report 5
AR6	Assessment Report 6
ASEAN	Association of Southeast Asian Nations
BAU	Business as Usual
BECCS	Bioenergy with Carbon Capture and Storage
BINGO	Business and Industry Non-Governmental Organisation
BMA	Bangkok Metropolitan Administration
BRICS	Brazil, Russia, India, China and South Africa
C40	Cities Climate Leadership Group
CBNRM	Community-Based Natural Resource Management
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CDR	Carbon Dioxide Removal
CGIAR	Consultative Group on International Agricultural Research
CMA	Conference of the Parties serving as the Meeting of the Parties of the Paris Agreement
CMP	Conference of the Parties serving as the Meeting to the Parties of the Kyoto Protocol
COP	Conference of the Parties
CTCN	Climate Technology Centre and Network
DAC	Development Assistance Committee
DHI	Danish Hydraulic Institute
DLT	Distributed Ledger Technology
KMS	Knowledge Management System
KOICA	Korean International Cooperation Agency
LDC	Least Developed Country
MIT	Massachusetts Institute of Technology
MOECAF	The Ministry of Environmental Conservation and Forestry (Myanmar)
NAMA	Nationally Appropriate Mitigation Action
NAPA	National Adaptation Programme of Action
NASA	National Aeronautics and Space Administration
NDA	National Designated Authority
NDC	Nationally Determined Contributions
NDE	National Designated Entity
NGO	Non-Governmental Organisation
ODA	Official Development Assistance
OECD	Organisation for Economic Co-operation and Development
PIF	Project Identification Form
PSP	Poznan Strategic Programme on Technology Transfer
RCP	Representative Concentration Pathways
RINGO	Research and Independent Non-Governmental Organisation
SBI	Subsidiary Body for Implementation
SBSTA	Subsidiary Body for Scientific and Technological Advice
SDG	Sustainable Development Goals
SEA	South-East Asia
SIDS	Small Island Developing States
SMEs	Small and Medium-sized Enterprises
SPM	Summary for Policy Makers
SSP	Socio-economic Pathways
STI	Science, Technology and Innovation

DNVGL	Det Norske Veritas and Germanischer Lloyd
DoUbT	Deltas' Dealings with Uncertainty
DRR	Disaster Risk Reduction
DSS	Decision Support Systems
DTU	Technical University of Denmark
ENGO	Environmental Non-Governmental Organisations
ESRC	Economic and Social Research Council
EST	Environmentally Sound Technologies
EU	European Union
G77	Group of 77 at the United Nations
GATT	General Agreement on Tariffs and Trade
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIS	Geographic Information System
GKN	Global Knowledge Networks
HAII	Hydro and Agro Informatics Institute
ICAT	Initiative for Climate Action Transparency
ICT	Information and Communications Technology
IGO	Intergovernmental Organisation
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contributions
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
KMS	Knowledge Management System
STIPO	Thai Science, Technology and Innovation Policy Office
STS	Science and Technology Studies
TAP	Technology Action Plan
TEC	Technology Executive Committee
TF	Technology Framework
TM	Technology Mechanism
TNA	Technology Needs Assessment
TT	Technology Transfer
UDP	UNEP DTU Partnership
UK	United Kingdom
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	United Nations General Assembly
UNHABITAT	United Nations Human Settlements Programme
UNIDO	United Nations Industrial Development Organization
UNISDR	United Nations Office for Disaster Risk Reduction
USAID	United States Agency for International Development
WIPO	World Intellectual Property Organization
WTO	World Trade Organization
WWF	Worldwide Fund

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"Humanity faces real, non-negotiable biophysical constraints: most resources are scarce and the capacity of the Earth to absorb human impact is limited—at multiple scales. Governing distributional conflicts and living within the planet's biophysical constraints lies at the heart of the political process, democratic or otherwise." (Jonathan Boston, *Governing for the Future*, p. xxvii).

"Capitalism, science and politics all depend on global connections. Each spread through aspirations to fulfil universal dreams and schemes. Yet this is a particular kind of universality: It can only be charged and enacted in the sticky materiality of practical encounters (…) Even if the bridge aims toward the most lofty universal truths——the insights of science, the freedom of individual rights, the possibility of wealth for all——we find ourselves hemmed in by the specificity of rules and practices, with their petty prejudices, unreasonable hierarchies, and cruel exclusions. We must make do, enmeshing our desires in the compromise of practical action." (Anna Tsing, *Friction*, pp. 1 & 85).

"Demarcating science from politics is easy once one accepts the idea of formative intentions. The problem of legitimacy and extension arise because the speed of politics is faster that the speed of science. Where there is no distinction between science and politics, then they would run at the same speed because they would be co-extensive. Thus, it must be possible to draw the line——the question is how." (Harry Collins and Robert Evans, *Rethinking Expertise*, 2007 p. 123).

Chapter One

A Series of Interdependent Problems

1.1 Introduction

The need for climate action has never been greater. Human activities are estimated to have already caused a 1.0ºC increase in the planet's global mean temperature, and in 2018 scientific experts expressed confidence that it could well reach 1.5ºC by 2030 at the current rate (IPCC, 2018a). Consequently, we likely face abrupt changes[1] in the climate system and potentially higher levels of uncertainty in the decades to come, which could affect how decision makers envision and deal with the future (Capela Lourenço et al., 2015).

Climate change is a "collective action problem" (Ostrom, 1990, 2010, 2014). It requires that nations and societies work cooperatively and seek creative ways to govern the integration of existing knowledge, develop innovative policies, and mobilise appropriate resources, tools and practices to address the challenge (Lorrae Van Kerkhoff, 2014). In this context, this PhD thesis aims **to advance our critical understanding of why and how formal cooperation networks negotiate, mobilise and utilise technologies and expert knowledge to steer future sustainability transformations**. In this thesis, formality refers to the established mechanisms and procedures that guide specific behaviours and activities of organisations and actors. The drivers underpinning knowledge applications through formal mechanisms and sustainable development practice are increasingly complex, interconnected and empirically understudied. This thesis critically unfolds the nature and role of formally coordinated 'global knowledge networks' that steer sustainability transformations in a variety of contexts. These involve institutionalised knowledge systems, persistent practices of technology transfer, and science–policy networks navigating narratives of futures and transformational change. This PhD study offers a contribution to better foundational understandings of decision-making processes related to climate change, and of possible futures of knowledge governance relating to critical social and environmental challenges.

Global climate governance under the Paris Agreement and the 2030 Agenda on Sustainable Development takes different forms, depending on a country's cultural context, political will,

[1] The IPCC in its Special Report on 1.5ºC defines abrupt change as: *"change that is substantially faster than the rate of change in the recent history of the affected components of a system."* (IPCC 2019 A.II, 118).

and the communities living inside its borders. These accords are to be approached following specific identified needs, priorities, institutional set-ups, funding, and implementation capabilities (United Nations 2015). Therefore, planning and coordinating implementation efforts is an inherent challenge. The literature outlines the growing recognition that effective integration of different knowledge systems will be required to get closer to achieving these ambitious targets (Anadon et al., 2016; Cash et al., 2003; Clark et al., 2011; Clark et al., 2016). In the process of working towards a more coherent 'global response', further research should be conducted on how to effectively and cohesively bring together available knowledge in order to implement solutions. A better understanding of such strategies could generate new perspectives on collective climate action and support global environmental governance performance.

Beginning with the above set of interrelated problems, this PhD thesis analyses current worldwide efforts to connect and nurture the boundary work of sociotechnical systems that actively pursue future changes in global sustainability policy and practice. The thesis examines the interplay between knowledge and action and delves into a critical evaluation of the applicability of knowledge in international environmental governance systems. It does so by empirically examining how such systems articulate and steer change through the negotiation, mobilisation and utilisation of expert knowledge and technologies in formal global development cooperation networks. This document is structured as follows: Chapter one contains the literature review, research questions, research framework and a conceptual map. Chapter two covers the methodology, research design, ethics, data collection and data classification for analysis. Chapters three, four, five and six are the empirical chapters of the thesis, with their analysis and discussions. Chapter seven contains the overall discussions, findings, contributions and conclusions of the thesis.

1.2 Literature Review: Environmental Governance, Global Knowledge Networks and Sustainability Transformations

1.2.1 Persistent Technological Fixes to Complex Environmental Problems

Models of technology-based solutions and innovations have accommodated global development interests, cooperation and businesses as usual for far too long without real transformative impacts; however, they continue to be sold as the best strategy to solve complex problems such as climate change (Mike Hulme, 2014). The majority of the models for cooperation systems tend to follow a one-way strategy, where global northern providers 'solve' gaps by deploying technologies to developing countries. These phenomena are obscure, opaque and unclear. They have become complex processes, as technological models of change have been implemented for decades across countries and continue to be deepened. International bureaucracies continue to focus considerable efforts and resources on technological transfer in development-cooperation.

Technology development and transfer are understood here as a social process of interaction between actors and institutions to transfer specialised knowledge and resources and facilitate the diffusion and adoption of technologies from one context to another. In particular, this PhD study demonstrates that 'techno scientific' rationality is embedded in socially constructed technology transfer activities and how the modernisation narratives of global technology deficit seek to justify the 'transfer' of technology from industrialised nations to 'underdeveloped economies', however, falling into numerous contradictions. In particular, 'technology transfer' continues to be the favourite model through which northern providers 'agree' to support developing countries to tackle climate change. Largely the United Nations Framework Convention on Climate Change is a global climate regime that acts as a framework that aims to regulate human activity interaction with the global climate systems to mitigate climate change. One of its most praised mechanisms to do so is via the systematic process of technology development and transfer. In this context, the concept of regime is important. A well-known definition characterises regimes as *"the rule-set or grammar embedded in a complex of engineering practices, pro- duction process technologies, product characteristics, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures"* (Rip and Kemp, 1998: 340). The UNFCCC fits well under this definition. However, studies from sociology of science and geography suggest that cognitive rationalities are influenced by culture and location and that such rationalities can be institutionalised to such degree that they become taken from granted and moved from their place of origin (Bunnell & Coe, 2001; Meyer et al., 1997). Furthermore, to date, transition studies offer a small conceptual understanding of the actual mechanism and processes involved in the transfer of technologies and the mobilisation of cultural-cognitive rationality through space (Fuenfschilling & Binz, 2018). Consequently, it becomes unavoidable when thinking about global climate regimes and technology transfer processes to elaborate on why and how techno-scientific rationalities travel through such regimes and gain influence beyond their places of origin. Furthermore, the need to understand the systemic processes underpinning the formation of technology-driven global cooperation networks driving such transfer activities.

1.2.1.1 Early distinction of socio-technical networks and socio-technical systems in the context of technology transfer.

In the context of technology development and transfer, it is crucial to refer to socio-technical networks and make an early distinction with the concept of socio-technical systems. A socio-technical network can be described as a constellation of actors and institutions interlinked through the systematic interactions with technology (Elzen et al. 1996). Such interlinkages are the combination of social and technical elements and comprise a dialectical force that offers the reconfiguration of technical pathways (Rip and Kemp 1998). Linked to this phenomenon is the idea that technology is socially constructed (Bijker *et al.* 1987). Therefore, socio-technical networks consist of human actors and organisations––as groups of human actors that interact and form networks. Notably, this is different from actor-network theory, where technology also constitutes an actor in the network (Latour 1987). However, the processes of technology transfer include human interactions as well as interactions with technological artefacts. These interactions are defined, in the case of technology transfer, mainly by technoscientific rationality.

Socio-technical networks are different in the literature than socio-technical systems. Socio-technical systems recognise the interaction between people and technology and refer to the interactions between society's complex infrastructure and social behaviour and organisations, and recognises systemic boundaries (Baxter & Sommerville, 2011; Coenen et al., 2012; Ravena et al., 2012). They refer to clusters of technology, institutions, policies, regulations, science, culture, markets and infrastructures (Kemp et al. 1998, Rip and Kemp 1998, Geels 2002). Socio-technical systems are typically contextualised around functional domains for example energy, mobility and communication (Fuenfschilling & Binz, 2018; Geels & Kemp, 2007). Socio-technical systems are primarily described as situated configurations of social and technical elements, for instance, on national innovation systems (Enciso et al., 2015). The coordination and alignment of interrelated elements in socio-technical systems create stability, and change tends to be incremental and are said to be bounded by space (Geels, 2004).

In practice, there are closed interactions between networks and systems involved in technological development and innovation, and both concepts have a relational perspective on space. This calls for more significant consideration of embedded interaction as situated socio-technical systems but at the same time to avoid fixation on discrete scales as the locus for understanding processes such as technology transfer or innovation as spatially bounded. Instead, I argue that technological development and innovation processes in socio-technical systems are largely enacted through networks of social relations and organisations operating between and across scales and beyond national boundaries. This is particularly the case for technology transfer operating in large socio-technical networks seeking to influence socio-technical systems worldwide. The development of systems thinking, and socio-technical systems applications are expanded in section 1.3 of this thesis.

1.2.1.2 Technology Transfer and the UNFCCC

This PhD thesis empirically studies globally connected networks attempting 'climate technology development and transfer' under the United Nations Framework Convention on Climate Change (UNFCCC) Technology Mechanism and shows how its multiple agencies pursue change in practice. Technology transfer has been recognised as a priority by the United Nations since 1992, and certain countries have made commitments to promote it in developing countries as the 'effective way' to move technologies, resources and knowledge (UNFCCC, 1992). The IPCC defined the term as: *"covering the flows of know-how, experience and equipment, for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, NGOs, and research/educational institutions."* (IPCC, 2000, p. 5).

Under the 'global climate regime', technology transfer has endured as one of the central efforts on climate action. For example, it continued to be high on the agenda during the Marrakesh Accords (2001) and the Poznan Strategic Programme on Technology Transfer (PSP) in 2008. More recently, it featured in the Cancun Agreement (2010) and the Paris Agreement (2015). It is clear that international policy bureaucracies continue to develop frameworks and funds for the 'transfer' and 'diffusion' of 'climate technologies' as the way to deal with mitigation and adaptation to climate change. Despite critiques to this approach, the majority of experts involved in climate change issues still believe that technology is and will be the ultimate solution (Hulme, 2014). Furthermore, this "techno scientific rationale" (Contreras, 2002) is rapidly gaining ground today as science, technology and innovation push the frontiers of sustainability and marketability of technical solutions to complex issues. The global climate regime under the United Nations is no exception. For example, Article 10 of the Paris Agreement provides the techno scientific rationale for technology development and transfer as means of implementation, both as a development strategy and as a collective action framework (Haselip et al., 2015). This is critically analysed in detail in this thesis by looking at networks of experts influencing the global response and the consolidating drivers 'scaling up' technological transfer projects as the ideal way to implement climate action globally.

Debates around the concept of technology transfer are tightly coupled with notions of the 'north-south' divide as it is linked to development-cooperation (Bry, 2017)). Development can widely be understood in these contexts as the set of social processes induced by operations and changes to a social environment, promoted by external institutions and supported by the transfer of resources, technologies, and knowledge (Contreras, 2002). It implies a process of directed and 'controlled' change, typically following the modernist paradigm (Escobar, 2004). Consequently, the north-south division is still applied today in international development policies and in the negotiation of global environmental agreements (Roberts & Parks 2006). For example, initially under the UNFCCC, southern perspectives claimed that, since developed countries were to blame for causing climate change, developing countries should not make commitments to reduce greenhouse emissions (Kyoto Protocol 1997). However, while northern countries accepted their 'historical responsibilities', they increasingly pointed out that many developing countries occupied the blurred space of development, due to the emergence of the BRICS[2] nations, for instance (Moak, 2017). The debate has shifted to include developing countries, which need to take greater responsibility for mitigating and adapting to climate change (Haselip et al., 2015). However, this has paved the way for insisting that developing countries enhance their technological capabilities 'fast' in order to be up to the challenge (Karakosta et al., 2010; Nakwa & Zawdie, 2015). Furthermore, it has supported the notion that northern providers of 'know-how' and technologies are best suited to support this endeavour (Bulkeley et al., 2012; Kruckenberg, 2015; Roberts T, Parks, 2006). The wider political

[2] Brazil, Russia, India, China and South Africa.

discussion around the meaning of technological transfer in the context of climate change suggests that these assumptions are still not sufficiently questioned across this science–policy space. The formal mechanisms framing and steering these processes have become highly narrow, path-dependent and instrumental.

The concept of technology transfer has often had a limited understanding and applicability in climate policy beyond the notion of 'hardware'. For example, widespread efforts of international environmental agreements focus mostly on 'tangible' aspects of technologies, resulting primarily in one-off and discrete deployment of technologies (Flamos & Begg, 2010). Some argue that such technocratic framings influence the negotiation of policies, generating overly technical discussions influenced by neoliberal pro-market narratives, which are widely accepted as common sense (Haselip et al., 2015). The thesis explores this tension by observing technology-driven knowledge networks in action. As it explains, technology-driven market-based mechanisms continue to appear as the instrument of choice when it comes to development and aid, to the detriment of alternative perspectives or other governance systems with potential to address the global climate crisis. The case of the Montreal Protocol may indeed have been an effective global framework to legislate the mitigation of chlorofluorocarbon using market incentives (Simmonds et al., 1999). Hence, the 'logical' next step was to develop other protocols to solve climate change. However, as the failure of the Kyoto Protocol has demonstrated, climate change comprises a broader set of overlapping and multiple issues (Rosen, 2015; Sardar, 2010). The Kyoto Protocol was the market-based instrument *par excellence*, through its mechanisms, though it has proven less than straightforward. This unstructured and rapidly escalating problem demands more than designing activities, targeting economic sectors, and using technological potential toward effective reduction of climate change (Creutzig et al., 2016; Patt, 2017).

Under the Protocol, countries were able to combine a 'hardware' focus on technology with a free-market orientation, resulting in decades of discussions and analysis of which incentives would work best (Ockwell & Mallet, 2002). However, neoliberal policies have several shortcomings. First, they neither understand nor produce the context for effective governance of public affairs. This extends to frameworks and policies related to technology and innovation (Fairhead et al., 2012; Mazzucato, 2015; Mosse, 2013; Reno, 2011; Utting & Zammit, 2009). In addition, studies of technology transfer have focused too narrowly on understanding where technology transfer occurs, rather than on how it takes place. Similarly, technology transfer studies, which are often model-based and theory-based, continue trying to find cost-effective ways to transfer whilst remaining oblivious to the ‘intangible’ elements of technology, especially knowledge (Bell, 2012). The prevailing technology fix model based on pro-market ideologies dominates policy discussions, ignoring the empirical understanding of why technology transfer may fail.

Given the fact that the event of technology transfer is often seen as a one-off project or intervention, we lack a clearer understanding of how technology-driven networks operate in practice—how they link to and are affected by institutional and social processes at network levels. Addressing this gap means paying attention to the deeply ingrained practices of specialised organisations, as well as their institutional systems and the political, material and symbolic conditions through which specific technologies are disseminated from one context to another and maintain path dependency (Biermann *et al.*, 2018; Burch et al., 2018). This calls for an empirical analysis of knowledge governance involving sustainable development (van Kerkhoff, 2013). The literature suggests the need for further research on the context-specific dynamics and governance features which underlie the processes of technology mobilisation (Mosse, 2013; Rajak, 2011; L. van Kerkhoff & Pilbeam, 2017). In particular, more research is needed on ‘softer’ elements such as institutional capacity, skills, and “tacit” knowledge belonging to the organisational side of technologies (Gudowsky & Peissl, 2016). It is necessary to dive deeper into the broader social construction of technological systems (Bijker et al., 2012) and examine the interrelationships between knowledge and artefacts (Hornborg, 2013; Latour, 2005).

So far, the conceptualisation of technology presents challenges in its categorisation, particularly across international climate policy environments (Shackley and Wynne, 1996; Arthur, 2009; Spaargaren, 2011). The practice has revealed that the issue of what technology is and how it should be interpreted and operationalised in different contexts remains largely unresolved (Nygaard & Hansen, 2015). Within the United Nations Framework Convention on Climate Change (UNFCCC), definitions of technology include a taxonomy distinction of hardware, software, and orgware (Flamos & Begg, 2010). This distinction is one of the results of a wider discussion in the literature linked to the concept of technology transfer, primarily from economic and engineering perspectives (Nygaard & Hansen, 2015). Within the distinct views on technology dissemination and transfer, two main characteristics are highlighted. The most noticeable perspective views technology as a material artefact, while the other sees technology as multidimensional, including a body of related knowledge that can be represented in a variety of forms, including but not limited to artefacts (Martinot et al., 1997).

In the UNFCCC context, debates in the science–policy interface often take two sometimes contradictory standpoints, one emanating from the Global North and the other from the Global South. Broadly described, the northern view understands technology transfer's primary objective to be rapid diffusion of physical tools to developing countries to foster transitions to sustainability through industrial economic growth (Kerr et al., 2015; Stock et al., 2017). Southern negotiators mostly grouped under the G77 leverage for the 'softer' side of technologies. For example, they advocate for the mobilisation of capacity building and knowledge transfer through enabling frameworks. The classification of technologies into 'harder' and 'softer' acts as a taxonomy that seeks to manage and tailor technological transfer more cost-effectively. However, this thesis examines the implications of particular technology guidelines and frameworks designed by expert institutions for technology transfer as they attempt to accommodate technoscientific rationality in a context characterised by divergent cultural values. Nevertheless, the developing world is already part of this complex socio-technical fabric, rooted in technoscientific discourse. These are ethnographically mapped and questioned throughout. For example, developing countries seeking to access funds and technological transfer programmes must comply with the technology guidelines created by expert institutions to demonstrate readiness and comply with other assessments. The guidelines analysed for this purpose are the Technology Needs Assessments (TNAs), which among other things assume the existence of a 'technology continuum' for building up strategies and comparing and identifying technology needs (Nygaard & Hansen, 2015). The process includes institutionalised policy making boundary work and implementation contexts, which are examined in this research.

As the thesis expands, development policies have taken as an obligatory reference the process of introducing and extending 'scientific rationality' and its techniques outside their original spaces of production. The attempt to transfer certain types of knowledge and artefacts involves the transfer of forms of 'agency', from one system of meaning to another. Due to historical modes of transfer and the dominating discourse of rationality, local knowledge systems are still subordinate as non-scientific, irrelevant or too complex and contextual. This has led to an unbalanced professional culture among international development institutions. There is, however, a rich and dynamic multiculturalism that goes unrecognised in many practices of sustainable development not open to it. Target populations—the 'recipients' of technologies—possess other knowledges, and techniques, and ways of understanding risk and uncertainty. They may hold different values or perceptions of positive change. The transfer of technologies to the developing world involves re-contextualising tools designed and used in highly industrialised societies, developed to satisfy specific societal needs according to a 'modern' model of human capital and social organisation (Contreras, 2002; Harding, 2009). Moreover, the transfer of technology is an 'enduring' means that is complicated and unfolding, thus becoming a target of study critically attuned to understanding social and material interventions of development and of 'sociotechnical imaginaries' of change (Jasanoff & Kim, 2015). The process of transfer is an opaque type of social phenomenon in which the participation of actors, networks, technologies and knowledge requires comprehensive research through qualitative, ethnographic immersion.

Chapter one identifies several interrelated theoretical and practical problem domains connected to the study of global knowledge networks and environmental governance. The review starts with identifying persistent technology-based solutions to complex environmental problems (1.2.1). Followed by a critical approach to international development (1.2.2) which offers the geopolitical context for the study of development cooperation networks, focusing on the travelling of rationalities and structural economic conditions of development cooperation networks today. The review continues with a debate on expertise in the context of environmental governance and global knowledge networks (1.2.3), referring to futures and outlining how this thesis approaches the study of uncertainty (1.2.4). Section 1.3 synthesises the literature and builds a research framework for researching sustainability transformations. It builds on diverse components from structural analysis to the study of systems and of agency (1.3.1), the study of socio-ecological and socio-technical systems (1.3.2) and then indicate critiques to the transition paradigm (1.3.2). And section 1.4 integrates perspectives and practical challenges. Finally, the chapter concludes with the research questions (1.5) and a conceptual map and logical syntax of research applied to the thesis (1.6).

1.2.2 A Critical Approach to International Development in the Context of Climate Change

The geopolitics of international cooperation and aid have been characterised by historical and geographical distinctions between the so-called 'developed' and 'developing world' and have followed specific socio-economic criteria from Western countries, particularly the US and Europe (Crewe and Axelby 2013). The end of the European colonial rule and the decades following the end of the Second World War saw the emergence of sovereign states in Latin America, Africa, and Asia. However, the dominant development paradigm during this period continued to be the "modernity project" (Ferguson, 1999; Habermas, 1981). The definition of modernity of Harry S. Truman, exacerbated the temporal and spatial division of what is commonly referred to today as the 'Global North' and 'Global South' (Therien, 1999). Under this conception, there is an embedded idea in western cultures about a clear progression line that marks the "different stages of economic growth" from "underdeveloped" to "developed" (Rostow, 1959). Modernisation theories, whose foundations lie in the historical experience of the industrial revolution in Europe and North America, continue to be present in development cooperation practice (Crewe & Axelby, 2013; Escobar, 2004; Flachs & Richards, 2018; Sahlins, 2005). However, unsustainable production and consumption, as well as the high pace at which global capitalism has contributed to accelerating climate change and global inequality, require us to use a critical lens when examining climate action in the context of global development cooperation (Jackson, 2017; Moore, 2015).

Modernisation narratives include an explicit model of international cooperation in which the horizon of industrialisation and economic growth still dominates the landscape. Development efforts include the re-orientation of norms and values associated with reducing poverty, at the same time as liberalising markets. Structural Adjustment Programmes (SAP) are now widespread blueprint 'solutions' for addressing macro-economic inefficiencies and the preferred strategy to remove barriers to trade and investment in some 'southern' nations. SAPs are loans given by international funding institutions such as the IMF and the World Bank to developing countries or economies in transition. Both institutions require that countries implement particular neoliberal policies in order to receive the loans. The Washington Consensus is the paradigmatic example of policy prescriptions set by the International Monetary Fund (IMF) and the World Bank in 1989, seeking to reform developing economies by introducing a combination of neoliberal policies and governance mechanisms (Sheppard & Leitner, 2010). Development paradigms since the 1950s have largely been set by the United Nations system and the Bretton Woods system; they have dominated views of development and aid (Larner & Laurie, 2010). While the UN focused on poverty reduction, the Bretton Woods paradigm advocated for a global economic process by which economic reforms aimed at opening global markets and competitiveness were to narrow the inequality gap (Sheppard & Leitner, 2010; Williams, 2015). This economic discourse has been one of the primordial visions of the International Monetary Fund, the Word Bank, and the World Trade Organisation (WTO). For that reason, free-market economic policies still have a significant influence over policy makers in many parts of the Global South (Bracking, 2015; Ferguson, 2006; Reno, 2011; Sawyer, 2004). The social impact of the modernisation paradigm constitutes so-called 'travelling rationalities' that tend to prescribe and homogenise development policy among communities of experts

(Mosse 2011; O'Brien, 2013). Thus, in many cases, the geopolitical impact of neoliberal development cooperation has been the weakening of the developmental role of the State. It has been marginalised through the privatisation of public services and delegation of authority in economic planning, and displaced from its driving force of innovation and change (Mazzucato, 2015; Williams, 2015).

1.2.2.1 The Environmental Turn in International Cooperation

Until 1987, no global paradigm was concerned about safeguarding or balancing the environment and the socio-economic policies and international development agendas. The environment appeared as a new political space for concern during the 1970s, for example, through the creation of a global environmental program under UNEP. However, much has been debated about why the environment has been treated—similar to poverty—as an externality (Jackson, 2017). Hence, both the development and the environmental branches of the UN never really scaled up and became full governing organisation bodies with comprehensive operational budgets. Both have kept their status as 'programmes' inside the UN-system, despite continuing pledges for reform (Biermann, 2014). The debate started to move into a globalised conversation when the World Commission on Environment and Development (WCED) released the Brundtland Report, which stressed that developing countries were to suffer the most from poverty associated with environmental degradation (Brundtland report 1987). However, its key message, which now resonates ever more strongly with climate change, was the inherent interdependency of social, economic and environmental systems (WCED, 1987). From the Brundtland Report onwards, problems associated with the economy, the environment and society started to include notions of 'sustainable development'. Its definition is now a classic point of reference: *"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (WCED, 1987). Although much criticised for its vagueness and the 'apolitical' notion of development when encountering 'ecologies' (Biersack, 1999; Wolf, 1999; Robbins, 2012), it is still today the most widely accepted definition of the term (e.g. similar versions of the definition are still used in all the IPCC reports). Thus, the concept highlights an important tension in that the very notion of combining 'sustainability' and 'development' remains largely unresolved. The report, however, included the historical responsibilities of countries and the problem of global environmental change under the umbrella of the term.

Climate change has brought back narratives of development-cooperation, including alternative 'south-south' alliances, but these are not new. Since 1955, independence from Western powers through the exchange of resources, technologies and knowledge between developing countries has been a clear ambition (Seng Tan & Acharya, 2008). The formation of what is known as 'South-south cooperation' (SSC) can be traced to the Bandung Conference, which has been widely acknowledged as the starting point of alternative aid mechanisms beyond those of the Global North (Gosovic, 2016). In the late 1970s, the United Nations launched the SSC Unit in order to promote Global South trade and development in coordination with UN agencies such as the UN Commission on Trade and Development (UNCTAD). However, the advent of neoliberalism in the 1980s, together with the international debt crises accumulated by developing nations, meant southern countries' efforts were overshadowed by the rising hegemony of the Organisation for Economic Cooperation and Development (OECD). The geopolitical affirmation of northern powers affect development-cooperation architectures to this day, especially in matters related to research and innovation, and technology development and transfer (Zhou, 2019). Furthermore, the UNCTAD, initially in support of restructuring global patent systems, stopped such restructuration and adopted a northern preference towards privatisation (Abdel-Latif, 2015). Since then, the discourse has been divisive around International Patents Protections (IPPs) and is ruled by the World Intellectual Property Organisation (WIPO) and the General Agreement on Tariffs and Trade (GATT) to ensure the control over the flows of technological and knowledge transfer from northern countries to developing countries (Gray & Gills, 2016). Such measures have had a significant knock-on effect on the World Trade Organisation (WTO), which gained force in regulating the flows of knowledge and technologies, securing and increasing the monetary value of knowledge. As a result, the idea of a southern stream of cooperation on matters related to knowledge and technology only started to carry weight in international development at the end of the 1990s.

The decade of 1990 marked a maturation process in the coordination of global responses to aid. Since then, new forms of development-cooperation have emerged and, albeit slowly and with difficulty, are now scaling up to become increasingly relevant in technological transfer, innovation, and environmental governance (Bry, 2017). For example, an important turn in the discourse of technology transfer institutions regains strength after the Copenhagen Accords (2009) with the establishment of the Technology Mechanism to open a dedicated channel for technology-based cooperation between the Global South and the Global North under the UNFCCC. As the thesis expands, the Technology Mechanism establishment has not been free from underlying tensions between equity-based redistribution claims of intellectual property rights and neoliberal approaches that have consolidated market-based cooperation of technology transfer from the outset. (McGee & Wenta, 2014). The role of intellectual property regimes and international development in the context of climate change and policy has been a source of deep controversy and disagreement, particularly on matters related to knowledge and technology transfer under the UNFCCC (Abdel-Latif, 2015). The retention and control of technical knowledge has been used as a powerful mechanism leveraged against one of the most pressing barriers to long-term financial commitments to technology-based international cooperation: 'ownership'.

Another important point of controversy with regards to Official Development Assistance (ODA) models of support 'from north to south' is the resilience of control-based models aided by Information and Communication Technology (ICT) (Campo et al., 2017; Khodamoradi & Abedi, 2011). The spread of knowledge-based organisations in the past fifteen years is accelerating (Patt, 2017; Diane Stone, 2002; Tödtling et al., 2012). This includes the emergence of myriad forms of global networks in the form of partnerships in the academic, public, and private sectors (Rennkamp & Boulle, 2017; Seguin et al., 2006; D. Stone & Maxwell, 2005; Utting & Zammit, 2009). At first glance this could be seen as a good sign of technological conditions enhancing cooperation. However, in the case of international development agencies, there are unresolved tensions around whether institutional systems are prepared to govern technologies and resources in ways that will be conducive to effective climate action. Despite the many technological and managerial innovations in the use of ICTs, several unresolved issues point to the social dimension of technological systems (Bijker et al., 2012) given the increasing fragmentation of global environmental governance (van Asselt 2013). In particular, it remains to be seen how existing knowledge, technologies and resources can bring a plurality of solutions to collective action problems (Cornell et al., 2013; Gerritsen, Stuiver, & Termeer, 2013; Ostrom, 2010)—and in a way that supports global climate governance's capacity to change business as usual.

1.2.3 Concerning Knowledge and Environmental Governance

1.2.3.1 Pragmatic Accounts of Knowledge and Expertise

In epistemology, there are continuous discussions about the nature of knowledge and the conditions for what counts—and does not count—as truth and justification (Habermas, 2003). We do not have firm answers to these questions (Kitcher, 2012). However, if knowledge is a combination of facts, information and skills acquired through experience or education, then in a philosophical sense it refers to truth and justified forms of belief, rather than mere opinions.[3] In particular, valuable questions about how the processes of discovery and transmission of knowledge is ultimately applicable in the contemporary world to solve problems (Kitcher 2012) is of particular importance in this research. As John Dewey emphasised: *"Man has never had such a varied body of knowledge in his possession before, and probably never before has [he] been so uncertain and perplexed as to what [his] knowledge means, what it points to, in action and consequences"* (Dewey, 1929/1960. P.313). It then follows that the search for knowledge has important 'practical bearings' (Peirce, 1992).

Pragmatism acknowledges the possibility and importance of diverse forms of inquiry, which are not independent of all justification and thus should correspond with reality (Putnam 2012). Pragmatism seeks to understand the practical consequences of accepting ideas or propositions as true when they appear to work satisfactorily. It then may be presented as a way of clarifying epistemological disputes concerning theories and models and to judge them primarily by their consequences (Lipscomb, 2011). The extent to which a theory or model works is informed by the possibility that it will eventually have to be replaced by another theory that works better. A variation of this thinking can be found in Popper's falsification methods applied in his philosophy of science: the idea that theories may still be rationally accepted provided repeated attempts to falsify them have failed (Popper, 2002). However, from a pragmatist perspective, the utility of a theory is a matter of its problem-solving ability to address tensions between, for example, knowledge and power or between democracy and expertise (Wolfe, 2012). Therefore, pragmatism is about solving problems of philosophy as it is about solving problems of people and hence applying a critical lens when examining the practical bearings of knowledge. Furthermore, critical pragmatism holds that sometimes experience that should be perceived as unsatisfactory is not recognised as problematic. This is most common where power is unequal and when

[3] From Stanford Online Encyclopaedia of Philosophy, 2019: https://plato.stanford.edu/entries/epistemology/#WhatKnow

dominant interests tend to control information, communications and knowledge (Feinberg, 2015). Consequently, a critical pragmatism enables the study of powers relations in knowledge production and knowledge use. It is thus on the lookout for systemic "silences" or distortions in communications (Habermas 1971). Critical pragmatism can then become a valuable approach to the study of expertise and decision-making in environmental governance and understand the consequences of knowledge claims and directionality of change proposed by those who claim expertise.

The importance of knowledge in this thesis draws from a critical pragmatism that focuses on researching particular practically formed understanding of knowledge use––of 'expertise'. It does so in specific interconnected and formal contexts of sustainability policy and practice. Expertise is defined as a combination of substantive possession of skill or knowledge in one or more fields, resulting from the acquisition of knowledge through socialisation processes. Such proficiency is the result of the historical division of epistemic labour (Kitcher 2012). Experts may acquire tacit substantive knowledge individually, but there is also a relational element to it; expertise is socially constructed. This posed an inherent tension between formal accreditation and real substantive knowledge. The former being the result of training and evaluations, for instance, in a university. While the latter represents the social process itself and the contextual conditions that render such knowledge demonstrably real––by applying and demonstrating such expertise to solve real-world practical problems. Therefore, expertise is much about substantive knowledge about the social contexts in which a specialised level of knowledge or skill is applied to particular problem domains. Experts continuously develop skills to understand particular phenomena, as well as tools to validate their knowledge claims.

This thesis looks at global institutional contexts in which expert knowledge maybe be seen as authoritative and grounded in the practice of environmental governance. For its normative grounds, this work claims that greater capacities——to deal with existing systems of knowing—are needed to support scientific and technological innovation in meeting critical social and environmental challenges. Consequently, it seeks to understand the practice of expertise as inseparable from the agency within it (Wolfe, 2012). Since pragmatism focuses on the fallibilism of knowledge and values; propositions concerning empirical knowledge can be accepted, even though when they cannot be proved with definitive certainty (Putnam 1995). Therefore, a pragmatic account of expert knowledge considers the meaning of practices and the meaning of uncertainty and ignorance (Petersen 2014). In this context, it is important to rethink the assumptions of 'those who know', and study the socialisation involved in the process of making expert judgements and claims (Collins and Evans 2007). Thus, the concept of 'expert knowledge' is applied to analyse the conditions in which particular knowledge counts as justifiable expertise in science-policy spaces which attempt to govern sustainability problems.

1.2.3.2 Knowledge Governance in Sustainability

Sustainability debates stressed the critical importance of 'governing knowledge' in order to pursue global sustainable development (van Kerkhoff 2013). However, the social construction of knowledge about sustainability is complex, uneven, and contested (Demeritt et al., 2011; Ely et al., 2013; Escobar, 2011; Kagan, 2010; Leach et al., 2012; Ponte & Cheyns, 2013; Shiroyama et al., 2012; Sovacool & Bulan, 2013). Every piece of information, fact and skill acquired through education and experience reveals an understanding of natural and social phenomena based on a plurality of knowledges embedded in multicultural systems (Goodenough, 1976). As a result of the diversity of worldviews that exist, the development of knowledge and its associated tools and technologies are never value-free or neutral. The production and use of artefacts encompass wider social, cultural, moral and political processes (Crewe & Axelby, 2013; Latour, 1987, 2005). For example, it is not unusual to encounter situations where experts 'perform authoritative advice' on policy issues (Hilgartner, 2000); and assume that 'rational' and 'evidence-based' expertise are the best alternative to contestable policy problems (Stirling, 2010). Another example pertaining to sustainable development research is the common contrast between what is assumed to be 'universally applicable' science as opposed to 'other' traditional forms of knowledge (Sillitoe, 1998). As recognised in the anthropology of development, ways of knowing may be stratified, contested, unbalanced, biased, and bound by judgments, gender, class, age, physical spaces, and time (Crewe & Axelby, 2013; Demeritt et al., 2011; Descola, 2005; Fabian, 2014; Haraway, 1988; E. Wolf, 1999; E R Wolf, 1982). Hence, all forms of knowledge production and their uses respond to wider social, cultural and political frameworks. However, this is seldom recognised in confined spaces of expert policy and practice. And as such, these spaces tend to neglect the intrinsic plural and conditional nature of knowledge (Cornell et al., 2013; Stirling, 2008). Thus there is a need to challenge technical rationality with critical attention to the negotiated character of knowledge in policy settings (W.C. Clark, Van Kerkhoff, et al., 2016; Jasanoff, 1994, 2004; Jasanoff & Kim, 2015; Owens, 2015).

In “Some Social Implications of Modern Technology”, Herbert Marcuse refers to technical rationality or technological rationality as the dichotomy of rational instrumentation being used as the primary source to develop technological advances and solve problems, while on the other hand subsuming other rationalities which do not apply rational instrumentation (Marcuse & Kellner, ((1941) 1998). Technical rationality then risks becoming all-encompassing and attempt to replace or dominate different political and social reasonings. In the case of expertise, Bruno Latour suggests that engineers and scientists build systems of knowledge and cultures of expertise by institutionalising the way knowledge is produced and mobilised toward specific outcomes (Latour, 1987). However, this apparently ‘normal’ scientific knowledge production is in reality the result of a particular ‘linear’ vision of progress that can be traced back to the 18th-century enlightenment, and which has accumulated and become authoritative knowledge and practical wisdom (Funtowicz & Ravetz, 1993). Consequently, there is a solid basis to claims that scientific knowledge is the product of context-specific socialisation and cannot escape social and political dimension, even though particular communities of experts may attempt to reproduce technical rationality and reinforce these through technologies and materials. Consequently, the generation of cultures of expertise, as Latour suggests, results from socially constructed spaces of specialisation. Thus, the process of knowledge production and its epistemic and political qualities are also the product of complex relations, for instance, between time, people, materials and context. In science and technology studies, there is a social process known as “black boxing”, which is based on Bruno Latour’s definition that black boxing is the way scientific and technical work is made invisible by its success (Latour, 1999, p. 304). And the process that follows is opening the black box, or attempting to understand the complex internal workings of a given system (Bijker et al., 2012). Such systems are the result of complex phenomena that requires to open up in order to understand their internal dynamics. Similarly, in the context of sustainable development ‘expertise’, it is important to pay attention to the relationship between knowledge and power and the interaction of politics and culture in the production and evaluation of different knowledges and technological trajectories (Stirling, 2008). These dynamics are not to be assumed as open and require to empirically make links for example between knowledge production processes and policy development. This is not only because context is more complex as it spins off national boundaries, but because environmental problems such as climate change are indeed of global scale and require understanding how issues of power, authority and hegemony apply in a much more distributed and fragmented way across such boundaries.

Even more so, when Western technical rationality becomes the dominant discourse among practitioners of sustainability. It is not uncommon to encounter contested situations where claims of objective neutrality often disguise political agendas and hegemony in a globalised knowledge economy where unequal and competitive worlds impose power dynamics which shape discourse and practice (Gramsci 1971). And such discourses, rather than integrate visions, tend to exclude alternative ways of thinking (Fairhead & Leach, 2003; Ferguson, 1990; Rival, 2012; Stirling, 2008). In these circumstances, it appears that expertise in sustainable development tends to be measured and gain authority not necessarily according to its applicability or adequacy, but predominantly by the historical factors and social context from which it emerges (Crewe & Axelby, 2013).

1.2.3.3 Knowledge Boundaries, Boundary Objects and Boundary Organisations

The set of problems above requires to examine discussions about the boundaries of knowledge (Gieryn, 1999). In policy processes, knowledge has been observed to have a 'negotiated character' (Jasanoff 1990). At the core of this debate lies the idea that knowledge has intersections, such as those between science and policy. Therefore, why and how knowledge becomes salient in sustainability science–policy interfaces is of particular interest in this research. An important concept to clarify is that of epistemic communities. Epistemic communities are defined as scientific in composition and largely founded on codified forms of knowledge (Haas 1992). For example, professional consultants, researchers, and scientists share common policy ideas and seek privileged access to decision-making based on their expertise and scholarly knowledge. Consequently, epistemic communities can share normative values and beliefs that form the basis or rationale for their actions. Also, they share causal beliefs on professional judgements and similar criteria for validating knowledge. Finally, they share a joint policy enterprise or objective (Stone 2005).

Epistemic communities cohere around a preferred technical rationality and have a tendency towards technocratic policymaking (Stone 2005). There is an inherent tension between the negotiated character of knowledge with the socialisation conditions set by particular communities of experts based mostly on technical rationality. It is then the process of generating consensus––the negotiation between communities of expert that can potentially enable spaced for boundary work to occur (Gieryn 1995). Boundary work are the instances in which boundaries, demarcations and other divisions between field of knowledge are demarcated, made clear as well as integrated and managed in order to find common ground on problems which can have different interpretations. Boundary work requires to discuss and negotiate such boundaries. However, such negotiation spaces need to be created and cannot be assumed to happen. For example, Funtowicz and Ravetz (1993) refer to this process in post-normal conditions—in spaces where controversies exist, stakes are high, values are in dispute, and uncertainty abounds (Funtowicz & Ravetz, 1993). Cash et al. (2003) understood this to be a process by which different norms and expectations about the reliability of knowledge are addressed, arguments are made 'fair', and uncertainty is clearly characterised. Consequently, boundary work involves understanding the reasons as well as process of how knowledge is negotiated between different actors; more specifically, how knowledge generates 'saliency, credibility, and legitimacy' in the case of science-policy interfaces (Cash et al. 2003). Thus, boundary work is a sort of vehicle through which different perspectives are exchanged and boundary objects are produced. Guston (2001). A boundary object is said to represent information which can be interpreted and used in different ways when scientific work is heterogeneous and involves different actors and viewpoints (Star & Griesemer, 1989).

Boundary objects are defined here as being flexible documentation that can be interpreted differently across communities of scholars or practitioners but with enough scaffolding to maintain its original message. Boundary objects in the context of climate policy are policy documentation, guides, frameworks and assessments which allow coordination and some level of consensus––one that is likely to evolve and change as more discussions and refinements continue to shape such boundary objects. For instance, Kimble et al. 2010 refers to boundary objects as strategic documents which set the conditions to balance actors involvement in sharing knowledge in the context of innovation policy at the same time than playing a political interplay of controlling actors activities (Kimble et al., 2010). Furthermore, boundary objects can also become artefacts that reside in the interfaces between organisations and groups of people and the means to build bridges to facilitate cooperation and understanding among different groups (Huvila et al., 2014). There are caveats to understanding the function of boundary objects without considering their context, political, social and situated dimensions, which play a role in determining their composition. In the context of this PhD, the UNFCCC negotiation documents represent good examples of boundary objects to be analysed: for instance, the Technology Needs Assessments, the Technology Framework which guides technology transfer and the Paris Agreement itself. All these are appropriate examples used in the context of this PhD research.

Aligned to the rational of boundaries is the concept of 'boundary organisations' which helps explain how the process of knowledge sharing becomes institutionalised (Guston, 2001).

This is of particular relevance, as international organisations often have to negotiate, produce and use boundary objects. Boundary organisations are dedicated or invest a significant part of their activities in research and knowledge integration and serve the function of sharing and communicating relevant knowledge to specific audiences to generate such bridges, for example, across the science-policy interface. In this context, science advice is understood to be a process that helps structure and institutionalise instances through which governments and politicians consider the voice of science, technology, and innovation as essential input and knowledge necessary to develop better-informed policy decision-making. Science advice forms a crucial building block of environmental governance. In particular, organisations such as the IPCC and the CTCN represent boundary organisations that carry out science advisory roles to governments and science diplomacy in the context of intergovernmental policy discussions. Science diplomacy uses scientific collaborations among nations to address common problems and build constructive international partnerships. For example, The IPCC reports are institutionalised at the boundaries of science and policy. They are used to communicate and guide decision-making using the evidence and scientific consensus on climate change inside the United Nations. Another example analysed in this PhD research is the Subsidiary Body for Scientific and Technological Advice (SBSTA) function as a boundary organisation. The lens would be on mapping and analysing why and how organisations deal with particular assessments and frameworks and examine the scientific adequacy of knowledge production in light of stakeholders' divergent positions regarding contested climate policy negotiations inside the UNFCCC process.

1.2.3.4 Scientific Advice on Global Complex Phenomena

On many occasions today, science cannot always provide expertise——delivering "truth to power"—at the speed of politics (Collins & Evans, 2007). The production of scientific advice as a practice in boundary organisation is fundamentally changing due to increasing connectivity and the practically unstoppable growth of Information and Communication Technologies (ICT) and what some now call the "Internet of Everything" (Nilanjan, 2019). This rapid development in information technology is coupled with radical re-evaluations and redefinitions of environmental problems, including the way global challenges are understood and addressed (Disco, 2002). The proliferation of complex problems signals the need to address the increasing uncertainty inherent in future sustainability policy and practice (Sardar, 2010). There is a need to rethink our epistemic traditions as well as our governance practices, which are still largely based on assumptions of knowability, causality, and predictability; there is a need to 'keep it complex' (Stirling, 2010). Further questions arise about how science and technology are balanced against the public good (Petersen, 2012; Lorrae van Kerkhoff, 2013). Further, it questions how to make expertise more accountable to the public, as well as more useful in delivering substantive change. There is a need for new forms of knowledge that are more open, democratic, and integrative when planning and governing sustainability (Cornell et al., 2013; King, 2011; Stirling, 2014).

Today, the increasingly interconnected spaces where expert knowledge meets environmental governance challenge the idea that sustainability problems can be addressed by looking at national boundaries or national expert groups. The interconnected spaces of global environmental governance (Gupta et al., 2012) require a network approach—an interconnected analytical understanding of globalised political spaces and international institutions permeating different levels of action in sustainability. Furthermore, a critical stance is necessary when analysing the reasons and means through which experts confront the rapid changes imposed by highly interconnected spaces of power affecting the environment (Bierman & Pattberg 2012). For the practical purpose of conducting research, this thesis defines global environmental governance as the combined efforts of international environmental regimes where expert networks attempt to steer change towards sustainability. Consequently, it does not deal specifically with localised environmental governance at a community level, as this requires a different level of granularity beyond the scope of this thesis. The next section focuses on discussing the emergence of global knowledge networks as a subject of study and their linkages to the study of futures and uncertainty.

1.2.4 Global Knowledge Networks, Futures, and Uncertainty

Global networks are increasingly associated with the rapid mobilisation of expert knowledge, and collaborative networked capability is arguably a significant contributor to organisational performance (Arkadani et al. 2019). In this context, global governance scholars have studied the interlinkages between knowledge and governance for many years and the formation of global governance systems (Haas, 1992; Zürn, 2018). Their work has shown that knowledge is central in the exercise of authority in global governance systems, which required that experts and expert networks develop to influence and shape policy. However, there is much to learn about how international organisations build capacity to legitimise policies over time and how they shape and use networks in a fragmented environmental governance context (van Asselt, 2013).

Three key factors have increased communication mechanisms over the past decades: The development of ICT, advances in transport infrastructure, and the emergence of global knowledge networks in their various forms, including global policy networks (Betsill et al., 2014; Haas, 1992; Stone & Maxwell, 2005), scientific networks, and networks of experts (Gupta et al., 2012) and public and private arrangements (Ottaway, 2001; Wadell, 2011). This phenomenon has been conceptualised in the literature as 'global knowledge networks' (Stone, 2003, 2008).

Global knowledge networks are defined as arrangements that incorporate professional bodies, academic and research groups and scientific communities more broadly around specific subject matters and policy issues. The individual or institutional inclusion in global knowledge networks is based upon professional and or official recognition of expertise, policy relevance and scientific credibility. The primary motivation behind such networks' formation is to inform policy and apply changes to practices around particular problems. Diane Stone identify two broad functions: the transnational communication and dissemination of knowledge and second, the translatory role between epistemic boundaries (Stone 2008). However, I argue that globalised spaces where knowledge networks form, and act today are much more complex and dynamic and need greater understanding about why and how their increasing interconnectedness generates complexity and ungoverned spaces between the sites of knowledge production and the sites of knowledge application. Traditional models of governance architecture are challenged by rapid technological developments in information and communication technologies with unprecedented impacts in the way global knowledge networks operate and manage their knowledge in systemic ways and across spatial, epistemic and normative boundaries. For this purpose, this research interrogates the concept of 'networked organisations' as a heuristic to refer to temporal conditions that happen when: *"a variety of autonomous organisations, geographically distributed and heterogeneous in terms of their operative environment, culture, social capital and business goals collaborate to achieve common or compatible goals better, and these interactions are supported by computer networks"* (Camarinha-Matos and Afsarmanesh 2005a). Networked organisations—in the plural—form interconnected systems of knowledge that are formally interrelated for a period of time and with a common set of objectives.

In the context of global knowledge networks and networked organisations, future studies have given little attention to how communities of experts working at transnational levels, and their tools (e.g. technologies and policies) influence environmental governance in different parts of the world. Moreover, there is not enough empirical research about how global knowledge networks operating as global policy networks (Stone 2013), deal with uncertainty in environmental governance—particularly with deep uncertainties. In 'futures' studies, the concept of expertise and the practice of policy analysis are commonly associated with 'foresight' (Sardar, 2010) and 'anticipatory governance' (Fuerth & Faber, 2012), that is, the capacity to envision, imagine, evaluate and strategically respond to anticipated events (Boston, 2017). Environmental governance requires planning for and anticipation of possible futures—practices swamped with uncertainties under post-normal science conditions and in complex systems (Funtowicz & Ravetz, 1994; Young 2017). These conditions underly the rise of global knowledge networks attempting to govern environmental problems. Global knowledge networks are diverse, with changing functioning dynamics around negotiation, mobilisation, and use of expertise. These phenomena are understudied and require further empirical research.

This thesis investigated understudied formal network arrangements and refers to global knowledge networks to address intergovernmental efforts of incorporating a range of expert domains, including scientific knowledge, engineering and public policy, which are applied in global knowledge networks in the form of global policy networks to mobilise resources, implement technology transfer projects, and carry out environmental planning. Consequently, my approach focuses on the tools (e.g. modelling technologies) and techniques (e.g. institutional operations, data interpretation, knowledge management, and scenario planning) that together constitute expertise in anticipatory governance (Guston, 2014) which is applied through global knowledge networks. For example, modelling technologies combined with expert knowledge not only support the forecasting of immediate variability in climate and hydrological systems, but also generate foresight for informed environmental planning (Vermeulen et al., 2013). Thus, the use of technologies, along with expertise, can generate performative actions of authoritative knowledge, steering possible futures, imagining potential for change, evaluating assumptions, and experimenting with new approaches (Vervoort & Gupta, 2018). The rapid expansion of connectivity affects the development and mobilisation of networked organisations (Scheel, 2002). This development results in active networks with central organisations (an indicator of strategic behaviour and influence), and other organisations that remain more marginal. This thesis argues that closer examination of both the global patterns of network structures and the relational setting of ties between organisations through the use of tools and techniques allows us to better distinguish different strategies used by organisations to gain influence, which in turn is used to build capacity in anticipatory governance.

1.2.4.1 How this study approaches uncertainty

The concept of uncertainty holds different meanings depending on the field of inquiry and the particular disciplinary expert's approach and mental model of the world. For instance, the physical sciences, engineering, statistics, economics, and philosophy will all have their specific scope of problem areas, theories and methods regarding uncertainty (Petersen, 2012). In the context of policy analysis, integrated assessments and risk assessments, there is neither a common terminology nor full agreement on a typology of uncertainty. I use the following general definition of uncertainty as being "*any deviation from the unachievable ideal of complete deterministic knowledge*" (Walker et al., 2003, p. 3). Hence, uncertainty refers to a state of knowledge, not simply to the absence of knowledge. Funtowicz and Ravetz describe uncertainty as a situation of inadequate information, which may reflect inexactness, unreliability and ignorance (Funtowicz & Ravetz, 1993). In fact, situations in which there is abundant information can prove to be uncertain, as new knowledge about a problem can reveal uncertainties that were previously unknown.

In the context of environmental governance under 'post-normal' conditions (Funtowicz and Ravetz 1990), experts are often asked to provide assessments that support decision makers to understand climate policy problems and evaluate potential courses of action and cooperation (von Krauss et al., 2005). In this respect, there are important interlinkages between uncertainty and cooperation. The literature, for instance, suggest that uncertainty tends to destabilise cooperation and may hinder collective action with regards to climate change (Raihani & Aitken, 2011). Uncertainties of GHG emissions and global climate patterns, probabilities of significant temperature increase and complex underlying complex physical and socio-economic and political processes have profound implication for organisations propensity to cooperate. To provide better direction to the management of uncertainties, environmental agencies may provide classification systems with which to map, evaluate and communicate uncertainties. For example, the Guidance for Uncertainty Assessment and Communication (2012) identifies Six dimensions of uncertainty: location uncertainty, nature uncertainty, range uncertainty, recognised ignorance, methodological uncertainty and value diversity. For example, location uncertainty refers to where uncertainties may manifest among the elements of an expert's practice, for example, in a computer simulation (Petersen, 2012). Nature uncertainty expresses whether uncertainty is a consequence of incomplete 'fallibilistic' knowledge, which is named 'epistemic uncertainty', or when is due to the system being studied (ontic uncertainty). Range uncertainty refers to two primary sources: statistical and qualitative; the latter also known as 'scenario uncertainty.' In particular, deep uncertainties which cannot be expressed statistically can still be conveyed in range, that is, the terms of a range of plausible futures or events under 'what-if' statements. Recognised ignorance occurs when there is an acknowledgement about uncertainties that cannot be estimated due to the lack of knowability or due to unknown emergent properties, as in complex systems (Petersen et al., 2012).

This PhD thesis focuses particularly on issues of 'value diversity' as an important dimension of uncertainty in environmental decision-making. Value diversity refers to uncertainties present in general epistemic values, discipline-bound epistemic values, and non-epistemic 'normative' ideas such as socio-political principles (Petersen et al., 2012). The 'value' dimension of uncertainty denotes assumptions that can be present, for example, in the choice's experts make—consciously or unconsciously—and which carry a subjective component possibly influenced by culture, ethics, and worldviews. Its distinctive feature is value-leaden assumptions, which can be branded as 'bias' when present in other dimensions of uncertainty. Groups of experts may make value-laden choices at any stage of a research or policy process and in giving scientific advice. For instance, many policymakers consider 'good policies' to be those developed with the best knowledge available. They use authoritative discourse to increase the credibility of a policy, while ignoring underlying assumptions about a problem domain (Thissen & Walker, 2013). As a result, policy elites often strategically make 'scientific' claims to lend their values and political agendas more credibility, which has led to the 'scientisation' of politics and the politicisation of science

(Heazle, 2010). In environmental governance, the 'scientisation' of politics can act as an enabler of, as well as a barrier to, consensus and the development of legitimised policies.

Visions between science-policy and decision-making can be typically identified as 'modern' or as 'precautionary' (von Krauss et al., 2005). The former represents positivism and the logic of objectivity, whereby technocratic control over events is assumed to be possible. The latter accounts for complexity and uncertainty as inherent elements, some of which are manageable, while others are not (Saltelli & Funtowicz, 2014). When the uncertainties are irreducible, the proposed strategy is to emphasize caution and consideration before making decisions (Read & O'Riordan, 2017). For these reasons, science-policy practitioners play a crucial role in highlighting the unknowns when trying to govern environmental futures. For example, a fundamental piece of the IPCC's work has been to develop a criterion to assess the quality of knowledge on climate change. 'Uncertainty qualifiers' help experts to understand how scientific claims are established and what level of confidence can be attributed to such findings (Kouw & Petersen, 2018). However, in contrast to this rigorous practice, some decision makers tend to dislike uncertainties. They often argue that the 'analytical services' provided by policy experts should aim at reducing or removing uncertainty so that an 'optimal solution' can be achieved (Thissen and Walker 2013). This tension further highlights how instrumental rationality attempts to 'reduce the unknowns to measurable risk', which often enforces a narrow focus and bounded rationality on complex problems (Stirling, 2010). In addition, decision makers sometimes ignore uncertainties and employ bias judgement instead, which can have disastrous consequences. For that very reason, taking uncertainty into account is central—if not essential—to every policy process if we are to build realistic and attentive pathways toward robust policies.

For practical purposes, this study explores **signals of uncertainty**––defined by the context and situations when limited knowledge about the future, past or current events unfold in the science-policy process. It is, therefore, a heuristic that seek to identify the underlying assumptions of policy actors involved in negotiating, mobilising and utilising expertise in matters relating to environmental governance. In science-policy practice related to sustainability, it is crucial to understand the different types of uncertainties and their sources. For example, there are many unknowns about the magnitude of climate change or what it might mean in specific contexts (Lewandowsky et al., 2014). The future impacts of climate change are not equally distributed geographically and socioeconomically. For instance, densely populated deltas in Bangladesh, Thailand, Myanmar and the Netherlands have relatively similar hydrological conditions: they are embedded in river deltas, landforms created by sediment deposits carried by rivers when the water flow slows or stagnates as it enters an ocean or sea (Nicholls et al., 2020). However, their cultural practices, socio-economic and political conditions are very different. Consequently, the solutions to future challenges posed by rising sea levels and storm surges are not the same in every context. These are complex socio-technical-environmental systems (Patterson et al., 2017) with different future implications for decision making in the context of climate change. However, in some policy contexts, scientific uncertainty is often assumed to be a problem for the development of environmental policy (Shackley & Wynne, 1996). For instance, an inability to provide 'secure scientific knowledge' can be perceived as a problem for authority and credibility when experts are expected to provide evidence-based and salient policy (Kunseler et al., 2015). Especially in 'boundary work', scientific knowledge and its credibility can be identified as a signal of negotiated—and sometimes imposed—authoritative knowledge (Clark et al., 2016). This thesis argues that the different contexts and conditions through which knowledge is negotiated, mobilised and used tend to reshape representations of uncertainty.

For example, experts 'frame' climate negotiations under the UNFCCC as a scientific and political issue of 'equilibrium climate sensitivity' discussed by 'science diplomats' at the IPCC (Kouw & Petersen, 2018). The estimates of global mean temperature increasing between 1.5ºC and 4.5ºC relative to pre-industrial levels is an issue subject to continuous deliberations. In a sense, it is a political 'decision' that the world should be kept below 2ºC and that it should pursue efforts to limit global warming to 1.5ºC. However, these values are based on theoretical estimates, and are subject to uncertainty. Nevertheless, the political correctness of keeping the discussion about 'ambition' has fostered unresolvable disagreements amongst policymakers and scientists about the plausibility of a 1.5ºC world and how to achieve it. This is a signal of controversy, especially when technological 'fix' narratives abound (Hulme, 2014) . Furthermore, there are growing technical uncertainties and complexities around how to make international policy coordination work to deliver a 1.5ºC world—another reason for concern. Decision makers are often unfamiliar with the technicalities required to act cooperatively and with caution on environmental issues. Consequently, it comes as no surprise that after 25 years of 'climate deliberations', greenhouse gases continue to rise and the emissions gap is widening; the issue of coordination is not only essential, but also increasingly difficult.

Uncertainty prevails in policy making. In some cases, situations with abundant material and information available have proven to augment; more information can reduce as well as increase uncertainty (van Asselt 2002). Thus, the capacity to identify uncertainty is essential to every attempt to address it. This is very different from risk. Risk is the situation under which the outcomes of decisions and their probabilities can be known to the decision-maker. In this respect, research on decision-making under risk and uncertainty has two central angles, one that uses normative models and another that is descriptive.

Descriptive studies focus on how decision are made under risk and uncertainty, whereas normative approaches seek to understand how decisions should be made under risk and uncertainty (Francis Park & Shapira, 2017). Some uncertainties can be treated, and others cannot. Uncertainties that cannot be treated––and turned into risk via optimisation tools and 'predict-and-act' models are often characterised as uncertainties, and sometimes identified as 'deep uncertainties' (Lempert, et al., 2003). Deep uncertainties can be said to exist when parties to a decision do not know, or cannot agree on, the system model that relates actions to consequences (Marchau et al., 2019). Deep uncertainties are the most worrisome kind and are of particular interest when dealing with assumptions about future circumstances that involve the state of complex phenomena and the human factors that may affect decision-making under such circumstances. Descriptive studies of uncertainty are potentially well placed to expose normative models' weaknesses by describing people's judgment applied to decision-making and identifying signals of uncertainty and different perceptions of risk. Especially when emergent, unexpected situations occur and future circumstances are unknown. Taleb (2007) named these situations *black swans*, noting that they typically lead to deeper crises (e.g., 2007 subprime crisis and the 2020 COVID-19 virus pandemic). We know absolutely nothing about optimisation techniques for this type of situation. There are no 'most likely policy' prescriptions that promise certainty. In these cases, it is possible to imagine multiple plausible futures (Thissen & Walker, 2013). As the climate change planning horizon stretches toward the distant future, the nature of the policy problem changes in a significant qualitative manner.

Decision making over time—and in different cultural settings—illustrates the limits of predicting future physical and societal changes. The Anthropocene is characterised by large-scale human influence over the Earth System (Biermann et al., 2018a), as well as our current difficulties in solving global problems collectively (Galaz et al., 2018). Human activities and rapid technological development are changing the world system, yet in practice we still cannot coordinately direct change. In an era driven by informatics, options and social influences; the dynamics of collective decisions are becoming more uncertain.

What’s more, there is the risk of outsourcing decisions to technologies, which rely on copying and optimising recent popular decisions (Bentley & O’Brien, 2015).

The spread of knowledge practices from one context to another is empirically understudied. Different dimensions of uncertainty proliferate in policy processes involving global networks and communities of experts. The production of boundary objects and other sources of information can be traced and analysed. By searching for ‘signals’ in situations when limited knowledge about future, past, or current events unfolded in science-policy practice can help identify the travel of uncertainty. Consequently, these signals can be studied in the negotiation of knowledge, in the travel of rationalities, and in the mobilisation of bias. The parties that participate in a policymaking process may exhibit strategic behaviour in the pursuit of their own objectives, even if these objectives conflict with public interest or policy objectives (de Bruijn & Heuvelhof, 2018). In controversial and complex issues, impartial experts do not exist, and new solutions can indeed generate more problems or introduce more bias. In this approach, knowledge is little more than negotiated knowledge. Furthermore, we can study the practice of mobilising bias as a dimension of the exercise of power (Bachrach & Baratz, 1962). For the purpose of studying this phenomena, the concept of ‘traveling rationalities’ (Mosse, 2013) is particularly useful. The notion refers to the consensus of how expert judgment arises and gains authority across spaces of development and aid; Mosse explains it in the case of poverty. For example, experts may initially claim that locals do not know how to solve their problems and thus are poor; or worse, experts may employ consultation and narratives of ‘local ownership’ while implementing other agendas instead. Current development narratives across the international development community often claim to be self-reflective, suggesting that aid agencies no longer make intervention, but rather support the requisite conditions to empower beneficiaries of their programmes. However, how many of these narratives are applied in practice? The global consensus also supports the travelling rationale of ‘good governance’ and ‘accountability tools’, which are dependent upon the existence of certain institutional conditions. Hence, global policy thinkers will tend to transfer their rationality and promote their own theories of change for the contexts in which their agency wishes to intervene. Finally, global policy discourses of change are decontextualized from the expert communities that generate them. The implications and consequences of this carry through to the travelling rationalities building ‘capacity’ through networks. This topic requires further elucidation.

1.2.5 Capacity Building Through Formal and Relational Mechanisms

This study approaches the concept of capacity as both a formal and a relational property embedded in networked organisations. Following the IPCC categorisation in the context of climate change, adaptive capacity can be defined as the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences (IPCC, 2018b, p. 542). Following Wieczorek and Hekkert (2012), to express the attributes of specific components or relationships of innovation systems, terms like capacity, quality, or intensity can be used in both a positive and negative sense (Wieczorek & Hekkert, 2012). For instance, a network can be too intense or too weak, an institution can be too stringent or too weak (Larsen 2019).

The mobilisation of expertise across organisations involves overcoming the knowledge barriers between groups, which in turn enables such 'capacity' to develop (William C Clark et al., 2011; Lorrae van Kerkhoff, 2013). Such mobilisation requires patterns of interactions that include actors, technologies, and institutional settings. The concept of 'de facto governance' describes a process involving various types of actors that are not formally part of a governmental arrangement (Gupta & Möller, 2018). These actions affect collective outcomes. Hence, even when sources of governance may not intend to govern an event directly, they still generate a governing effect (Rip, 2010). The concept opens up methodological opportunities to triangulate and complement methods that bring actions and interactions into focus (e.g., multi-sited ethnography) with analytical methods that examine patterns demonstrating the existence of preceding actions and interaction (e.g. social network and policy analysis). This approach allows for distinguishing between formal and relational mechanisms. Formal mechanisms of governance are defined as organisational and legal features such as corporate ownership, structural design, and legally binding contracts (e.g. strategic alliances and joint ventures). Relational mechanisms, on the other hand, describe forms of governance that rely upon the social ties created by past actions and trust built from prior experiences between partners, constituting *de facto* governance practices. This research uses the concept of 'de facto governance' as a guiding heuristic for the analysis of the informal elements embedded in the activities of networked organisations. Relational mechanisms highlight the importance of interpersonal relations and trust across institutions—essential building blocks of collaborative platforms (Fischer, 2015). Formal and relational mechanisms can operate in a complementary fashion. As the study shows, social networks underpinning strategic behaviour can *de facto* influence the creation of new ties, but also affect the design, governance and consolidation of partnerships.

Relational mechanisms enable repeated interactions and expand spaces in which to govern the development of inferential capacity over time. Over time, such alliances allow for the actors to target strategic directions designed to maintain and sustain frequent interactions, generating governance effects on how expert knowledge develops and gains authority. A relational quality of trust over time enhances feasibility prospects and allows for ungoverned spaces to be governed not by shared norms, institutional arrangements and formal rules, but rather through strategic engagement and the continuous performance of expertise that links capacity with governance arrangements.

1.3 Sustainability Transformations: A Research Framework

Achieving substantial changes in sustainability policy and practice continues to be a challenge. The above literature review highlighted a set of interrelated problems regarding complex environmental issues, such as the persistent tendency to frame innovative solutions in terms of technical rationality and technological fixes. In particular, the literature points to the gaps between knowledge and action in areas of international development and cooperation on climate change. Hence, the debate centres on the problem of governing knowledge for sustainability, as, for instance, in the practice of 'expertise' in science-policy domains, or the boundary work conducted through formal global knowledge networks conducting anticipatory governance and advising. The literature review further highlights how the travelling of rationalities—and their associated uncertainties—is empirically understudied. Issues of power and politics require that researchers trace the tools and practices of those who claim expertise. In addition, global knowledge networks must be an object of analysis and assessment in order to determine how expertise is negotiated, mobilised and utilised in attempts to steer future sustainability policy and practice. Consequently, these interrelated problems serve as the optics through which to examine how these 'connected developments' unfold. Finally, if the literature review highlighted important concepts to be used as 'lenses', these lenses are then applied to a research framework—that of sustainability transformations.

1.3.1 The Study of Change and the Emergence of Systems Thinking

The study of social change is not new. The classical political economy theory developed by Karl Marx has long offered a paradigm through which to analyse historical tensions of labour, capital and technologies leading to social and economic revolutions (Marx, 1976). Similarly, the earlier conceptualisation of transformations emerged from the work of Karl Polanyi (1994) when he described the process of fundamental institutional changes creating new states and new economic relations (Polanyi 1944). His work has been inspirational to emergent economic thinking on degrowth and the politics of structural changes (Jackson, 2017; J. Martínez-Alier & Muradian, 2015; Joan Martínez-Alier et al., 2010). Structural perspectives of change have been seminal in analysing the historical and material conditions that give rise to social transformations. However, they are less applicable to future environmental sustainability. Structural perspectives offer rich past accounts, but often do not consider the role of agency and the potential of future-oriented research.

Currently, environmental governance continues debating whether to pursue incremental or more radical approaches to change (Gillard et al., 2016; O'Brien, 2012). Complex sustainability issues cannot rely solely on structural approaches, as they require attention to systemic dynamics and the governance of short-term futures while pursuing long-term responses to change (F. Biermann, Pattberg, & Zelli, 2014; Boston, 2017; Vervoort & Gupta, 2018). Systems thinking gained notoriety when Meadows (1989) emphasised that shared social paradigms carried deep assumptions about the nature of problems as unsystematic and based on a linear way of reasoning. These assumptions, in turn, produced linear-type answers, which in reality reinforced more and more persistent systemic problems such as environmental degradation, poverty, and conflict (Meadows, 1989). System dynamics appeared as one of the most popular analytical options for studying change and has been ever after. Systems reasoning acknowledges non-linearity, uncertainty and inherent complexity in systems interplays leading to change (Meadows, 2009).

1.3.2 Socio-ecological Systems and Socio-technical Systems

Two main frameworks have been developed based on systems theory: socio-ecological systems and socio-technical systems. **Socio-ecological systems** focus primarily on human-nature interactions based on problems of collective action (Ostrom, 1990), ecological studies of resilience (C. Folke, 2006; Carl Folke et al., 2010) , social ecology (Rival, 2006), and political ecology (Biersack, 1999; Forsyth, 2003; Kottak, 1999; Robbins, 2012; Eric R. Wolf, 1999). The latter has addressed issues of power dynamics in human-environment interactions, leading to the socio-political 'shift' in resilience studies (Brown, 2014). This framework had led to the study of transformations from a socio-ecological systems perspective (Leach et al., 2012; Olsson et al., 2014) under the umbrella of "planetary boundaries" (Galaz et al., 2012; Steffen et al., 2015) as the "safe operating space for humanity" (Rockström et al., 2009). On the other hand, another popular framework for studying change is **socio-technical systems**. Questions about the unknown drivers of change in social and technological interactions moved the field's focus toward the idea of technological 'transitions' involving complex social systems of technology, infrastructure, and industry (Geels, 2002). This framework has been widely used to study socio-technical transitions in sustainability, initially with the intention of managing technological change (Rip & Kemp, 1998), advancing to the practice of transition management (Loorbach & Rotmans, 2010), and finally applied to analyse innovation systems pursuing transitions to sustainable development (Geels, 2004; Geels and Schot, 2007; Grin, Rotmans and Schot, 2010; Anadon et al., 2016). Over the years, the concept of 'sustainability transitions' has commonly referred to processes of change, particularly from one system state to another via periods of non-linear disruptive change (Loorback et. al., 2017). Therefore, sustainability transitions research is a popular framework to explain dynamics such as path dependency and lock-in trajectories, as well as tracking opportunities for sectoral innovation. For example, this lens has been applied to the study of changes in transport systems, renewable energy, agriculture, and water (Clark, 2014). In particular, 'niche', 'regime' and 'landscape' make up a common lexicon in the transitions framework, with significant implications for the theory and practice of studies of change (Ravena et al., 2012).

Within academic research on technological change, the multilevel perspective (MLP) has become a widely cited theoretical framework for the study of socio-technical systems. The MLP recognises the interaction between people and technologies, and identifies three main dimensions: the niche level in which innovation occurs on a small scale; the regime level, involving the current practices; and the landscape level, representing long-term changes (Geels 2011). Accordingly, the socio-technical regime is the meso-level, where the existing large-scale systems of technologies operating in particular societies, such as transports, energy and water systems, are represented. The regime encompasses "cognitive routines", and a certain established technological trajectory incorporating not just a particular technological system, but also rules, regulations and normative roles (Schot & Geels, 2008). The macro-level known as socio-technical landscape represents the broader environment which transcends the direct influence of both the micro- and meso-levels. This level is commonly characterised by macroeconomics, cultural patterns and the macro-political setting (Geels & Schot, 2007). Actors at the niche level hope to introduce changes at the regime level, however this is by no means easy or straightforward, as the meso-level is engrained and locked into path dependency trajectories. Consequently, the main hypothesis behind the multi-level perspective is that sustainability transitions occur when niche-level actions have acquired sufficient momentum by that moment when changes at the landscape level start creating the necessary pressure in the regime, thus enabling a 'window of opportunity' for particular innovations to break through and produce a regime shift (Geels, 2002).

1.3.3 Critiques to the Transition Paradigm

Transitions research has been criticised for a lack of attention to the role of agency, as well as a sometimes overly optimistic focus on innovation in the management of complex socio-technical system dynamics (Geels, 2011). The interdependencies of systems should suggest the need for stronger empirical attention to the social dimensions of change, integration of socio-ecological views, and investigation of current assumptions about technological and institutional drivers. This research should give special attention to power dynamics and the politics of change (Meadowcroft, 2011). Further considerations include the issues of diversity and plurality in the study of transitions research (Stirling, 2011). More recently, the conceptual identification of 'transitions' and 'transformations' has become increasingly linked to the problem of governance (Patterson et al., 2017), although there is much to clarify, as the terms tend to be used as synonyms. On this last point, there have been interesting deliberations about the need to reconsolidate structural, systemic and enabling approaches (Scoones et al., 2020). Enabling approaches put a stronger emphasis on the agency and uncertainties present when negotiating—and sometimes imposing—directions and pathways for the future. To this end, transitions research should also be reflective, examining ethnocentric claims about technological change. What is assumed to be desirable sometimes depends on historically-bounded rationalities based on Western ideals of 'capacities' and 'institutions' with further assumptions that better management will ultimately lead to more equality and improved prosperity (Blythe et al., 2018; Shove & Walker, 2007). Finally, the urgency of large-scale transformations requires us to think deeply about the emergent properties of institutional systems that are pursuing narratives of change, and then evaluate the extent to which their agency, social innovation and governance dynamic are addressing these challenges. Emphasis on the social dynamics of change calls for new research strategies that consider the governance of present and future knowledge systems, investigating the very meaning of transformations.

1.4 Reconciling Perspectives and Practical Challenges

Researching transformations implies a diversity of conceptual foundations. It can be said that the study of transformations is inherently social, and thus should also pay attention to its political nature. Another condition should be stated at this point: The Anthropocene describes an era in which societies and the Earth System are undergoing significant transformations (Biermann et al., 2018a). These transformations are happening regardless of our ability to anticipate, adjust, or steer a normative pathway for a sustainable future. From this perspective, transformations toward sustainability are a positive aspiration full of practical challenges and sometimes contradictions (Blythe et al., 2018). Today, rapid and unprecedented change requires us to work collectively to find epistemic and normative configurations to build different futures where the word 'sustainability' is more than just an aspiration (Enserink et al., 2013). These challenges can also be seen as opportunities to imagine and 'transform' our societies, our economies, and our relationship with the environment in unprecedented ways (Jasanoff, 2010). However, the very notion of 'transformation' is full of caveats. What is transformation? What does it mean in practice? Transformation for whom, and by which means? Conceptually, transformations imply *"fundamental changes in structural, functional, relational and cognitive aspects of socio-technical-ecological systems that lead to new patterns of interactions and outcomes"* (Patterson et al., 2017).

This definition demands that we somewhat reconcile, put into dialogue and complement different analytical and normative lenses. For example, leading authors in transitions-transformations research recently came together to try and balance different approaches (Scoones et al., 2020). They offered complementary lenses to structural, systemic and enabling views. They illustrate that, *"structural, systemic and enabling approaches are thus complementary. Instrumental systemic change in policies and institutions can be enabling of social movements and novel alliances seeking to address sustainability challenges in diverse ways, and at the same time, to lay the ground for a reconfiguration of broader structures"* (Scoones et al., 2020, p. 5). While it is critical to take diverse knowledges, plurality and politics seriously, there is still a strong need to provide more empirical observation and analysis of the deep structural realities present and their tension with the realm of possibilities and aspirations. For example, some argue that the concept of transformation has high 'elasticity', and that there is a risk of rendering the term meaningless (Feola, 2015). The inherent vagueness and lack of empirical grounding of the concept of transformation could lead to its political nature be misused and confusion be opportunistically used against any genuine radical change. It is fundamental to question which systems of knowledge and contextual conditions inform transformational policies, particularly among formal policy networks steering sustainability pathways.

In sustainability policy, the challenge of articulating visions and negotiating knowledge boundaries across policy domains remains mostly unresolved. For example, in the broader policy landscape on climate change, the need for a 'paradigm shift' that effectively modify 'business as usual' has long been debated (Bracking, 2015). In this divergent perspective, continuous debates on whether to pursue incremental adjustments or more radical changes are common in environmental policy (Gillard et al., 2016; O'Brien, 2012). Further research is needed to empirically assess the human drivers of transformations in policy networks, as they are intertwined in complex relations between agencies, systems, and structures. Business as usual still reigns in international institutions promoting sustainable development and transformational change. Unsurprisingly, critical questions about how to generate transformational responses to climate change are high on the global political agenda, and more 'ambitious' also means addressing the collective climate action problems differently. In practice, however, this endeavour would necessitate broad scientific, political, and public participation in order to maximise the diversity of pathways leading to a sustainable future (Gudowsky & Peissl, 2016; Hebinck et al., 2018; Jasanoff, 2004; Jasanoff & Kim, 2015; Spruijt et al., 2014). In addition, transformational accounts are augmented by the sustained reliance on technological 'fixes', particularly with the rise of geoengineering, blockchain, artificial intelligence, and other so-called 'disruptive' technologies (Gupta & Möller, 2018; M. Hulme, 2009; Mike Hulme, 2014; Mazzucato, 2016; Reijers et al., 2016; Rose & Chilvers, 2018). The patterns in climate action continue to derive from a technocratic society. For these reasons, it is imperative to examine which strategies for anticipating institutional governance are being considered in planning collective climate responses. Finally, it is crucial to seriously explore tensions between binding, short-term 'smart' futures and 'wiser', long-term visions of change, reflecting on how future organisational design dimensions may help shape more realistic and transformative pathways for sustainability.

1.5 Research Questions

This thesis seeks to address the following research questions:

Main research question:

- *WHY AND HOW DO FORMAL GLOBAL KNOWLEDGE NETWORKS NEGOTIATE, MOBILISE AND USE TECHNOLOGIES AND EXPERTISE TO STEER FUTURE SUSTAINABILITY TRANSFORMATIONS?*

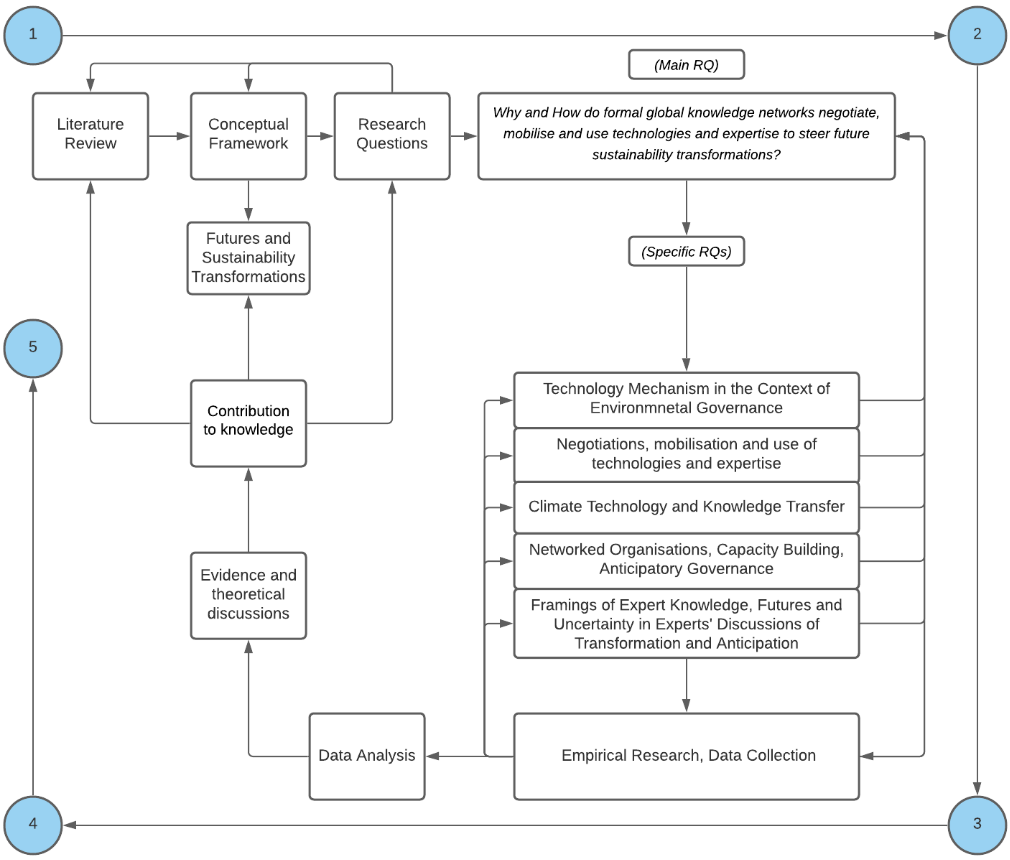
Specific research questions:

1. TO WHAT EXTENT CAN THE TECHNOLOGY MECHANISM UNDER THE UNFCCC BE ANALYSED AS A FORMAL GLOBAL KNOWLEDGE NETWORK IN THE CONTEXT OF ENVIRONMENTAL GOVERNANCE? (ALL)
2. HOW ARE TECHNOLOGIES AND EXPERTISE NEGOTIATED (CHAPTER 3), MOBILISED (CHAPTER 4) AND USED (CHAPTER 5) UNDER THE TECHNOLOGY MECHANISM?
3. HOW DO CLIMATE TECHNOLOGY AND KNOWLEDGE TRANSFER WORK UNDER THE UNFCCC? (CHAPTER 4).
4. HOW DO NETWORKED ORGANISATIONS BUILD CAPACITY FOR ANTICIPATORY GOVERNANCE THROUGH PROJECT-BASED INTERACTIONS? (CHAPTER 5)
5. WHICH FRAMINGS OF EXPERT KNOWLEDGE, FUTURES AND UNCERTAINTY FEATURE IN GLOBAL POLICY NETWORKS' DISCUSSIONS OF TRANSFORMATION AND ANTICIPATION? (CHAPTER 6)

1.6 Conceptual Map and Logical Syntax of Research Process

Figure 1 is a conceptual representation of the logical syntax of research, including inquiry in five steps. Step 1 contains the literature review leading to the development of a conceptual framework and research questions. Step 2 refers to developing the main research questions and articulation with specific research questions that inform each empirical chapter of the thesis. Step 3 indicates the process of empirical research and data collection (explained in detail in Chapter 2: Methodology) and the iterative loops between data collection, analysis and research questions. Step 4 is the process when the data is translated from analysis into evidence that informs theoretical discussions. Finally, step 5 represents the logic by which the evidence and theoretical discussions contribute knowledge by addressing the literature review's gaps, the thesis's conceptual framework, and the research questions.

Figure 1 Logical Syntax of Research Process



Source: Author, 2020

Chapter Two

Methodology: Combining Multi-sited Ethnography with Social Network Analysis and Policy Analysis

2.1 Research Design

To address the thesis's research questions and aims, I developed a research design following a mixed-methods approach drawing mainly from social anthropology, social network methods, and policy analysis. The design followed an epistemological position of pragmatism as argued in section 1.2.3.1 of the literature review: Pragmatic Accounts of Knowledge and Expertise. The research design also departs from the general interest in studying social practices, organisations and networks. This research applied an interdisciplinary focus to contexts, situations and actions which inform antecedent conditions. The situations of inquiry grounded the research strategy. They allowed me to engage with subjects and institutions during the earlier stages of the pilot phase and conduct systematic and participatory observation for over three years (2016-2019) at inter-organisational levels conceptualised in the literature broadly as global knowledge, in particular, global policy networks.

2.1.1 Introduction to methodological design

The study of social practices and institutions has spread widely in the social sciences and disciplines in organisation and management research. In this context, as the principal methods employed in anthropological studies, ethnography can widely be defined as the investigation and description of cultures and societies through fieldwork-based research. The ethnographic process that I utilise in this PhD thesis involved empirical research and immersion into institutional and inter-organisational networks settings.

2.1.1.1 The Study of Networks in Anthropology

While the study of patterns is not new to anthropology, it is essential to highlight some key contributions to the study of networks in anthropology. The early study of networks in anthropology was originally approached by Bronislaw Malinowski (1992) in his studies of the *Kula* Ring, the ceremonial ring of exchanges between different aboriginal communities across the islands of Papua New Guinea. Findings of reciprocity patterns and social ties are particularly relevant and have greatly influenced social theory and economics. Similarly, the work of Karl Polanyi (1968) and Marshal Sahlins (1972) are important reminders of how pre-capitalist societies were based on different social norms and institutions based on reciprocity and distribution as rulers of socio-economic life and deeply dependant on underlying social structures. Therefore, understanding social ties and social networks is important in analysing economic transactions, social relations, political ties and communication links within and between social systems. Schweizer (1997) work is also an important contribution to the study of networks in anthropology, for instance in using Freemans (1979) graph-theoretic models in the understanding of degree centrality and the role of gifts exchange in social networks (Schweizer, 1997). While the legacy of studies linking anthropology and network theory are relevant to this research, thus far, social network analysis and ethnographic approaches have not yet incorporated such methods into the study of complex organisational structures at global levels, for instance, on global environmental governance organisations and global knowledge networks.

Furthermore, while the study of interorganisational relations and their effects on organisations have been researched extensively, in-depth studies of whole networks are rare (Provan et al., 2007), and recent advancements of mixed methods design point to the need to integrate social network analyses with ethnographic methods in the study of modern organisations in what has been coined “network ethnography” (Berthod et al., 2017). The authors of this article proposed a research design that balances well established social network analysis with a set of techniques of organisational ethnography specifically to the study of inter-organisational networks. Network ethnography applies qualitative and quantitative research in a parallel fashion and seeks ‘convergence’ during data interpretation (Berthod et al., 2017). Social Network Analysis or SNA is a well-established analytical tool. The application of social network analysis to the study of interorganisational context, where many organisations interact, offers an overall, explicit view of networks attributes using quantitative measures of actor’s ties, density of relationships and clustering of tendencies (Borgatti et al., 2009; Wasserman, 1994). However, ethnography offers qualitative approaches to look at the process and mechanisms that explains structural properties of the so-called interorganisational networks under the “network ethnography” approach (Moynihan 2009 and Nicolini 2011).

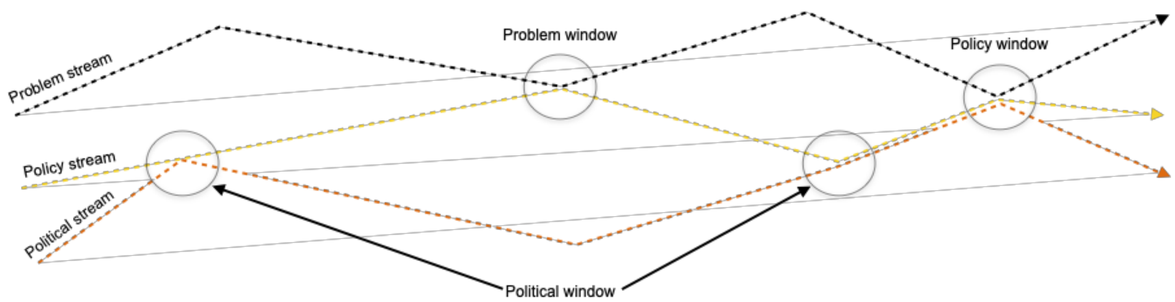
This PhD's ethnographic process is particular since it involved a more extensive "global" context on knowledge networks and their application across international organisations working on science and technology policy discussions on technology transfer and climate change. The context is, therefore, different from the study of communities in geographically bounded spaces. However, it does recognise that knowledge has a situated character that travels because of the development of networks and boundary organisations. The ethnographic process is closer to a combination of what Marcus (1995) refer to as multi-sited ethnography, combined with social network tools and policy analysis. It required empirical immersion into global knowledge networks and the process of establishing rapport with boundary organisations using qualitative techniques such as participant observation and open interviews and description (Robben and Sluka, 2015). While the use of SNA allows the research validation of networks formation across interinstitutional spaces, the application of multi-sited ethnographic methods enables the study of people, time and places and their multiple representations of knowledge and expertise in boundary organisations. As Donna Haraway has said, approaches to knowledge must recognise its situated and located character, which accounts for the position and contexts from which the researcher speaks (Haraway 1991, p.195). In particular, the research interrogated these spaces searching why and how particular forms of expert knowledge are negotiated, mobilised and applied to sustainability issues across global knowledge networks—recognising that the situated nature of knowledge requires reflection and consideration of the moral and ethical dimension of the research (see 2.3 Practical Implications and Ethics), and reflexivity and positionality (see 2.9 Reflexivity and Positionality).

2.1.1.2 My Approach to Policy Analysis

Critical Pragmatism largely informed my approach to policy analysis when looking at knowledge and expertise (See section 1.2.3 *Concerning Knowledge in Environmental Governance*). In particular, when studying complex issues related to climate change, futures and collective action problems, there is no business as usual in the 'normal sense'—although policy solutions might be framed as a response, a change to antecedent conditions (e.g. renewable energy policies that move away from fossil fuel regimes). In the case of complex, wicked problems, 'the usual' may also be an assumption; thus, the stability of a process not influenced by a "new" policy cannot be assumed, since policy problems may, in fact, also change fast, and no policy direction can be assumed to be right—nor what is assumed to be previously "stable" trajectories. However, business as usual may refer to persistent practices that seek to reinforce conditions, for example, in the case of technology development and transfer. However, global environmental changes are characterised by uncertainty and lack of understanding how to "best" solve complex problems when they emerge or endure over time---—partly because there is no "normal" in practice.

For this purpose, during the pilot phase, I examined policies and institutions as a process in boundary organisations. Kingdon's streams (1995) helped guide the initial analysis of technology-driven policy processes inside UNFCCC organisations with attention to how particular knowledge and policies are negotiated, mobilised and utilised. (e.g., the Convention Process, the Kyoto Protocol, Paris Agreement and the implementation of the Technology Mechanism).

Figure 2 Kingdon's Streams Model



Source: Author, adapted from Kingdon (1995)

Figure 2 shows a representation of Kingdon's policy model in terms of policy streams. Kingdon suggested that policy change comes about when three streams: problems, policies, and politics connect. Figure 2 shows that while the three streams may be functioning independently to one another, in order to for a policy to emerge, all three needs to come together. Each of the streams has its purpose and force. The policy model focuses on the importance of the timing and flow of policy actions. The streams do not meet only by mere chance, but rather because of policy advocates' consistent and sustained action. Figure 2 is a credible model to understand science-policy negotiations inside the United Nations Framework Convention of Climate Change. Climate policies emerge from perceived problems and acknowledgements of policymakers and other stakeholders' role in proposing policies and acting on policy options. Therefore, it is the policy process of advocacy, the agency of actors and institutions which build problem windows, political windows and policy windows to negotiate and mobilise momentum for policy change. For instance, such moments are the Conference of the Parties that happen each year, leading to the Kyoto Protocol's formation (1997) and the Paris Agreement (2015). Over a dynamic and complex process that takes years, science-policy advocates seek to introduce new agendas and negotiate decisions that can be successful in unsuccessfully implemented.

2.1.1.3 Linking Ethnographic Research in the Context of Policy Negotiations

In particular, ethnographic observations of the negotiation of policies served to inform my policy analysis by identifying the different dynamics between institutional structures, systems and agency and identify paradigms with techno-economic policies negotiated at the COP. These were analysed to identify systemic path-dependency in policy arguments and value-laden assumptions of the subjects of study and global knowledge networks' organisational characteristics. In the analysis, I look for constraints, decision-making contexts, and uncertainties in the communication of policies inside policy advisory committees and in the production of boundary objects (Page and Jenkins, 2005; Thissen and Walker, 2013). This methodological strategy allowed for the empirical mapping of unresolved tensions and followed experts narratives, the negotiation and production of boundary objects and artefacts. The approach to uncertainty (characterised in section 1.2.4.1 How this study approaches uncertainty) was a helpful heuristic method to trace epistemic and normative assumptions inside boundary organisations. The research strategy enabled tracing and analysing policy processes, combined with multi-sited ethnographic observations and social network analysis to converge, interpret and visualise network formations.

Consequently, I examined the processes and conditions through which tools (e.g. technologies), practices (e.g. policy making, technology transfer activities, risk management and environmental planning), representations and ways of dealing with climate change-related challenges (e.g. uncertainties) in formalised networked situations (GKNs). The methodology enabled the study of situations that attempt to bridge linkages between knowledge and action and practical research of structural, systemic and agency contexts seeking solutions to epistemic problems (Creswell 2009). Therefore, the methodology implied dealing directly with the subjects and objects of study and required a flexible inquiry approach. A mixed-methods approach served to give empirically grounded accounts of highly complex social, historical, political and cultural contexts influencing knowledge and technological developments.

The research applied a specific ethnographic inquiry mode: a multi-sited ethnography across global knowledge networks (see details in 2.2). The research involved observing and participating in global situations of ethnographic interaction. The contexts examined the practices of 'science and technology policy and navigated the 'anthropology of development' and the travel of knowledge and technologies through institutional systems in multiple locations in Europe and South-East Asia. Interdisciplinarity was suitable to investigate the role of 'globalised knowledge artefacts' and 'cultures of expertise'. In my framework, observing how knowledge and technologies are negotiated, deployed and use under the UN-systems and through project-based interactions made data available in innovative ways. For instance, data on knowledge interactions and across communities of practice organise and transfer knowledge, technologies, and the agency embedded in their artefacts and expertise. Through participant observation, I was able to see and identify and collect unique procedural data about the implementation of technology transfer projects under the Technology Mechanism. This mechanism is a unique socio-technical system, which through a formal global knowledge network, it has provided numerous functions, including policy advice and the implementation of technology projects. Therefore, it accounts as a fruitful object of study to follow and draw relevant case studies.

The research work was carried out between the United Kingdom, The Netherlands, Denmark, Germany, Spain and South East Asia. In particular, in Thailand, I connected with experts from Thailand, Myanmar and the rest of the region. Global Knowledge Networks are still bounded by context and spaces where knowledge management occurs (e.g., headquarters and operative offices). These spaces represented institutionalised knowledge systems that operate and implement climate-related technology transfer projects from Europe to developing countries. The research dedicated efforts to explaining the transfer operations' institutional contexts in recipient South East Asian nations and trace their source, usually located in Northern European nations. The Technology Mechanism's policy and network systems are articulated from Europe. Experts, policies and technology projects are mobilised in multiple directions across the globe. In particular, in contexts where the transfer occurs. Mobility and different contexts are also required to follow cases of what was coined in this research as "project-based interactions" as a notion that encapsulates organisations' relationships and agency, their formal agreements, and relational mechanisms. Also, I observed contexts of international expert meetings, high-level advisory boards, capacity building sessions, expert reports, climate policies, modelling technologies and procurement systems.

The research design aimed to develop a robust and innovative methodology that studied science-policy negotiations and followed the on-the-ground implementation of technology projects in various locations. Hence, the research looked at the Technology Mechanism under the UNFCCC and several case studies from its network. During the research process, numerous organisations were engaged, described, outlined and analysed with attention to North-South dynamics. Overall, my research aimed: to comprehend how global knowledge networks negotiate, mobilise and use technologies and expertise to steer future sustainability transformations.

2.2 Ethnographies of Global Knowledge Networks

Contemporary ethnographic settings call for the study of experimental research, with a focus on global as well as local interplays. From this perspective, ethnography has evolved towards an increasingly off-site projection that sees at the widespread social and cultural contexts of interconnectivity (Marcus, 1995). Ethnographies of 'global connections' (Tsing 2005), of 'travelling rationalities' (Mosse, 2013), 'accelerated change' (Eriksen, 2016), and of resilient 'techno-idealism' (Sims, 2017) require to look for innovative research strategies. Practising 'multi-sited ethnography' as the entry point through which inquire networked events provide a shift from the usual one-site location and open up rich contexts of mobility and change. An ethnography of GKNs allows contextualising the construction of larger social orders appropriately.

Multi-sited ethnographies include research and participation in settings that challenge traditional dichotomies between the global and the local (Marcus 1995). The development of multi-sited ethnography is based on the following a set of assumptions:

1. Social relations are increasingly stretched across transnational space.
2. There has been a continuous proliferation of transnational institutions and multi-level organisations.
3. There is a real acceleration of many social, political and economic processes due to globalisation and technology.

As some anthropologists have seen, a hastened contemporary world does not hold still long enough to be studied through extended immersion. Finally;

4. There is an increasing acceptance that subjects of ethnographic enquiry are also highly educated professionals that understand the specialised language of research (Coleman & Collins, 2007).

Therefore, this methodology thoroughly connects, establishes relations, and builds a context that renders a good sense of place and practice. It is important to clarify here the limits of this approach. It is to acknowledge that traditional ethnography has significant value and enables the researcher to produce other kinds of knowledge and comprehension that one obtains by the long-term immersion in a local community or context. The potentials and boundaries of each design are in relationship to the depth of representations made of a particular cultural reality. Implications include that the multi-sited methodology must value not just a shifting plurality of tactics involving experimentation but a different type of fieldwork that properly considers other sources of data, material and objects, for example, research and analysis of archives, government records and statistical reports. In this frame, nearly any other object has the potential to support the understanding of global connections (Coleman & Collins, 2007). In this particular case, the research unveils a particular cooperation network and examines these events from a real-world practical orientation by recognising and engaging with diverse specialists.

2.3 Practical Implications and Ethics

The research conducted for the PhD formed part of the ORA/ESRC funded project *Deltas' Dealings with Uncertainty: multiples practices and knowledges of delta governance* (DoUbT) from the Department of Science, Technology Engineering and Public Policy (STEaPP) at UCL and has been fully approved by the UCL Research Ethics Committee (UCL Ethics Project ID Number: 9265/001)[4] for the period July 2016 to July 2020. The ethics of the project (9265/001) and its amendments (2016, 2018 and 2019) were carefully followed through the different research stages, that is the piloting and research proposal, the research design, methodology, during fieldwork, data collection and during analysis; and by giving free, prior, informed consent and anonymisation of respondents to the best of my knowledge in compliance with the UCL Research Ethics Committee and the UCL Doctoral School through my involvement in the Doctoral Training Programme (DTP) provided by UCL STEaPP regarding the Research Integrity Framework, Ethics and Impact.

The DoUbT project merged science and technology (STS) studies with the anthropology of development to investigate how uncertainties are understood and dealt with in environmental planning in South-East Asian deltas (DoUbT 2016). These deltas, for instance, the Chao Phraya in Thailand, are active and densely populated environments, affected by intensive agricultural development, fast urbanisations and vulnerability to climate change. The project hypothesis informed my research: much delta knowledge used in the global south comes from epistemic communities, whose knowledge travels because of global development cooperation networks. Following the project's method of inquiry, empirically followed and mapped global knowledge networks, in this case, linked to the Technology Mechanism of the UNFCCC. The project's methodology was based on observations and semi-structured interviews following a snowball sampling technique. It comprised meetings with European and South-East Asian specialists working in climate change-related issues (e.g. climate and hydrology), with a particular focus on technological artefacts such as climate and hydrological models, and boundary objects (e.g. IPCC reports, policy documents and secondary data). This was relevant to the case studies and field sites described below.

[4] See Annex 1: Research Ethics Forms 2016-2020 for full details.

2.4 Data Collection

I collected data through fieldwork interviews and desktop research, developing a multi-sited ethnography and an innovative strategy to map global connections (Fischer 2015; Marcus, 1995; Morita, 2014; Tsing, 2005). I identified respondents through a snowball sampling method and by approaching representatives of organisations found on the internet and in government records. The snowball sampling method is not a representative sample for statistical studies. However, this sampling technique can be extensively used to conduct qualitative research with a hard to locate population. Snowball sampling can be used when no sampling frame exist, but rather it expands as informants point to other informants who are relevant to the matter under study (Naderifar et al., 2017). This technique has also been applied successfully to the study of knowledge networks around science advice on complex issues (Spruijt et al., 2014). For the purpose of mapping global knowledge networks where "expert" policy networks operate, the technique began with a small sample or group of initial contacts, to then use these contacts to snowball sample out to other people these participants knew and will be willing to introduce them to. Therefore, this methodology for sampling in the context of an ethnography of global knowledge networks makes perfects sense, since it does not need to be purposive or representative–– I leave that to the ethnographic process to help guide and unfold the research setting, which in turn becomes representative of institutions and participants of the research (Marshall, 1996). In terms of the number of participants, these were concluded based on two criteria: 1) the data was exhaustive, and 2) the data and rapport generated through the ethnographic process over three years were judged as sufficiently comprehensive of the phenomena being studied.

The process of research itself started with web-based search, prioritising organisations connected to the CTCN network, and those with expertise in climate and hydrological modelling technologies. I applied the following keywords to map the activities of organisations: [climate change, climate modelling, adaptation, hydrology, hydrological modelling, capacity building, development and aid, technology transfer, policy and planning, South East Asia, and implementation]. I conducted 39 interviews with professionals between September 2016–January 2020. Further Skype interviews took place with respondents in Japan, Denmark and Thailand. The interviews were practice-focused and semi-structured, with questions aiming to grasp:

1. the connections between organisations,
2. the strategies and aims of organisations and their operations, and
3. specific significant actions and events remembered as conveyed by vignettes.

The interviews were recorded in audio form and complemented with field notes. Secondary data included official reports, policies and plans, as well as the implementation projects, which were compared with formal connections between organisations and making database for further analysis. I concentrated on formal connections, that is, interactions that have legal documentation, such as project contracts, project pipelines, or a Memorandum of Understanding (MoU) associated with them. A protocol guided the selection of variables for coding and analysis (Table 1). The variables included [Label] (i.e. name of an organisation), [Type] (e.g., a Research Institute; a Private Sector Organisation), [Activity] (e.g., capacity building, development and aid, technology transfer, policy and planning, R&D and Innovation), [Scale] (e.g., a locally operating organisation, globally operating organisations), [Location] (the city of the organisation's headquarters and regional offices), and [Description] of relevant context and operational reach.

Table 1 Research protocol

Nodes	Type	Activity	Scale	Location	Description
Organisation	[Intergovernmental Organisation [IGO]] [Government = [GOV]]	[Capacity Building] [Development and Aid]	[Global] [Regional	[Place]	[Operational reach]
	[Non-Governmental Organisation [NGO]] [Private Sector Organisation [PSO]]	[Education] [End User]	[National] [City]		
	[Knowledge Network [KN]]	[Financing]	[Local]		
	[Local Council [LC]]	[Implementation]			
	[Research Institute [RI]]	[Investing]			
		[Policy and Planning]			
		[R&D and Innovation]			
		[Technology Transfer]			

Source: Author

2.5 Fieldwork Sites and Main Organisations Engaged

2.5.1 Fieldwork in the City of Bangkok, Thailand (2016 – 2018)

The fieldwork in Thailand was conducted through three visits between September 2016 and November 2018 and was carried out in the capital of Bangkok. This urban landscape is a central nodal point of international organisations working in development and aid across South East Asia, and many of their headquarters and facilities are located here. Accordingly, it is a strategic point for expert's networking and relationships, making Bangkok a hub of development-cooperation in the region. Participant observation and data collection was done in a set of national and international organisations with ties to the Climate Technology Centre and Network (CTCN) but also beyond this system. Throughout my visits, I conducted 16 interviews with officials, took field notes and obtained secondary data utilising the UNESCAP library, as well as recognising important reports and policy documents. The following organisations were engaged consistently: 1) The United Nations Economic and Social Commission for Asia and the Pacific (ESCAP); 2) The Science, Technology and Innovation Policy Office of Thailand (STIPO), 3) UN Environment (UNEP), 4) Danish Hydraulics Institute (DHI), 5) The Thai Hydro Agro Informatics Institute (HAII) and 6) the Asia Disaster Preparedness Centre (ADPC).

As part of the research, I participated in the DoUbT project inception meeting in Bangkok. The members of the project got together to hold a workshop on various topics. I presented a policy paper on water policy in Thailand linked to the Technology Mechanism of the UNFCCC. The meeting was useful to reach other researchers working in Southeast Asia, and I learn about national organisations working on natural disaster, water and adaptation issues in the region. During my time in Bangkok, I established social networks through the CTCN and with other United Nations agencies. I had access to ESCAP facilities during my field visits, which allowed me to interact with other UN officers and other country experts. I had the opportunity to attend meetings with members of STIPO and HAII, interview them and participate in official TNA events through the generous invitation of UNEP DTU Partnership. During the official TNA III phase meeting, I was able to interview national consultants working in Thailand and Myanmar, and representatives from these two countries. I also travelled to Ayutthaya (ancient city of Siam) and visited the Bangkok khlongs system across the city. I visited universities and national ministries and took part in meetings with DHI, interviewing staff who were executing technology transfer projects in the region.

2.5.2 Fieldwork at UN-City in Copenhagen, Denmark (2017 – 2019)

The fieldwork in Denmark was conducted during three visits between August 2017 and August 2019 and was carried out in the city of Copenhagen. In particular, I spent most of my time at the UN-City, a conglomerate of UN agencies. The research included participant observation and desk data collection about a set of UN organisations, operations and partnerships. Here I observed the daily operations of the Climate Technology Centre and Network (CTCN), UNEP DTU Partnership (UDP) and UNEP DHI Partnership on Water and Environment. During fieldwork in Copenhagen, I took part in the 10th Advisory Board to the CTCN and conducted 14 interviews with UN officials, consultants, DHI officers and UDP researchers. This fieldwork inside a UN facility was possible due to the generous support of UNEP DTU, which facilitated intranet access, a workstation, reports, and invited me to meetings and events with consultants and colleagues. In Copenhagen, I assembled decisive data on CTCN operations, their knowledge management systems, theory of change, monitory and evaluation system, technical assistance request by developing countries and overview of the UNIDO procurement system. UDP was most supportive in explaining me the Global TNA process and in connecting me with specialists and advisers from the network working in Thailand and Myanmar.

2.5.3 Fieldwork at COP 23, Bonn, Germany (2017)

Fieldwork at the 23rd Conference of the Parties (COP23) occurred at the UNFCCC headquarters in Bonn, Germany. As an observer, I attended the technology negotiations steered by the Subsidiary Body for Scientific and Technological Advice (SBSTA) in its 47th session. In particular, I observed the joint annual report process of the Technology Executive Committee and the Climate Technology Centre and Network to the Convention, contained under the SBSTA 47 agenda item 6(a) and SBI 47 agenda item 14(a): Development and transfer of technologies. Also, I attended the consultations on the Technology Framework under Article 10, paragraph 4 of the Paris Agreement and talked to experts from CTCN, UDP, GEF, GCF, EU delegates, developing country delegates, technology negotiators and stakeholders associated to the Technology Mechanism.

2.5.4 Fieldwork at COP 25, Madrid, Spain (2019)

Fieldwork at the 25th Conference of the Parties (COP23) happened in December 2019. The Convention, initially to happen in Chile, needed to change location and direction due to social unrest in Santiago, the capital of Chile. Thus, COP23 occur in Madrid, Spain. As an observer to the negotiations, I attended the technology consultations under the Subsidiary Body for Scientific and Technological Advice (SBSTA) in its 51st session. On this field trip, I put special attention to new discussions on the Technology Framework (agreed in COP24, 2018), as well as the discussions of Article 6 of the Paris Agreement with regards to support and implementation. I also attended the SBSTA-IPCC Communication sessions and their Systematic Observation sessions. During the COP, I maintained rapport with CTCN, the TEC and GCF officials, technology negotiators, IPCC experts, and stakeholders from the global response: other entities public and private organisations involved in the UNFCCC process. In particular, with technology and climate finance stakeholders, such as Climate-Kick, Climate Chain Coalition and UN Global Pulse, among others.

2.6 Fieldwork Data Sources

Table 2 Fieldwork data sources (2016-2019).

Source of data/Period	Location/Organization	Type of data
Fieldwork with national and international organisations. September 2016 — November 2019	Bangkok, Thailand: UNESCAP | STIPO | DHI HAII | ADPC | UNEP	Participant observation and Semi structured interviews (16) based on interview guide for Thailand. Participant observation of the organisation's activities. Reports and documents
Fieldwork with national and international organisations. August 2017 — September 2019	Copenhagen, Denmark: UN-City. United Nations agencies and partnerships: CTCN | UNEP DHI Partnership UNEP DTU Partnership	Participant observation and Semi structured interviews (14) based on interview guide for Denmark. Participant observation at the 10th Advisory board Meeting to the CTCN. Reports and documents
Fieldwork with national and international organisations. November 2017.	Bonn, Germany, Conference or the Parties (COP23): (multiple)	Participant observation of the technology negotiations under SBSTA 47: agenda items 6(a) and 14(a): Development and transfer of technologies and Technology Framework under Article 10(4) of the Paris Agreement.
Fieldwork with national and international organisations. October 2018	Bangkok, Thailand: UNEP DTU Partnership | LDC Countries (Myanmar) STIPO (Thailand) | AIT | UNFCCC Secretariat | GEF GCF | UNEP	Participant observation and Semi structured interviews (3): TNA III Sessions for LDC Countries. Kick-off of Third Phase Workshop.

Fieldwork with national and international organisations. December 2019	Madrid, Spain, Conference or the Parties (COP25): (multiple)	Participant observation and open interviews (2) of the technology negotiations under SBSTA 51: Development and transfer of technologies and Technology Framework under Article 10(4) of the Paris Agreement. Negotiation of Article 6 of the Paris Agreement; SBSTA-IPCC Communications on Special Report on Land and Cryosphere; SBSTA-IPCC Systematic Observation; Technology and Climate Finance for the Paris Agreement official sessions
Other fieldwork and meetings related to the DoUbT project between March 2017- October 2018	The Netherlands (Amsterdam and the Hague), Thailand (Bangkok and Ayutthaya) and Japan (Kyoto)	Interviews with experts in hydrology and climate modelling (4). Participant observation of meetings and project workshops. Development of protocol and data set for Social Network Analysis

Source: Author

2.7 Data Classification and Analysis

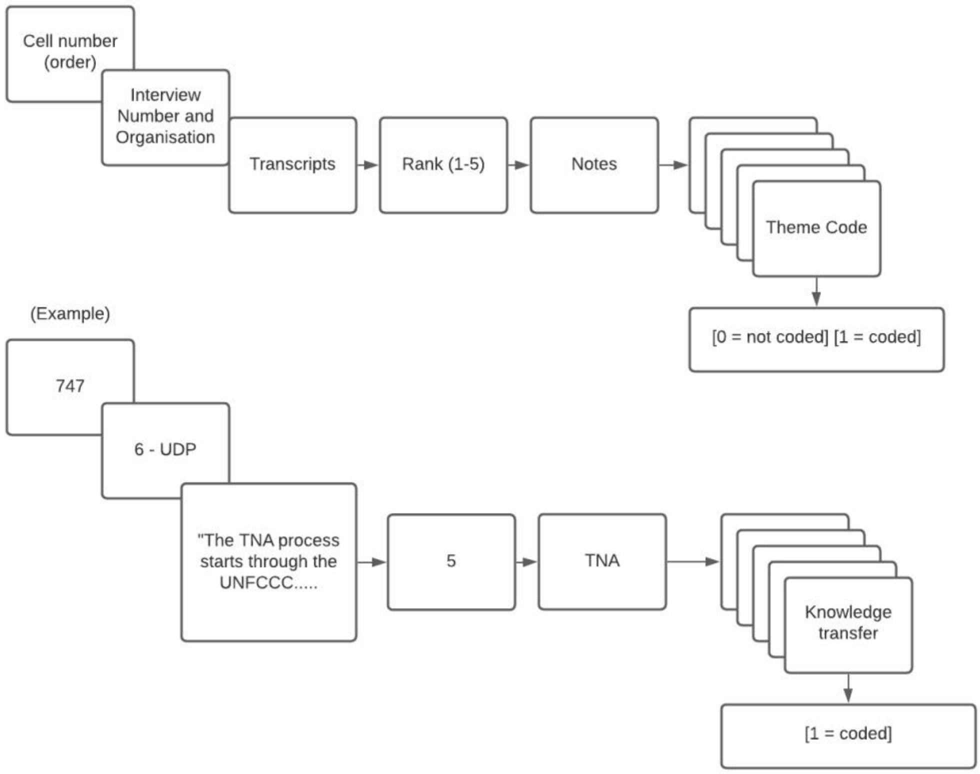
There are many techniques to discourse analysis (Jones, 2012). In this context, qualitative content analysis is commonly used for analysing qualitative data (Hsieh & Shannon, 2005). Content analysis is a research tool used to determine certain words, themes, or concepts within some qualitative data (i.e., text). Using content analysis, researchers can quantify and analyse the presence, meanings and relationships of certain words, themes, or concepts. For example, researchers can evaluate language used within a news article to search for bias or partiality. Researchers can then make inferences about the texts, the writer(s), the audience, and even the text's culture and time. Sources of data were collected from interviews, open-ended questions, field research notes, conversations, and from policy documents and reports and other grey literature, including official UNFCCC documentation and IPCC reports.

2.7.1 Data Classification and Coding of Interviews

First, data sources were classified and ordered in Excel according to their nature. For example, transcribed interviews were initially ordered given an interview number (e.g., 1, 2, 3…) and organisations (e.g. CTCN, UDP, DHI…) generating a classification (e.g. 1 – CTCN, 2 – CTCN, 6 – UDP, 8 – ESCAP…) and generating an **interview log** which immediately **anonymise the respondents**. This was followed by adding cells containing transcripts, a rank 1-5 to mark importance of **paragraph as thematic units** (1 = not important/ 5 = very important) and colour coded. The ranks were followed by cells containing [notes], [research questions], and initial codes by subject [global networks], [socio-technical systems], [technology transfer/capacity], [anticipatory/knowledge governance], [mitigation], [adaptation and DRR], [transformations], [technologies], [expertise & knowledge systems], [policy, responses and plans], [financial resources], [implementation and outcomes]. Each paragraph of every interview which was ranked more than 2 were marked in the cell as '1' when it related to a code. This allowed for a systematic search in Excel and comparison of interview data.

Figure 3 explains the logical syntax employed to code the data into Nvivo. In the figure, the cell gives a unique number for each paragraph, followed by an anonymised log indicating the interview number and organisations, followed by the transcribed paragraph and a rank from 1 to 5 indicating importance (1 not relevant to 5 very relevant). Notes and observations are connected to coded themes (thematic units) and decide whether to code or not code into the thematic units for analysis.

Figure 3 Coding Example



Source: Author, 2017-2019

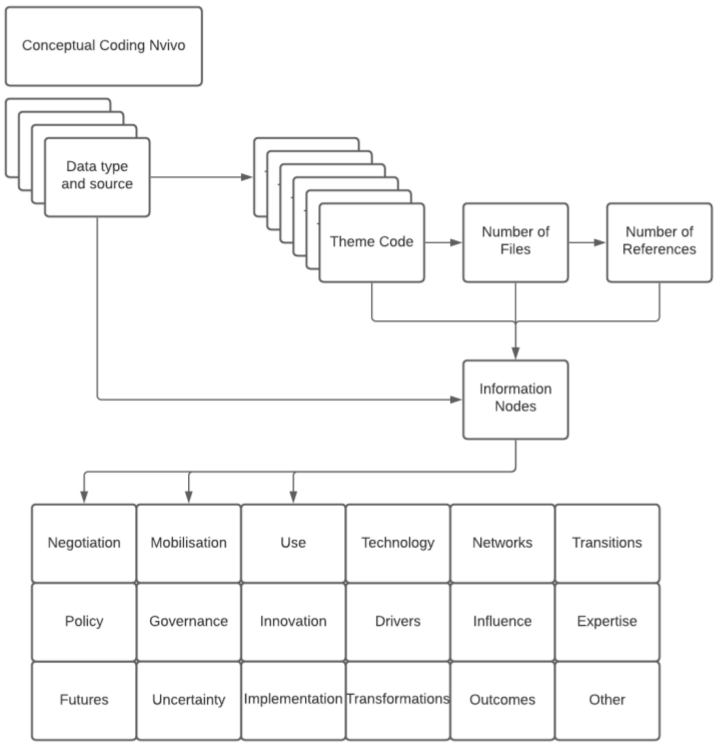
2.7.2 Data Treatment and Analysis Using NVivo

NVivo is a qualitative data analysis computer software package produced by QSR International. It has been designed for qualitative researchers working with very rich text-based and multimedia data, where deep levels of analysis on small or large volumes of data are required (Richard, 1999; Woolf & Silver., 2018).

Different sources of data were imported in NVivo between 2016 and 2020: transcribed interviews, key reports, institutional documentation, policies and plans, expert publications, IPCC reports (AR 2, AR3, AR4, AR5 and SR15), official UN documents of negotiations and decisions, including SBSTA/SBI informal consultation meetings, field notes, Technology Needs Assessments, National Adaptation Plans and other formal and informal documentation gathered on field sites The total of inputs analysed in NVivo was selected 126 documents and 32 interviews our of 39.; giving a total of 158 elements.

The Coding process for NVivo involved gathering all the material about the key identified themes in the literature and themes of the thesis and generate 'nodes' corresponding to each theme. This allowed me to maintain reference to specific topics, themes, actors and other information contained in different data formats. Creating nodes for analysis is a strategy that allows bringing the references together, cluster them and maintain track of sources and new materials. The following codes were created for the purpose of analysis between 2016-2020: [knowledge negotiation], [knowledge mobilisation], [knowledge use], [drivers of change], [influences], [global networks], [socio-technical systems], [innovation systems], [technology transfer], [knowledge transfer], [capacity building], [anticipatory governance], [knowledge governance], [mitigation], [adaptation], [disaster risk reduction], [transitions], [transformations], [expertise], [knowledge systems], [global response], [policies and plans], [climate finance], [resources], [tools and techniques], [modelling technologies], [implementation], [outcomes and impact], [South East Asia], [futures], [uncertainty].

Figure 4 Conceptual Coding Using NVivo

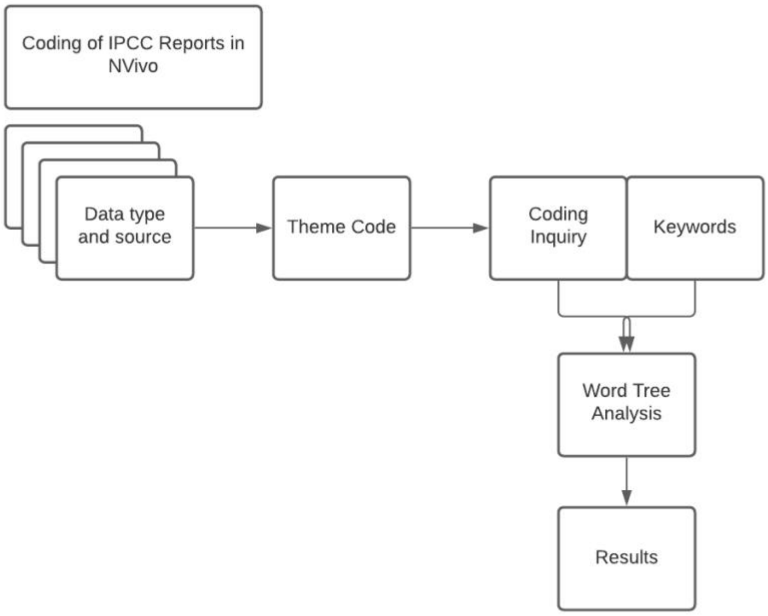


Source: Author using NVivo. 2018-2019

Figure 4 represents the process of conceptual coding applied in Nvivo for this research. It starts with a classification of data type and its source, followed by a correlation with the themes coded based on the conceptual framework, identifying the number of files linked to the particular themes code and the number of references created through the coding of data. Once the theme codes are linked to files and references inside files, the programme produces information nodes, which map the theme codes against the data.

The Summary for Policy Makers (SPMs) of five IPCC reports (AR2, AR3, AR4, AR 5 and SR15) were integrated analysed using a list of coded word queries: [transition (s)]; [transformation (s)]; [transformation pathway (s)], [transformation (s) to sustainability]; [sustainability transformations]; [transformational]; [transformative]; [transformative adaptation]; [transformational change] and [transformative change]. The coded links were explored and analysed systematically across five reports using NVivo's word frequencies and word search and apply into Word Trees Analysis to understand the pathways of each code inside the reports, in relation to other reports. Word Trees facilitated data visualisation of large reports and enhanced the analysis of content pathways combined with empirical observations and interviews. The IPCC documents were treated as data, not as part of the literature review. The data nodes were analysed using cross-comparison of themes by running 'coding inquiries', 'summaries' and 'word trees' to see interconnections between codes and data between files, references and coverage in documents. Hence, the information contained in the reports and their evolution—for instance, transitions and transformations, were contrasted with the IPCC-SBSTA's boundary work. These were contrasted with interviews and fieldnotes. This data was used in Chapter 6.

Figure 5 Coding of IPCC Reports Using NVivo



Source: Author using NVivo. 2019-2020

Similar to figures 3 and 4, figure 5 explain the coding of IPCC reports using NVivo. In this Analysis, the reports were treated as objects of Analysis and as data produced by science-policy experts. The IPCC documentation was treated using the same theme codes as previously, and a specific coding inquiry containing keywords was applied to produce Word Tree Analysis. After conducting an early **analysis**, patterns emerge. Hence **word trees** helped to visually display those patterns and understand the development of salient policy concepts in such reports, particularly in matters related to the use of "transition(s)" and "transformation(s)" (See Chapter 6 for Analysis of results in the context of IPCC–SBSTA science policy discussions observed at COP). Complete visualisations can be found in the Annex at the end of the thesis.

2.8 Social Network Data Analysis (SNA)

The analysis included a set of strategies (Table 3). First, I applied qualitative methods of coding, analysis and interpretation of data from the interviews, participant observation and field notes. Secondly, I combined the interview data with secondary data (e.g., government reports, project reports and MoUs), policy analysis (e.g., policy problems, stakeholders, institutional frameworks and uncertainties) and social network analysis (e.g., identifying connections, measuring centrality and selecting a cluster for further analysis).

Table 3 Data Analysis

Interview Coding	Secondary data	Technology	Policy Analysis	Connections and metrics	Network structure and cluster selection
[Global networks]	[Government reports]	[Climate models]	[Problems]	[Connections from]	[Hydroclimate dataset]
[Anticipatory governance]	[Project reports]	[Hydrological models]	[Stakeholders]	[Connections to]	[Total network = 198]
[Capacity building]	[Concept notes]	[Others]	[Frameworks]	[Closeness centrality]	[Random Sample = 100]
[Modelling technologies]	[Delta plans]		[Institutions]	[Betweenness centrality]	[20 with highest values for each metric]
[Formal mechanisms]	[MoUs]		[Uncertainties]	[Eigenvector centrality]	[Selection of 10 highest for each metric]
[Relational mechanism]	[Databases]		[Implications]		[Selection = 15 [Hydroclimate cluster]]
[Expert knowledge]					

Source: Author

Accordingly, the descriptions of interactions between organisations and events served to map a global network with which to identify activities and evaluate the performance and behaviour of such connections. Notably, I paid attention to organisations with an active presence in Thailand and Myanmar dealing with climate and hydrological modelling and conducted Social Network Analysis using three measures of network centrality: Closeness centrality, Betweenness centrality and Eigenvector centrality (Scott & Carrington, 2011). Centrality is a measure of the information about the relative importance of nodes and edges in a graph. Centrality measures the number of links incident on a node and is used to identify nodes that have the highest number of connections in the network. High degree centrality represents a crucial role in the information flow and cohesiveness of the network; thus, such nodes are considered central to the network due to their role in the flow of information.[5] Using a total network of 198 organisations identified and added to the dataset (see Annex for complete dataset), I ran closeness centrality, betweenness centrality and eigenvector centrality tests using SNA software KUMU and input the data into R Studio to get a random value sample of 100 organisations (See Chapter 5, p.161-162). Kumu is an Open-Source metrics engine which includes several Social Network Analysis metrics and applies community detection to calculate connections of elements. SNA done on Kumu include Degree, Closeness, Betweenness, Size, Indegree, Outdegree and Eigenvector amongst others. Kumu includes a detection system based on the SLPA algorithm, which identifies connections based on the principle of overlapping communities. Metric can be run with a data set produced in Excel and uploaded into the software. This was followed by building a network structure and pre-selected the first 20 organisations with highest rank and value

[5] See Glossary for complete definitions of centrality, principles and notations of metrics. See Annex for complete organisations' dataset.

for each metric, of which 10 within the highest ranks were clustered, aggregating a total of 15 organisations across the metrics (the most incidental, the direct and indirect nearness between nodes, the information bridge nodes, and the most influential nodes). Based on this selection, I named the 'Hydroclimate cluster' and analysed it to gain an in-depth understanding of their strategies and evaluate their influence in transferring climate and hydrological modelling expertise.

I used the three centrality measures in order to test and increase the confidence of the most relevant organisations under different conditions. I observed marginal variations between the three measures, confirming that: a) the ranks correlate and so do the organisations in direct and indirect nearness, b) the ranks show the leading organisations in information flow, and the ones that act as key knowledge transfer nodes, and c) the ranked organisations are the most prominent given their incidental characteristics. It is important to clarify that I did not consider the results of Social Network Analysis in isolation and that they are not sufficient on their own. Hence, I combined them with ethnographic data, interviews and policy analysis. The study triangulated the qualitative results based on the interview analysis and conceptual framework with secondary data in order to conduct social network analysis and policy analysis (Table 3).

2.9 Reflexivity and Positionality

2.9.1 On Studying Up

It is essential to open up and reflect here about the differences in studying down versus studying up and what it means in anthropology to clarify for those unfamiliar with the method and its implications. In social anthropology, there is a kind of ethnography known as studying up, initially influenced by Laura Nader (1972) but primarily as the critical reflection of decades of top-down ethnographies and power dynamics issues in social research.

For most of his history, ethnography has been used to study down—people with power study those without it. Anthropology was organised around studying the life world of so-called 'Other', or 'primitive', small-scale societies. In reality, these were disempowered by colonialism, and anthropologists themselves often work for colonial powers using their research on local customs to assist colonial governments, for which the British are a prime example. The ethnographic method was built on this imbalance of power dynamics, making it hard for this subject to refuse to be studied and posed serious ethical problems regarding how researchers use their findings. And anthropology has had a crisis of conscience in the mid 20th century regarding their complicity with colonial projects, and they have spent much of the time since then trying to come to terms with the colonial legacy of the ethnographic methods.

Today, anthropologist reach knowledge through different rapport processes, building real friendship and trust as they developed fieldwork to serve as an advocate for research participants without losing a critical eye. I am also part of these anthropologies, which are a far cry from the past exploitative studies, such as research on social cohesion among tribal groups, often commissioned by colonial governments to break them down and dominate others. In her work, Nader suggested that anthropologists should also point to ethnographic ways of studying up people with power and influential organisations, including transnational corporations, governments, the wealthy, scientist, the policy, the military, and public policy elites.

Studying up means, in this context, refocusing the eye to a kind of anthropology that challenges its ethnographic methods. Studying up faces research problems that may not arise while studying down, like the process of acquiring access to corporate offices or having to convince lawyers or policymakers of the merit of the research at hand. While studying up, the researcher realises that many standard elements of fieldwork seem strange when applied out of their traditional comfort zone. So much so that research has been brought up inside highly specialised laboratories, or energy physicist plants, biologist and biochemist, producing exciting and complex ethnographies. Furthermore, science and technology studies have been utilising ethnographic methods to study the development of technologies inside corporations and academic research labs, drawing attention to underappreciated aspects of science and technology. For instance, in the influence of culture, society and politics in settings that are often assumed to be purely rational or value-free. Studying up specialised knowledge has become a way to understand the cultural structures behind high-tech organisations and the social dynamics that shape technical decision making.

While studying up is not a replacement for studying down but studying up is a valuable approach that allows for a contextualising perspective of other forms of studying knowledge, power and complex organisations. It is essential to reflect that the ethnographic methods have not formed out of anywhere. They have a history that has changed substantially as researchers have experimented with new practices and got involved in other inquiry forms. The tools of ethnography can help us appreciate the thickness and specificity of these different ways of knowing people. A better understanding of how power works through studying at expert organisations can give a unique perspective for understanding social phenomena. In this particular research, studying has proven to be a necessary tool. As a social anthropologist from the global south, I have mainly managed to study intergovernmental organisations up to highly specialised UN organisations. Organisations that operate at international boundaries and have power dynamics that would be impossible to understand if not from within.

The organisations studied in this PhD belong to highly specialised global policy networks dealing with sophisticated expert knowledge about climate change, sustainable development, and technology transfer policy under the UNFCCC. Therefore, studying up such organisations involved ongoing conversations, pitching and gently opening doors, map stakeholders, reach to them, pitch my ideas, participate in their discussions, and eventually travel to research and observe their doings. This is no easy task. Nonetheless, it was done with preparation and guidance from supervisors and colleagues in my department. Finally, to mention that highly complicated and sophisticated institutions also have particular norms, functions, procedures and language that needed to be learned to generate rapport and understanding of their worldview and activities. These included the language of research and policy in science, technology, engineering and public policy, mostly dominated by white people from European institutions. In a sense, studying up in this particular ethnography across a global policy network has been quite successful, as it has gently shown that the process of rapport building, and patience can open many doors at high levels of policy spaces where decisions are discussed and taken.

2.9.2 Ethnographies of the Other, or other Ethnographies?

I am a social anthropologist from the global south and have lived, travel, study, and conduct ethnographic research in many South America countries, particularly Chile and Argentina, Peru, Brazil, Bolivia, Ecuador, and Mexico. In these countries, I have collected stories of far and of different people. I have worked with numerous indigenous groups in Amazonia and support their work in protecting their way of life and protecting the natural conservation areas which form part of their ancestral territory. I have also collaborated with various international organisations, including the United Nations and in research and academia, for most of my professional life.

My journey started in 2012 after finishing my studies in Social Anthropology in Santiago, Chile. During my studies, I spend much time working with indigenous communities in the Ecuadorean Amazon, looking at the relationship between traditional knowledge and modernisation narratives brought by colonisation and the expansion of Ecuador's oil industry. I was interested in the political ecology of resource use inside protected areas with Cofanes and Huaorani communities under voluntary isolation. There we modernisation narratives bringing technological advancements such as GPS to monitor conservation areas with indigenous groups. Many cooperation agencies where involved, including TNC and USAID. I explored these tensions and realised I wanted to learn more about the politics of sustainable development in international organisations. I moved to London and did a master's degree in Anthropology, Environment and Development, working and studying part-time. I worked under Dr Jerome Lewis's supervision, who has done fascinating work linking anthropology and engineering through the Extreme Citizens Science Project: mobilisation of GIS tools to empower Pygmies in the Congo to monitor and report illegal logging. I wanted to understand more about the process of expert knowledge and technology mobilisation across cultures and contexts and experiment with interdisciplinary research. I joined the Department of Science, Technology, Engineering and Public Policy at STEaPP, where I could experiment with new ways of doing research and changed my regional focus to Europe and South East Asia.

There are many gaps in our understanding of the interlinkages between knowledge, institutions, power, public policy, international cooperation, climate change and technology policy across communities of experts and global policy networks. I wanted to do a PhD that provided new interdisciplinary tools and dialogue with technology and public policy. Moreover, I wanted to learn these skills through empirical research and seek the possibility to study up intergovernmental organisations and how they go about mobilising such technologies, knowledge and resources to bring about change in sustainable development at global network levels.

Little ethnographic studies have been done to date from inside global policy networks and high-level institutions such as the United Nations, and thus I wanted to travel through such networks and explore these communities of experts and expert systems. There are several implications of this mode of enquiry. Researching professional lives, 'study up' (Nader, 1972) and through (Wedel et al., 2005) and writing ethnographic accounts of those expert's communities open up important methodological and ethical issues entirely separate from the techniques for describing how networks function by 'following the policy' (Wright & Shore, 1997). There are aspects of professional environments that perhaps make the typical ethnographic description rather challenging and sometimes even contested.

First, it is agreed to be difficult to subject expert communities to ethnographic description, as professional communities working in policy environments are often closed to be objectified in these terms (Riles, 2006). Some refer to the ethnographic problems associated with attempts at research on and with expert subjects whose own paralleled theorising already incorporates specialised analysis (Miyazaki & Riles, 2006). A traditional anthropological process based upon difference may conflict with the potential epistemological sameness present in expert groups rather than non-experts. Therefore, there is an inherent tension that the ethnographer has to navigate between knowing the ethnographic subject and the need to be accepted as such from the point of view of the subject. The strategy in this mode of inquiry then turns into avoiding failure to identify the ethnographic subject and then generate a particular type of rapport, a peer-to-peer rapport. One also requires maintaining a distance between the ethnographer and the subject to avoid "going native".

There was, in this research, a constant learning process where I had to maintain a distance of the subjects of study whilst spending significant time attending their daily activities and generating rapport and trust-building. I often thought of the para-ethnographic dimension of expert knowledge and expert institutions. Studying up was then much about understanding how specific institutional environments create framing around specialist expertise and attention to experts' own reflections of challenges and opportunities in their organisations and the social dimensions of their activities. As Marcus puts it, the invitation was much more on collaborative exploration (Marcus 2005) and experimentation of open questions around the topics of interest. However, building trust inside institutions by communicating horizontally, trying to find this collaborative ground, where the expert subjects of my research are neither natives nor colleagues, but people who stand as counterparts.

Intuition and heuristics played a big part in building bridges and connections and maintaining subjects interested in my work. It was not a collaborative ethnography because the subjects did not modify my methods, but they largely influenced my thinking during the ethnographic process. I had to be open and explain my research to specialist audiences who provide critical feedback to my questions, and then through extended and repeated dialogue, we co-generate an understanding of the issues. However, when presented with my ethnographic process and account of the social production of what I have assessed to be success or failure, I often received positive confirmation of my thought, but the informants also raised many objections to my knowledge. For instance, the Secretariat of the CTCN was not happy that I started to discover pretty evident gaps, such as the power imbalance between North and South technology providers. Although this constitutes a fact that can be checked in their progress reports in later years, when I discover this was an issue and discussed it with high-level experts, they were concerned about how such findings might impact their organisations. Moreover, they had the right to feel that way. I was, after all, an outsider who start to gain ground and attend high-level meetings and hear informal talking about processes. When confronted with the issue, some experts were unwilling to discuss it further, either for being too confidential or because it was not yet decided what the course of action was.

My interactions with experts on this matter proved to be positive in the end. After all, I was invited to participate in an advisory board meeting and had the chance to listen and provide input to them, which they appreciated. However, this required me to really think of how I would play the institutional game and participate in their activity without compromising my research credibility and not raising doubts about the value of my contribution to their work. Furthermore, I needed to remain critical. So, there are many tensions and power dynamics that need to be managed in studying up, which affected the writing process without a doubt. I had to remain somehow diplomatic to the context I was involved in, and in that process, I discussed with my primary supervisor a way to go about writing the thesis. Not necessarily from a first-person narrative, but relatively more neutral, describing the global policy network contexts I was working with, apply different methodologies to analyse and understand the relationships between what was being said in the interviews, what was observed in practice, and what was reported or documented and then provide a thorough assessment.

But in that process, my voice as an anthropologist––or rather, the ethnographic voice, was somewhat lost in the text. And it was then not clear how it all came to be. So, it could have given the impression that my work with professionals encouraged a habitus that transferred the actuality of events into preconceived categories legitimized by these institutions, which is not the case. Nor is the case that I am a northern white male anglophone researcher with disciplinary networks hosted by elite global research institutions, but rather, a working-class Latino who came from an unprivileged background and, by effort and dedication, has learned the ways of knowing and understand different modes of power in various cultural contexts.

Studying up was, for me, empowering. I have learned over the years how to navigate complexity and deal with different epistemic and normative positions as you interact with specialised scientist and policymakers with a variety of worldviews, backgrounds, ethnicities, races, classes and genders––you learned their language. So, as I wrongly stated at some point in Chapter 3 of the thesis, the' ease of access' should have said instead that studying up organisations is only a result of hard labour, years of dedication, and network building. It is not given for granted, and networks evolved and certainly did not stay the same. In a sense, studying up by applying ethnographic methods into highly complex networked policy contexts was challenging and an out-of-comfort-zone endeavour pursued with dedication, strategic planning, ethnographic skill, and seizing the opportunity. It required the digestion and understanding of different perspectives and evaluated the strength to assert particular epistemological commitments throughout the thesis and its implications. It also required, in the end, to do a belated process of reflexivity as a way to clarify and open up to scrutiny. Further, it was also necessary to open up to critical questions regarding context, research participants, data, motivations, role, positionality, identity, power, and voice.

Traditional ethnography tends to deny others their cosmopolitan claims by describing and contextualising place, time, people, and relationships. The time-space relationship concerning human interactions may reduce international expert networks' global claims to the trivial context of knowledge practices and daily routines. However, in my own ethnographic process, I decided, together with my supervisors, to focus on a kind of anthropological knowledge that is inseparable from the globalised contexts in which particular forms of policy knowledge is framed and function. Rather than focusing on describing the cultures of expertise as geographically bounded, I was concerned with understanding the processes of technology and knowledge transfer as embedded in professional institutions and their incumbent actors and how their knowledge counts as justifiable expertise mobilises policy action. The language used when studying up was different than in the traditional first-person approach used by ethnographers. However, it is true that studying up should also account for critical accounts between the so-called medical model and the bottom-up model of research. Perhaps then, it is important to clarify to the readers that as they go through the thesis, there should keep in mind that this PhD is not only about ethnography and generating anthropological theory but is also about highlighting underlying tensions between different ways of understanding social phenomena from a pragmatic orientation and a mixed-methods approach. The thesis is indeed about knowledge and power, and thus it delves into a critical evaluation of the applicability of knowledge when the subjects of research worked to develop a solution to their policy problems across global knowledge networks.

The combination of anthropology and policy was fruitful to the goals of the PhD. They were equally interested in understanding the cultures and worldviews of those policy professionals from different countries such as Denmark, the Netherlands, Thailand and Myanmar. In my case, the subjects of anthropological knowledge involved policy experts who introduce changes to environmental governance issues through their policies and decisions. Therefore, I observed what happened at the executive board level. The annual negotiations of climate policies in intergovernmental arenas and the study of policy through the process and relations involved in the production of policy. Therefore, my approach to studying up the context of power requires understanding agency and context and the underlying structures, the socio-technical networks, and the strategies that give direction to policy mobilisation in the context of technology transfer under the UN system.

It is essential to acknowledge that a more critical focus could have been applied as a narrative strategy to communicate results in the PhD. However, the thesis is sufficiently descriptive in accounting for power relationships at the institutional macro level, from one form of knowledge system to another. Studying up expert systems, in this case, requires utilising an approach to policy models and policy processes that are grounded on context and experts' perspectives. However, the social dimension of studying global policy networks also required to show how policies actively reinforce problematic trajectories and particular dilemmas which arise where the users of research are also the subjects of research, and where the kinds of anthropological and policy-relevant knowledge generate information of other 'non-public aspects of professional lives and cultures of expertise. An anthropologist working with policy might find this reflection useful as new interconnected environments require to find modes of fieldwork interactions with professionals and public knowledge regimes that solicit responses and allow objections to ethnographic forms of representation while still acknowledging the genuine underlying tensions in epistemology and purpose.

Furthermore, writing up and communication style in a study up approach to studying expert networks may benefit from a balanced combination of open and reflexive accounts that protect participants and constructively critique theory and practice. A well-noted point for further analysis and dissemination results in implications for the wider science-policy contexts involved in global environmental governance organisations. Finally, to think more carefully in studying global organisations can be done without compromising new forms of empirical research and participants in ways that provide accurate description and analysis and critical reflection that help improve institutional dynamics and support them in addressing social and environmental challenges.

Chapter Three

Global Knowledge Networks and Negotiations in a Formal Environmental Governance Context

3.1 Introduction

While I was waiting for a flight at Heathrow, London, a new email appeared in my inbox: *"Very nice to hear from your interesting piece of work. I am copying all relevant experts to see how to arrange contacts with them, best regards, Programme Director; Cc: Network Manager, Technology Manager, Capacity Building Specialist, Knowledge Specialist...(continues)".*[6] Thus began my research journey through a formal global knowledge network inside the United Nations system. The world of development-cooperation is highly interconnected. It is not surprising that people use information technologies and other means such as 'travelling through' organisations to conduct development practice. I established links and rapport over time with these experts—and expert institutions—and institutional gatekeepers helped open the doors of formal global knowledge networks operating under the UN-system.

In a highly formalised context, learning how to navigate protocols and bureaucratic processes matters. Protocols and rules are fundamental pillars in any institutional context—in this case, the UN-system. Rules serve as a gateway for establishing new connections, navigating, and gaining access to 'closed' spaces of global governance. The practice of rapport was useful for learning the rules, as well as building trust to access formal globalised networks. For example, another interaction illustrates this dynamic: *"I hope you had useful information from our meeting in Bangkok last week. If you have time when coming to Denmark in August, you can contact my colleagues at the UNEP-DHI centre who may share useful insight from our work on climate and hydrological modelling, Regards, Operations Director".* In a period driven by information technologies and 'hyper-connectivity', it would seem self-evident that there are frequent opportunities for networking. However, traditional governance structures and regulated organisational systems have to handle protocol and lengthy processes. On top of that, international civil servants are usually very busy with meetings, field trips, missions, or other tasks. The governance structures upon which the UN system operates requires an organisational

[6] Names are anonymised for data protection purposes. Instead, their formal roles are used.

system which many consider 'slow' and sometimes 'inefficient' due to its gigantic and fragmented apparatus. However, the system performs its functions in keeping with the combination of strict rules and social relations, which is what gives life to an active and distributed social-technical environment.

In this chapter, I used research-immersion in these institutionalised 'networked' contexts to illustrate empirically observed situations of expert's negotiations inside the Technology Mechanism—analysed as a formal global knowledge network. A significant part of the international response to climate change is leveraged by experts who are connected in a combined space of intergovernmental systems and other networked institutions. This chapter explains the institutionalisation of technological transfer taken by this large and complex socio-technical system in which the figure of the expert and their networks blends. The chapter describes these highly bureaucratic spaces and the process by which global knowledge networks negotiate formal technology and expertise-based action under the Technology Mechanism of the UNFCCC. This chapter outlines formal mechanisms of networking and the incumbent global agents that deliberate and negotiate the frameworks and terms of reference under which such a global apparatus is expected to perform. It continues with an analysis of the processes and contextual conditions that determine how this global network is meant to deliver its visions of change. Finally, it concludes by examining the fragmented environmental governance conditions under which the Technology Mechanism is intended to function.

3.2 The Technology Mechanism: A Brief Background

In order to explain the deliberative role of the Technology Mechanism as an articulating institutionalised network, this section gives a brief characterisation of the system and its role and functions. The efforts to produce a Technology Mechanism can be traced to the start of the United Nations Framework Convention on Climate Change (UNFCCC) process. The UNFCCC was adopted at the Rio summit in 1992 together with the UN Convention on Biological Diversity and the Convention to Combat Desertification. The Convention formally recognised the dangers of human activity for the climate system, based on the international scientific assessments of the Intergovernmental Panel on Climate Change (IPCC).

Ever since, the Convention's ultimate goal has been, *"to stabilise greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system."* It also declares that, *"such a level should be achieved within a timeframe* *sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner"* (UNFCCC 1992). Even though adaptation received less attention than mitigation in the early stages of the Convention, it acknowledged all countries' vulnerability to the effects of climate change and demands that specific attention be paid to developing countries, as these lack the resources, technologies and capacity to deal with the consequences.

Of all the working areas involved in the Convention process, members have particularly promoted technology development and transfer as the way to support countries to accelerate sustainable development. In particular, article 4.5 of the Convention already sealed its path in 1992. December saw the Convention adopt the Kyoto Protocol in an attempt to reach an international agreement to bind emission reduction targets to those countries involved in the process. It also acknowledged developed countries as those mainly responsible for current levels of GHG emissions as a result of more than 150 years of industrial development, leading to the principle of "common but differentiated responsibilities."(UNFCCC, 1998). The Clean Development Mechanism, or CDM, still aims to reduce compliance costs associated with promoting sustainable development in developing countries through a series of targets and schemes. For example, the CDM measures progress through a 'unit' called the Certified Emission Reductions (CERs). This has proved to be a difficult endeavour, and little progress was made in following years, as negotiators faced many challenges when attempting technology dialogues, especially where industrialised countries such as the US expressed no willingness to ratify the Kyoto rules. Nevertheless, the Kyoto Protocol is still being pursued and has gained deeper complexity; the international community perceives it as an important milestone in efforts to curb emissions and the first building block of international agreements in climate change. A negotiated decision at COP7 resulted in the Marrakesh Accords, setting the stage for ratification of the Kyoto Protocol and formalising agreements of the operational rules of the CDM and the Development and Transfer of Technologies (UNFCCC, 2001). The Accord decided, among other things, to establish the Expert Group on Technology Transfer dedicated exclusively to enhancing the implementation of article 4.5 of the Convention. The expert group was mandated to find ways to facilitate technology activities and make expert recommendations to the Subsidiary Body for Scientific and Technological Advice (SBSTA) to the Convention.

With technology transfer occupying an ever-higher place on the UNFCCC agenda, countries created the Poznan Strategic Programme on Technology Transfer (PSP) in 2007, when COP14 requested that the Global Environmental Facility (GEF) produce a strategy for scaling up technology mobilisation (UNFCCC, 2009). The aim was and is to enhance access to funding for technology development and transfer actions through, for example, the undertaking of technology needs assessments (TNAs), the piloting of technology projects prioritised by the TNA process, and the sharing of the GEF's expertise in technology-related policy. In 2007, the GEF was asked to establish a programme to promote investment in technology transfer as a potential solution to climate- and technology-related needs. Technology Needs Assessments (TNAs) were strongly emphasized in the Paris Agreement, and they also play a central role under the 'implementation' theme of the newly agreed UNFCCC Technology Framework, which provides overarching guidance to the Technology Mechanism of the UNFCCC. The TNAs build potential, ability and scale of climate change technologies linked to Nationally Determined Contributions (NDCs) through the development of country Technology Action Plans (TAPs). These assessments are market-based diagnostics which look to identify technology needs in a country and design a strategy for transfer, diffusion and uptake. TNAs are empirically explained in detail in chapter 4 in the case of Thailand and Myanmar).

The PSP received an initial funding of $US 50 million which helped the programme get started. By 2010, the GEF outlined its strategy, which included the development of climate technology centres in developing countries, as well as the development of TNAs and opportunities for public-private partnerships. Four regional centres were developed and are still under implementation in Africa with the African Development Bank (AfDB), in Asia Pacific (ADB/UNEP), in Eastern Europe and Central Asia (EBRD), and in Latin America with the Interamerican Development Bank (IBD). By 2009, the GEF had helped deployed TNA I projects (now completed) in 36 developing countries. TNA II followed in 2013 with 28 new countries, and a third round of TNAs (TNA III) targeted 23 Small Island Development States (SIDS) and Last Developed Countries (LDCs). The final phase began in an inception meeting in 2018 in Bangkok and is currently underway. TNA assessments inform our understanding of how national experts build up baseline characteristics of technology needs and country guidelines and prioritise the transfer of certain technologies for mitigation and adaptation. They base these priorities on techno-economic criteria and other factors crucial to framing the process of technology and knowledge transfer, build national plans, and ultimately receive funding. TNA assessments are addressed in detail in Chapter 4 for the case of Southeast Asia, with reference to other countries with relevant cases.

Since Poznan (PSP), policy momentum has been growing in climate negotiations advocating strengthened development of 'comprehensive technology packages' in support of developing country governments dealing with adaptation to and mitigation of climate change. This idea of 'packages' came up several times during this research, in particular it emerged out of an interview with the TNA Coordinator during COP23 in Bonn, Germany in November 2017. Briefly put, it refers to cost-benefit criteria and technical rationale for standardising the transfer of technology-based solutions in different contexts to make the process apparently more efficient. While PSP was gaining momentum, 2009 marked a change of overall direction due to the Copenhagen 'failure', which produced a policy change away from the Kyoto model and the idea that binding targets and timetables for emissions reduction would work. Since these strict measures were not meant to function, or were neglected for political and economic reasons, negotiators started to move in a different direction.[7] The resulting Copenhagen Accord was based on 'voluntary pledges' for emissions reductions. Countries would make non-binding promises to advance policy and action on future emissions. With regards to climate change adaptation, it was negotiated that parties shall give 'predictable and sustainable financial resources, technology and capacity building' to support implementation. One of the results of these negotiation sessions was the enhanced support of technology financing, particularly with the initiation of the new Green Climate Fund (GCF) in the role of Financial Mechanism. Since the inception of this fund, the assumption was that it would catalyse projects and policies targeted to mitigation and adaptation of non-binding pledges worth $US 30 billion for the period 2010-2012 (which was not met) and $US 100 billion by 2020. For instance, On April 3, 2020 the status of pledges for the GCF first replenishment (GCF-1) has received only $ 3.37 billion, as indicated by the 'pledge tracker' calculated on the basis of reference exchange rates established at the High-level Pledging Conference in 2019 (GCF/B.24/11). In addition to the GCF's current lack of disbursement capacity, this thesis will expand in more detail on many other policies and compliance issues facing agencies when they come to the fund. These include a great deal of negotiation and internal approval processes based on accreditation and criteria, which are time-consuming and difficult to achieve in order to receive the first GCF dollar. As observed at the CTCN offices, the development of Technical Assistance requests conducted between ministries of requesting countries, UN-staff and liaison with the GCF through extended periods of project development and bureaucratic engagement to ensure feasibility and alignment with previous processes such as TNAs and NDCs. However, a wide variety of sources, including public, private, bilateral and multilateral, expects the fund to grow quickly. Finally, the most notorious outcome of the Copenhagen Accord was the negotiation of a new mechanism for technology development

[7] Analysis using data from interview with CTCN Technology Manager, UN-City, Copenhagen, Denmark, August 2017.

and transfer, which culminated in the sixteenth COP (2010) with the formal creation of the GCF and the Technology Mechanism (UNFCCC 2011).

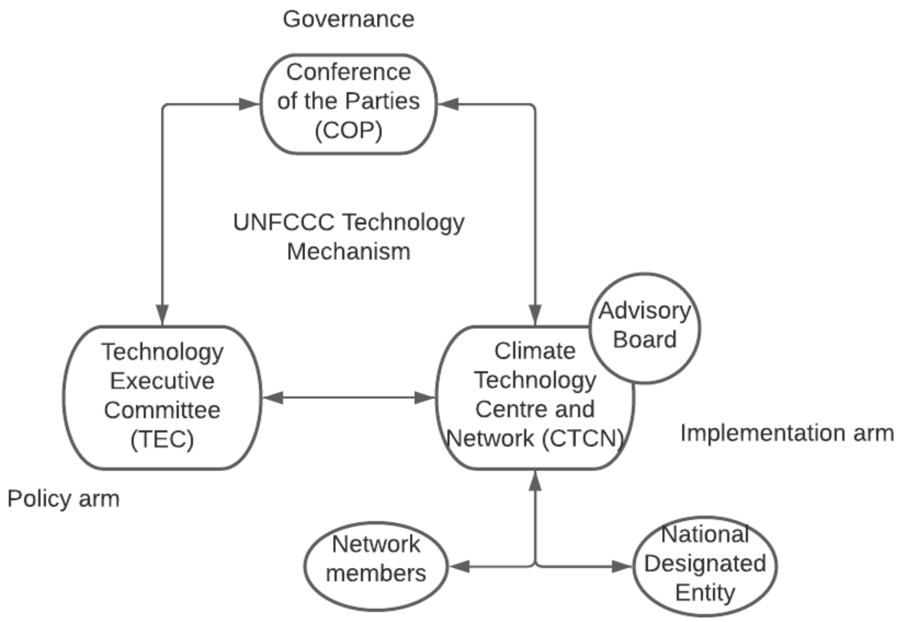
The last five years have seen significant institutional change inside the UNFCCC structure since the creation of both mechanisms, which heavily target the scale-up of technology development and transfer as the strategy of choice, but with renewed institutional arrangements. For example, the Technology Mechanism is intended to accelerate technology transfer following what is said to be a country driven process based on national priorities.[8] This renewed governance architecture is supposed to deliver a fresh vision of 'transformational change' based on boosting the transfer of so-called 'climate technologies'.[9] Within the UNFCCC process, nurturing technological transitions through the transfer from developed to developing countries continues to grow in relevance. In theory, this should bring additional opportunities for a wider scope of cooperation, including new alliances and alternative cooperation mechanisms. However, these transitions rely on the diffusion of innovation and material resources from places of higher technological development to places where there is supposedly less technological progress and innovation in mitigation and adaptation to climate change.

For this purpose, the Parties created the Technology Mechanism, which consists of the following structure: a governance component led by the Conference of the Parties, a Technology Executive Committee (TEC), and the Climate Technology Centre and Network (CTCN), a socio-technical network responsible for the implementation and transfer of technologies and expertise to countries upon request.[10] The TEC is composed of 20 rotating technology experts from northern and southern countries. It is mandated to provide policy recommendations to support climate technology development and transfer by addressing strategic policy areas of technology. The CTCN is the operational arm in charge of delivering and facilitating the transfer of technologies via three main services: the provision of technical assistance upon a developing country's request, the creation and sharing of knowledge relevant to climate-related technologies using a knowledge management system, and the promotion of stakeholders' collaboration through the use of a global network of regional and sectoral experts, international technology centres, networks, organisations, governments, and the private sector (CTCN, 2015; Nussbaumer et al., 2015).

[8] Analysis using data from interview with CTCN Knowledge Manager, UN-City, Copenhagen, Denmark, August 2017
[9] Analysis using data from interview with CTCN Knowledge Specialist, UN-City, Copenhagen, Denmark, September 2017
[10] Analysis using data from interviews with CTCN technology managers, UN-City, Copenhagen, Denmark, September 2017

Under the governance structure of the UN-system, the CTCN is hosted by two UN bodies, UN Environment (UNEP) and the UN Industrial and Development Organisation (UNIDO). In addition, the CTCN has an advisory board that provides strategic direction, as well as 11 consortium partners, also part of the global network. These 11 partners were selected as key funding implementers, although the network has evolved over the last five years since inception (2014-2019/20) to more than 550 network members, including public sector, private sector, and other mixed legal entities. The main point of contact for the Technology Mechanism at the national level is the National Designated Entities or NDEs, which typically sit in a ministry of science and technology, innovation, environment, or another related field.

Figure 6 The Technology Mechanism System



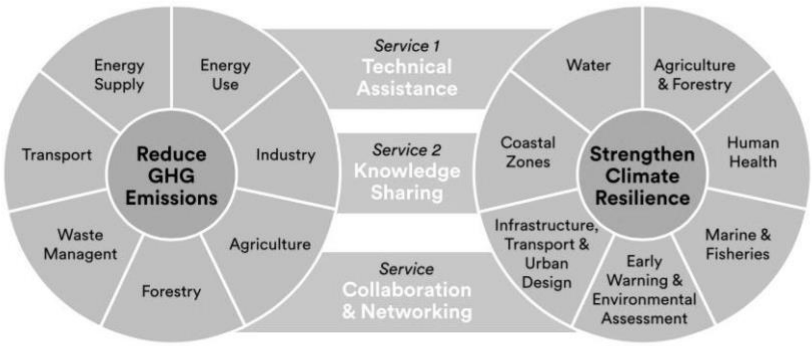
Source: CTCN Annual Report 2015

The UNFCCC expects the Technology Mechanism to be the operating entity to solve the implementation gap by enhancing action on technology transfer through the articulation of this global network system. In particular, the Technology Mechanism is intended to facilitate information sharing, training, and capacity-building for technology transfer through a formalised global knowledge network.[11] The model is based on the idea that by

[11] Analysis using data from interview with CTCN Knowledge Specialist, UN-City, Copenhagen, Denmark, September 2017

catalysing actors and managing a global network, human capital, resources and technologies should come together through collaboration between a wide range of stakeholders, establishing an ecosystem of national, regional and international institutions coordinated by a 'climate technology centre' and 'network'.[12] Under the Technology Mechanism, the CTCN promoted technology development and transfer for 'energy-efficient, low carbon and climate resilient development' as stipulated in the Paris Agreement (UNFCCC, 2015). Its core functions are to deploy technologies and expertise across a range of adaptation and mitigation sectors through its three services.

Figure 7 The CTCN Technology Transfer Services by Sector



Source: CTCN Annual Report 2015

CTCN provides technical assistance (Service 1) in response to requests submitted by developing country members via the focal points (NDE). It responds to these requests by 'mobilising' its network of experts and delivering a 'customised' technology solution. This includes, for instance, creating opportunities and sectoral analysis aimed at removing barriers for investment, or developing a solution for a specific mitigation or adaptation sector technology. Knowledge sharing (Service 2) is intended to foster technical assistance through an online technology portal where users can access relevant webinars and other information tailored to knowledge exchange and training, upon request. Finally, through collaboration and networking (Service 3), the CTCN targets a global network of technology users, decision makers from public and private sectors, providers, and investors. It has a

[12] Analysis using data from interview with CTCN Knowledge Manager, UN-City, Copenhagen, Denmark, August 2017

catalytic effect through regional forums and other collaborative activities leading to technology transfer based on a global platform.[13]

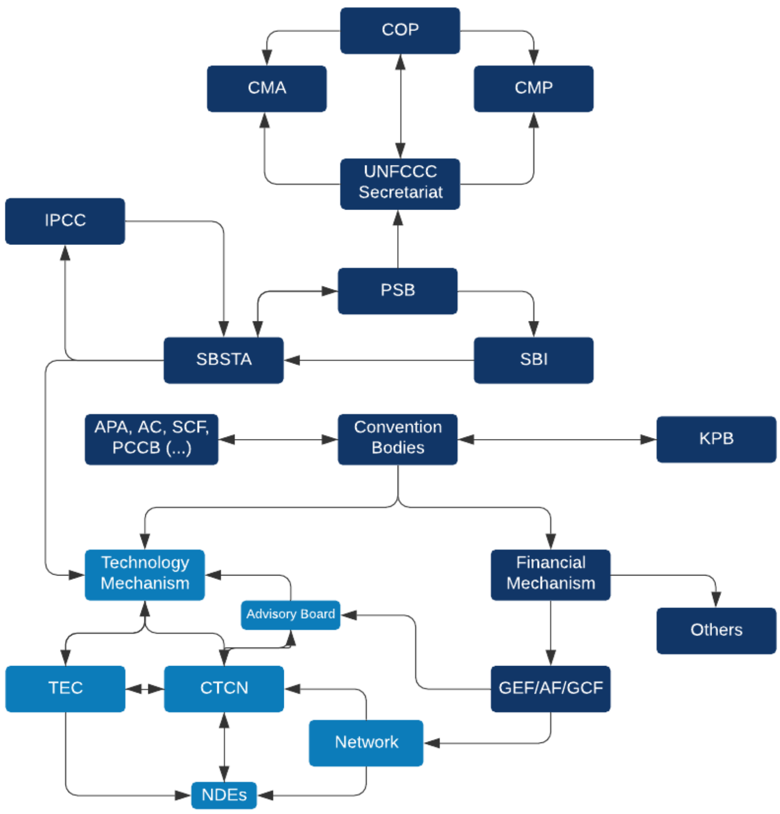
Political leaders and experts see the strengthening of a global climate regime through a technology transfer mechanism under the Convention as a critical tool to achieve success: *"The CTCN is a powerful example of a UNFCCC mechanism making a different on the ground, facilitating the delivery of climate technology expertise in support of developing country objectives"* (CTCN, 2016 p. 7). Consequently, the global climate regime under the UNFCCC is steering a path to facilitate and scale up international cooperation on technology development and transfer in order to pursue the goals of the Paris Agreement. However, the practical steps to facilitate this task are far from resolved, and the effective implementation of the mechanism by country parties requires the negotiation of the frameworks to guide key institutions and complex networked organisations.

[13] Analysis using data from interview with CTCN Knowledge Manager, UN-City, Copenhagen, Denmark, August 2017

3.3 Negotiating Technology and Expertise-based Cooperation inside the Technology Mechanism

The governance architecture of the UNFCCC comprises a complex socio-technical regime, which is characterised by a variety of permanent and subsidiary bodies, committees, expert groups, mechanisms, arrangements, facilities and funds which are too extensive to explain in detail, as it goes beyond the scope of this thesis. However, those bodies relevant to the Technology Mechanism are briefly characterised here to show the bureaucratic structure underpinning the technology-related negotiations under the UN climate regime.

Figure 8 Architecture of the UNFCCC and the Technology Mechanism



Source: Author, 2020

Figure 8 represents the UNFCCC architecture and the Technology Mechanism operative environment. Figure 8 distinguishes the Conference of the Parties (COP), the high-level political representatives of countries, the Conference of the Parties acting as the meeting of the Parties to the Kyoto Protocol, known as CMP, and the Conference of the Parties acting as a meeting to the Parties to the Paris Agreement (CMA). These represent the high-level 'bureau' of the UNFCCC. This is followed by the UNFCCC Secretariat and its two Permanent

Subsidiary Bodies (PSB), which are the Subsidiary Body for Scientific and Technological Advice, known as SBSTA, and the Subsidiary Body for Implementation, or SBI. The Technology Mechanism acts as the 'operational arm' of the Convention, and so can potentially coordinate with any other body when and if required, as was observed and discussed with CTCN Knowledge Manager during the technology negotiations at COP23.

In practice, negotiations reflect situations set up by a large scale global environmental governance structure. In addition, negotiations depend largely on the role and functions of experts and expert networks inside the Convention. This includes, for example, science diplomats working in the interface between science and policy at the SBSTA. They use the IPCC's knowledge to convey messages and coordinate expert groups on the range of topics that fall into climate action on mitigation and adaptation, including technology transfer. Other types of experts are typically legal experts in charge of procedural elements, involving co-chairing negotiations, drafting, and reporting in official UN language. There are other actors who fulfil multiple, loose, or even unknown functions. For instance, I observed during the technology negotiations known as "informal consultations" sessions that Saudi negotiators blocked the negotiations of the Technology Framework under the SBSTA/SBI during COP23, Bonn, Germany, November 2017. Saudi representatives were observed generally undermining progress on emission reduction targets and gender responsive policy deliberations. They would repeatedly wait until the last consultation sessions were about to finish to raise issues that were impossible to address or negotiate, because there was no time left. Consequently, they effectively delayed the agenda item for the following period. Other examples include a myriad of incumbents, interest groups, consultants and 'observers' who managed to access these closed negotiation spaces and watch, inform, or perhaps influence formal deliberations from backstage.

The deliberations on technology development and transfer have been a central point of debate since negotiations began at the Convention. The prospects for a deployment mechanism for technology in the context of climate change have been challenging since the inception of the UNFCCC due to the highly contested nature of technology-based cooperation. A senior climate expert, senior technology negotiator and the first to become CTCN director explained to me his experience:

> *"I have negotiated since COP three. I have to say that from the start, it was very difficult for the donors to get away from technology cooperation. 'Let's support developing countries on technology transfer'. This wording (expressed in the original article) was extremely important because it's the base of all technology*

discussions and negotiations under UNFCCC ever since. However, nothing happened for years and there were some attempts to have technology dialogues but there was no willingness for industrialised countries to move on this agenda item at all. They found out very early after Kyoto that developing countries were not ready to take any commitment. The whole atmosphere of the negotiations got very sour." (Former CTCN Director, Copenhagen, Denmark, September 2017).

In his view, when Kyoto was ratified, only industrialised countries took the initiative on absolute reduction commitments. The "spirit of Rio" —in 1992, as he expressed, was to follow the success of the Montreal Protocol, where countries took responsibility for reducing pollutants. This had clear targets, and experts established effective international instruments under Montreal through a dedicated Science and Technology Panel, with a Funding Mechanism and the country brokers. The Kyoto Protocol was different according to his perspective. However, even after the "Kyoto failure", the technology agenda continued into negotiations. 2001 marked a significant turning point when the Marrakesh Accords established the first Technology Transfer Framework under the PSP. This reference was a sort of guiding principle for steering negotiations on the subject of technology-based cooperation.[14] The mechanism itself was composed of an 'expert group on technology transfer'. However, divisions were clear between developed and developing country negotiators. The critical point of discussions then was deliberation about enabling environments. Technologies of any kind are not typically mobilised by intergovernmental bodies; rather, technology transfer is a business traditionally nurtured and developed by the private sector. Developed countries did not see economic sense in building a strong technology mechanism under the UNFCCC. Technology Transfer has always been a business of Technology providers.

In an interview with a Technology Negotiator at COP23, he commented that the technology strategy of donor countries has mostly been focused on how to generate an environment in developing countries for allowing Technology Transfer to happen at the business level, including through instruments such as taxation, incentives, and corruption monitoring, so that businesses would feel attracted to invest in developing country's technological needs. However, power dynamics between northern donors and southern nations has led to tension, as they have different agendas, as he explained to me:

"They (developing countries) wanted to have a dedicated technology fund which they announced already in 2001. But repeatedly after that, they wanted a full fund that will support the transfer of cutting-edge technologies for mitigation and

[14] Analysis using data from interviews with TNA Coordinator, COP23, Bonn, Germany, November 2017

> *adaptation. I remember in deliberations some even envisioned a huge warehouse where these new technologies arrived and were ready to be used. They wanted the intellectual property available too. It was, of course, totally rejected by developed countries."* (Technology Negotiator, COP23, Bonn, Germany, November 2017).

The situation at the technology negotiations has always been problematic because of the economic dimension of technologies. Donors see technology transfer as a business, a door to increase technology cooperation and trade, whereas developing countries frame the issue as a right under the Convention. For a time, under the technology negotiations, the WTO started to be more engaged in these discussions, particularly on the issues of intellectual property rights and the possibility of open up patent systems to allow knowledge and technologies to flow more rapidly to developing nations. However, the negotiations got 'very difficult', 'divided', 'controversial', and 'political'. For example, BRICS countries wanted to break the established trade rules and leverage for a new intellectual property regime that would facilitate technological transfer and the development of patent ownerships.[15] This has in turn been to the detriment of poorer countries such as Least Developed Countries (LDC) in Africa, Asia and Latin America, because they are economically smaller and disadvantaged. Furthermore, LDC countries could benefit from more open patent systems, with less protection or a mechanism that pays technology providers to transfer ownership to support LDC technology upscale as part of the Convention process. However, Copenhagen's manager perspective is different from ideals of collective ownership, but rather a much more pragmatic technology-cooperation approach. When it comes to the UNFCCC apparatus, he explained to me the difference between the policy and the concrete operations of the Technology Mechanism after it got negotiated:

> *"The developed nations really wanted to get a deal. And we did, finally got everyone on board, on paper. There we all agreed that a Technology Mechanism should be put in place. We created the TEC, which was relatively easy to convene, but the CTCN was very tricky. It was the operational arm and has to implement."* (Former CTCN Director, Copenhagen, Denmark, September 2017).

Mobilising technology policies under the TEC belong to the realm of a science-policy advisory role in the context of the UNFCCC. The work of CTCN, however, is of a different nature. The Technology Mechanism was developed on the negotiated understanding that a new framework should replace the old 'technology transfer framework' from Poznan (PSP)—one that would supposedly level the field through an operative structure under CTCN. The idea, primarily driven by developing country coalitions, started with $US 2 billion

[15] Analysis using data from interviews with CTCN Technology Manager, UN-City, Copenhagen, Denmark, September 2017

funds for activities; however, it was not well received by the donor countries because it meant more funding and less business. This, in part, explains why the Copenhagen Accords did not go as expected by negotiators in 2009.

In exchange, donor countries made the Green Climate Fund (with a 2020 target of $US 100 billion) a much more ambitious offer 'to mobilise'. This offer was still based on the underlying assumption that there would be a functional carbon market largely reliant on the Clean Development Mechanism under the Kyoto Protocol, which, as explained earlier, was already showing clear signs of trouble. That did not happen either, meaning the pledge of $US 100 billion was troubling from the start, and now the offer would encourage 'everyone', rich and poor, public and private, to participate. The Adaptation Committee played an important role in the negotiation of the Technology Executive Committee (TEC) and the creation of a centre for technology transfer and innovation, led primarily by the American negotiators. US negotiators thought that a stronger emphasis on market-based strategies through policy advice to developing countries in 'need' of technology and resources was called for, and that is what they wanted to offer, the then CTCN director shared:

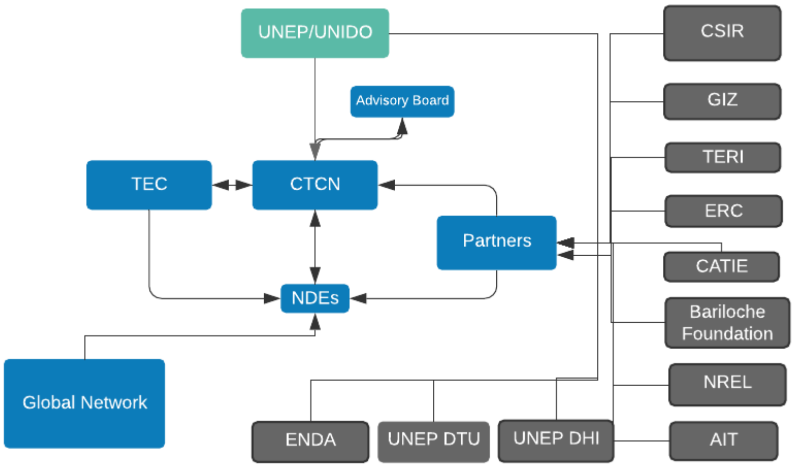
> *"The committee had in their mind the "ask an expert" service-type of approach. The model was that developing country officers will call to a global centre of expertise which would give them advice, especially in energy policies, laws, regulations, standards, measures (…) which would produce the enabling environments. It was a logical thing to do. That was the idea, but it didn't come like they wanted in the end. It came much more bureaucratic, like it is now. After Copenhagen (2009), when the details were negotiated in Cancun (2010), the Parties needed to also compromise, and this was not easy. National focal points (NDEs) are the ones who have to make requests to the mechanism, and well, the task became more and more complicated as it evolved."* (Former CTCN Director, Copenhagen, Denmark, September 2017).

According to his experience, the task of managing a formal global knowledge network under the UN-System has been more complicated than initially anticipated by the interest groups, and the network required a permanent host capable of providing continuous operational reach to providers and recipients of support. The initial strategy intended to avoid the UNFCCC Secretariat having to take an operative role. In addition, there was escalating tension between the already established Global Environmental Facility (GEF) and the emergent Financial Mechanism, which included other organisations such as the GCF. The GEF already had a technology programme with funding locked into the PSP—$US 50 million towards developing TNAs and their piloting projects. In a sense, their expertise in the matter and established legitimacy in the technology transfer stream of cooperation made them the stronger candidate at first. The GEF experts lobbied for a technology centre run from Washington. However, frustration was growing about how the GEF operated under the UNFCCC, and negotiators wanted to open up a new bidding process for the host institution in charge of the Climate Technology Centre and Network (CTCN). The idea of a technology centre came as a response to developing country negotiators who did not like the approach of the GEF, perceived as overly distant and technocratic. It was also an opportunity for northern donors to start new business opportunities afresh.

Negotiating technology-based cooperation under the UNFCCC is lengthy and difficult. For example, the decision about the hosting institution for the CTCN involved nearly 'impossible negotiations' over four years (2010-2014), with competing funding institutions debating over technicalities under the UN consultation rules. Sometimes in negotiations when there is diversity of expert opinions about a subject, or a conflict of interest between them, they cannot move forward until a unified consensus is achieved. This means that sometimes it is not possible to negotiate one document, let alone one page.[16] Further examples of this process are given later, specifically with regards to the negotiation of the new technology framework. For the purpose of selection, a panel of six governments evaluated ten bids, many of which came from the private sector. One of them was a UNEP/UNIDO joint proposal, which was regarded by the panel as irrefutably better than the rest. They created a consortium alliance with other centres of expertise supposedly representing a 'balanced' North-South distribution.[17] Figure 9 represents the CTCN Global Knowledge Network and its operating System of consortium institutions. UNEP and UNIDO are the hosts (in green), while the partners (in grey) are the implementors of technology transfer activities coordinating with the NDEs and other network members.

[16] Analysis using data from interviews with Technology Negotiator, COP23, Bonn, Germany, November, 2017
[17] Analysis using data from interviews with CTCN Director, UN-City, Copenhagen, Denmark, September, 2017

Figure 9 CTCN Global Knowledge Network & System



Source: Author, 2020.

The bid had southern partners, which made the proposal attractive to the panel. For example, it included the Asian Institute of Technology (AIT), as well as the Bariloche Foundation and Enda Tiers Monde, an international organisation based in Senegal with diplomatic prestige and working programmes on decentralised knowledge networks. All of the Partners were already involved in activities with UNEP and UNIDO, which made the bid stronger. As a result, the panel decided to sign it. In contrast, the GEF did not have any programmatic capacity as ambitious as the one made by the newly formed consortium. The new Technology Mechanism, similar to the fund's strategy, would be based on voluntary contributions.

Negotiations are consensus based. Their decision-making processes are laborious, and it can be difficult to finally reach an agreement. However, when a decision is made, it is almost impossible to reverse it. This is twofold. On the one hand, it means that under the UNFCCC regime, negotiations move slowly toward a particular agreement. On the other hand, once the agreement has been made, there is significant path dependency linked to implementation, and the policy trajectory becomes locked:

> *"When you create a mechanism like this is almost impossible to end. Parties will not undertake another bidding process. Because who could be given a public service, free of charge to the governments under the public control. The private sector cannot even understand the whole concept. And we have very close private partners and they still don't understand the kind of policy systems we have, which is essentially serving the governments under the UNFCCC."* (Former CTCN Director, Copenhagen, Denmark, September 2017).

For example, after the application was accepted by the evaluation committee and the offer made to UNEP/UNIDO, the CTCN pledged an initial $US 100 million to start operations for a period of five years. The pledge was to build the technology centre in Copenhagen, set up a procurement system and a knowledge management system, and start delivering technical assistance services, communications, and networking to attract network members and build partnerships. After another round of negotiations, the CTCN was offered $US 50 million—only half of the original budget in the proposal. In addition, donor parties requested the money to be 'earmarked', meaning that donor countries could claim their regional priorities and the type of technical assistance they would be willing to consider either for mitigation or adaptation. From the start, northern donors tied up the resources for their specific 'cooperation' agendas, something common in development and aid, but nonetheless politically contested. These 'voluntary' contributions would be dedicated to specific criteria set by each donor, according to what they considered to be future strategic sectors that advance their interest:

> *"The money is not coming in such a way that we can operate effectively. We need to wait for when the money is actually here and then immediately deployed. Donors have their own timetables, which are different from ours. A lot of this kind of politics comes from more than 12 different donors, each one of them with their attached conditions and different reporting requirements. It's very difficult to master that."* (CTCN Technology Manager, UN-City, Copenhagen, Denmark, September 2017)

The expert's perspective indicates donor reporting experience as a time-consuming and challenging activity that has to satisfy different needs. Furthermore, the institutionalisation of transfer is a complex process that involves convincing donors to make budgets sustainable to run operations successfully. Over the twenty-five years of the UNFCCC, the system's architecture has deepened structurally and become more complex in its finance and technological instrumentation. 2015 marked the Paris framework's introduction, together with an operative redesign: The Technology Mechanism and the Financial Mechanism. Together, they articulate an extensive socio-technical network of institutions and experts, each with their respective rules and procedures, incumbents, connections and budgets. They all blend into a highly bureaucratic space that constantly attempts to renegotiate its boundaries, add more layers of rules, and formalise a global cooperation network for technology. Expert-based action under the UN system does not exempt from controversy dependence on northern countries' global power structures. The following section shows some of the interactions of international agents that negotiate the terms of reference by which the global apparatus is expected to perform and highlights the underlying assumptions embedded in the institutional aims and visions of change.

3.4 How are Networked Experts Supposed to Deliver Change?

A globalised formal mechanism that manages change needs a vision of *what* it wants to transform and *how* it is supposed to do it. Section 3.4 outlines key contextual conditions that drive the strategic direction of this socio-technical network.

3.4.1 Between Frameworks and Assessments

The Climate Technology Centre and Network (CTCN) runs its operations from the UN-city in Copenhagen, with two campuses hosting eleven United Nations agencies. It is one of the northern centres of intergovernmental operations. However, experts working in these settings are highly mobile. They navigate across Europe and beyond to the 'developing world'. In addition to this central UN hub, the flows of experts working in the Technology Mechanism operate at the UNEP offices in Paris, France and the UNIDO headquarters in Vienna, Austria. Finally, they coordinate with the UNFCCC Secretariat, located in Bonn, Germany. The multi-sited fieldwork allowed me to 'follow' experts, for example to Bonn and later to Bangkok. However, spending significant research time in Copenhagen allowed me to observe the CTCN daily operations and Advisory Board meetings, and have a closer look at the UNEP DTU Partnership. During my fieldwork period on these locations (2017-2019), I was able to observe, participate and generate rapport with experts involved in different organisations linked to the Mechanism. The Advisory Board meetings were an important context of interim negotiations, as well as governance arrangements, particularly when the Mechanism strategically prepared to end the negotiations for the Technology Framework. As such, this section describes interactions between negotiations spaces in Copenhagen, as well as during the COP23 in Bonn.

The sessions of the Advisory Board are part of the governance structure of the CTCN and are formed by members of the Technology Executive Committee, the CTCN, the donor countries (e.g. EU, US and Japan), the UNFCCC Secretariat, host organisations (e.g. UNEP and UNIDO), invited network members (e.g. UNEP DTU, AIT), and invited National Designated Entities from developing countries.[18] It is a biannual opportunity to assess the

[18] Observed during the 10th Advisory Board meeting to the CTCN at the UN-City in Copenhagen, Denmark, 29th August – 21st August, 2017: https://www.ctc-n.org/calendar/events/10th-ctcn-advisory-board-meeting

implementation of the Mechanism, discuss challenges and opportunities, and advance preparations for 'under negotiation' agenda items, such as the Technology Framework in 2017-2018. Consequently, the sessions form part of the accountability process to the Conference of the Parties. The Advisory Board discusses various themes concerning CTCN's operations, which are latterly synthesised into a report (FCCC/SB/2017/3, 2017). This analysis draws on the meeting processes and identifies three nodal areas for further inquiry: The Technology Framework, the Technology Needs Assessments, and the CTCN's Knowledge Management System. Together, they inform the vision and means of implementation of technology development and transfer under this socio-technical regime.

Developing an overarching guiding document with which to articulate and govern the Mechanism has been under discussion for many years. The document would be a strategic elaborated by all the stakeholders and negotiated for adoption at the Conference of the Parties. This would make it a technical document with underlying political implications. For example, in 2017 the SBSTA was still coordinating the elaboration of the Technology Framework. Several elements needed to be considered, such as the undertaking and updating of Technology Needs Assessments (TNAs), previously developed under the old 'technology transfer framework' under PSP.[19] In addition, these updates were to enhance results, especially with regards to developing countries' Technology Action Plans (TAP), linked to project ideas and preparation of bankable projects (FCCCC/SB/2017/3 2017). Such blending of the old and new frameworks meant that the Technology Needs Assessments conducted under the Poznan Strategic Programme on Technology Transfer was valued as a 'positive' outcome of PSP, to be maintained under the 'implementation' section of the Framework. Arguably, the TNAs constituted a form of legitimised legacy that would give continuity to previous efforts made by donors, expert networks, and ultimately developing countries that had completed their TNAs in previous rounds. Consequently, the negotiation of the new framework worked favourably toward financially and technically promoting the implementation of TNAs and their results. Under the guidance of the new framework, this should lead to a greater focus on global assessments of technologies that are ready for transfer, as well as the national enabling environments for and barriers to the transfer of technologies.

In conversations with the Global TNA Coordinator, we discuss the implementation of TNAs

[19] Analysis using data from interviews with Global TNA Coordinator, UN-City, Copenhagen, Denmark, September, 2017

and their results as a point of leverage under the Technology Framework negotiations. The TNAs are, in a way, the evidence of products and project ideas, which shows some kind of 'progress' of implementation in close collaboration with one of CTCN consortium partners, the UNEP DTU. These activities are perceived as salient to the COP members because the assessment process is now directly linked to the Nationally Determined Contributions process (NDCs) and has been operating since the Poznan programme. The TNA experts comment on the long-lasting TNA programme:

> *"Global technology needs assessments started with the Poznan Strategic Programme on Technology Transfer in 2008. Since then, there has been implementation of TNAs, funded by the GEF. We had a first group of countries between 2009-2013 and a second group of countries between 2013-2017. A third group of countries will start in 2018."* (Global TNA Coordinator, UN-City, Copenhagen, Denmark, September 2017)

I could clearly observe participating in the technology negotiations and from talking to experts that the TNA is a pillar in the process. However, why are these assessments perceived to be so crucial to the Convention? Technology Needs Assessments are supposed to be a 'country-driven process'. National experts carry out these technical evaluations under UNEP DTU partnership guidance, which provides capacity building, methodology, and tools tailored to each country's specific requirements. As I expand in Chapter 4, it is through these country-driven processes that national experts build capacity to demonstrate feasibility for technology transfer projects and the commitment to NDCs and the work of the UNFCCC on technology. Further, through the TNAs, countries seek legitimacy to access funds at a later stage when applying for development financing in the context of CTCN and the GCF. The importance of the TNA process lies in the perceived assurance of quality of the assessments; in addition, its content serves as a roadmap for the transfer of specific technologies (UNEP, 2009). These processes support the national designated organisation of expertise in a given country to embed the assessment report with the rest of the Convention processes such as NDCs and NAPs are therefore supposed to generate coherence at the national level (Olhoff, 2015). How each national institution uses the technology guidelines of UNEP DTU and ultimately identifies what is needed—and what is not needed—is said to be up to the national experts. However, how experts assess which sectors and which technologies should be prioritised based on this external guidance is subject to debate.

The deliverables, on the other hand, which are the responsibility of the Technology Mechanism, now must be in coherence with the TNA process as stipulated in the Technology Framework. The suggested approach to 'technology' when conducting TNAs at country level is supposed to be 'universal'.[20] It is based on agreements of equal distribution under limited resources for countries conducting TNAs, which means each country would have approximately $US 150,000 available for their in-country assessment work over a period of three years. Meanwhile, UNEP is the official implementing agency for the TNAs through the UNEP-DTU partnership, and the outcomes are reported to UNEP and the GEF. The UNEP-DTU partnership has become the implementer of the project at a country level, whilst also engaging at the international policy level and in climate negotiations. The UNEP-DTU partnership has been engaging the Convention much more than in previous years in order to stay up to date on current Party dialogues and decisions being made. TEC created a specific TEC/TNA Task Force for this purpose (TEC/2015/11/6, 2015). Thus, the TNA process has become a fundamental building block for the technology stream of cooperation under the UNFCCC.

At the country level, several challenges are facing the TNA process. For instance, national agencies and national designated entities (NDEs) have pre-existing expectations about the 'transformational changes' that TNAs are supposed to bring with limited resources and funding. We discussed with the TNA expert, the fact that external processes are not always aligned with national strategies is another challenge; the entire delivery structure and systemic issues can become very complex and decoupled from other activities:

> *"This is, of course, also a question of donors and projects aligning considering it's a two-way process involving countries and national stakeholders. It is also about power relations and different types of interests that normally happen in every country. Optimally addressing these challenges would mean that projects and TNA processes are conducted in a way that they feed into each other and produce synergies that are cross-sectoral and based on collaboration."* (Global TNA Coordinator, UN-City, Copenhagen, Denmark, September 2017).

Therefore, already at a high-level governance, there are institutional framework challenges to the effective implementation of the ambitious frameworks such as the Paris Agreement and its linkages with subprogrammes that supposedly feed into each other such as the TNAs, the NDCs and the work of CTCN, for instance. However, national-level institutional enablers and capability building are still a major gap, as mentioned during the Advisory Board meeting in 2018. The Framework does mention a stronger turn towards intuitional environments, however, there is still much distance between the ambition and the implementation and results. For instance, the TNAs were initially divided into 'hardware,

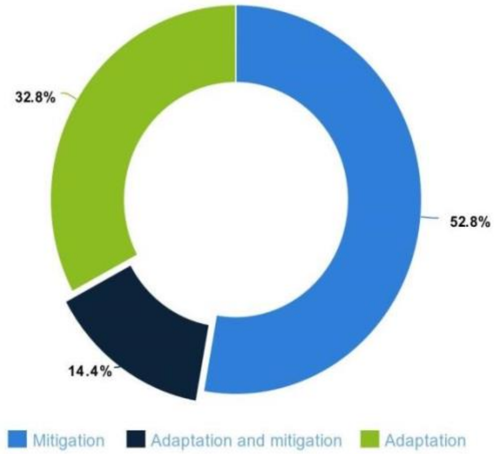
[20] Analysis using data from interviews with Global TNA Coordinator, UN-City, Copenhagen, Denmark, September, 2017

software and orgware', a taxonomy which derived in part from the older literature covered by the IPCC special report on technology transfer (IPCC, 2000), and from negotiations (UNFCCC, 2009). The evolution of the Technology Framework and the influence of 'innovation' approaches by the Technology Executive Committee (TEC, 2015) have brought this technocratic division into question. However, this is a recent development. For example, coastal zone, water and agricultural-related technologies are normally more heavily aligned with hardware; consequently, as countries identify their technology needs, they tend to prioritise 'harder' aspect of technologies, such as dams and coastal protection systems, according to their perceived relevance (Nygaard & Hansen, 2015). However, even if the TNA results come from national consultants, they remain based on TNA guidebooks, informed by the technologies suggested by the UNEP-UDP partnership.[21] In this sense, the organisation has an indirect influence on the decisions that consultants might take when conducting such assessments.

The national Technology Action Plans (TAPs) that result from TNAs are likely to include in their scope not only the types of technologies identified and prioritised for transfer, but also deeper analysis of market availability and other feasibility studies on attracting funding from donors.[22] The way expectations are managed in these networked spaces, how national experts decide which technologies to adopt, and how they appeal to donor interests for technical assistance under CTCN in preparation for subsequent piloting and readiness assessments for the GCF in later stages, all indicate a large bureaucratic process not at all exempt from uncertainties, divergent values, incumbent interests, and politics. The case of adaptation technologies illustrated this dynamic earlier on. For example, adaptation is more difficult than mitigation to justify in technical papers, because mitigation focuses on earlier actions, which means clearer methods have been developed for providing indicators and measuring impact in the short to medium term—much more difficult to do for adaptation. Currently, the main challenge facing adaptation, as discussed with the CTCN Adaptation Manager, is finding an appropriate form of measuring impact, as with water and agriculture, for example, adaptation actions are more in the long term and engage more the national processes, long-term planning and data collection, all of which need coordination, time and resources. It is tough to measure impacts on adaptation, but it might be possible to provide qualitative indicators in the long term.

[21] Analysis using data from interviews with TNA Specialist, UN-City, Copenhagen, Denmark, September 2019
[22] Analysis using data from interview with Global TNA Coordinator, UN-City, Copenhagen, Denmark, September, 2017

Figure 10 Distribution of Requests by Objective



Source: CTCN Report, 2017

Figure 10 shows the distribution of request by objectives by mitigation (52.8%), adaptation (32.8%) and cross-sector (14.4%). Even though TNA reports have an adaptation component, they initially reflected a preference for mitigation. When countries decide to look at TNAs, their NDEs are mainly officials working in ministries and thus rarely equipped for the tasks involved in comparing and evaluating the option's suitability, as trained engineers might be. Instead, they usually opt for what is easier to justify—in most cases, mitigation. Similarly, the CTCN collaborates with countries until the requests made are eligible to be sent to economic feasibility by the GCF. One consequence is that countries either won't have their TNAs completed before submission, or they will not use the TNAs appropriately to guide their processes, resulting in a number of projects being mis-prioritised at the crucial endpoint.[23] Furthermore, the CTCN may well face financial constraints due to a lack of funding and decide to implement a reduction to one technical assistant per sector per country annually, making implementation of additional requests contingent upon funding from the GCF.[24]

With CTCN membership having grown to about 400 members at the end of 2017, it is possible to imagine that members representing North and South are roughly half and half. However, an examination of who received the assignments through the international bidding process reveals that all implementing countries come from the Global North. The hypothesis at the CTCN was that developing countries were not able to make bids that satisfied the required technical level and rating standards for technical and financial

[23] Analysis using data from interview with CTCN Adaptation Manager, UN-City, Copenhagen, Denmark, September 2017
[24] Analysis using data from interviews with CTCN Director, UN-City, Copenhagen, Denmark, September, 2017

feasibility from GCF. Were the bids of poor quality? Or were the offers to implement solutions more expensive than the ones from the North? One issue might be that developing countries don't have the capacity for, knowledge of, or perhaps experience in making effective bids, meaning the CTCN itself might need to develop a decision support system and shift its focus to capacity building.[25] The CTCN also stated to the advisory board that its ongoing activities follow the key themes of the Technology Framework, including innovation, implementation, capacity building, enabling environments, collaboration, and stakeholder engagement and support. The Advisory Board has suggested, *inter alia*, to foster further collaboration with NDEs with regards to the implementation of Nationally Determined Contribution (NDCs), as well as include regional Technical Assistant requests. With this, they aim to promote collaboration between GCF and GEF, extend outreach to industrial associations, expand skills and create partnerships to build complementary strengths of existing services, and finally create awareness of additional resources such as pro-bono support (AB10/CTCN/2017, 2017).

[25] Analysis using data from interviews with CTCN Knowledge Manager, UN-City, Copenhagen, Denmark, August 2017

3.4.2 The CTCN's Theory of Change

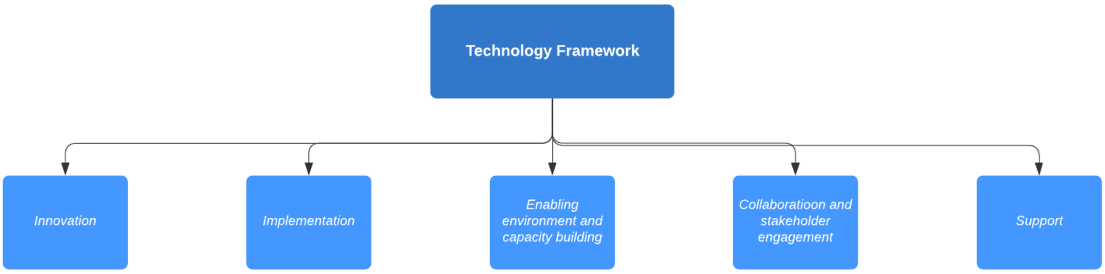
Formally, the Climate Technology Centre and Network aim to stimulate technology cooperation and foster technology development and transfer to serve the Convention's objectives. It provides a range of technology and knowledge services to organisations located in developing countries in 'need' of assistance or access to information about 'climate technologies' targeted to specific sectors on mitigation and adaptation (CTCN, 2019). It is also intended to facilitate collaboration through its global knowledge network.

CTCN is a specialised global knowledge network covering the transfer of technologies and expertise to developing countries. The CTCN built a theory of change to guide its activities and intended impact. In studying up the organisation, I was able to talk to many researchers and experts with links to the CTCN, many of whom openly expressed their reservations when it came to making the theory of change an operational impact model in the context of the organisations. In 2017, I was present when the SBSTA requested the CTCN to prepare a report on mapping climate technology transfer activities against implementing the objectives set out in the Paris Agreement. It is important to come back to the point in which the original Technology Transfer Framework (PSP) appeared in 2001, although its role was never fully agreed upon, as opinions diverged around what it should contain and how it should be made operative to deliver impact. Similarly, the formation of a new Technology Framework needed to build on concise and 'balanced' and comprehensive approaches to allow more flexibility than the previous TFT under PSP (FCCC/SB/2017/3, 2017).

As it is the translation of policy areas that such a framework needed to cover, the agreement should include innovation, enabling environments and capacity building, implementation, stakeholder engagement, and support. The idea was to overcome the previous frameworks, which was considered a technocratic approach to technology. However, since the inception of PSP's and later negotiations about writing a new framework, there were continuous deliberations about these key documents' principles and structure. Much to my understanding, generating a window of opportunity to negotiate a new framework took about ten years. Out of many concerns, it has been needed to include these expert communities called a 'transformational' approach. During my interactions with CTCN experts and participation in the advisory board meeting as an observer, I understood there were just a technical document and a political document that would steer the direction of activities leading to the vision and impact of CTCN and the Technology Mechanism more broadly.

The Technology Framework was finally adopted at COP24 in 2018. It served to establish a deal––a guiding principle, for a decade of negotiations. Figure 11 shows the TF's main components. Consequently, over the last four years, this document has become the strategy to implement CTCN's theory of change and directing the structure of the Mechanism's respective mandates. It proposed action around these five themes and steered the CTCN Programme of Work (PoW) forward after five years of implementation.

Figure 11 Technology Framework

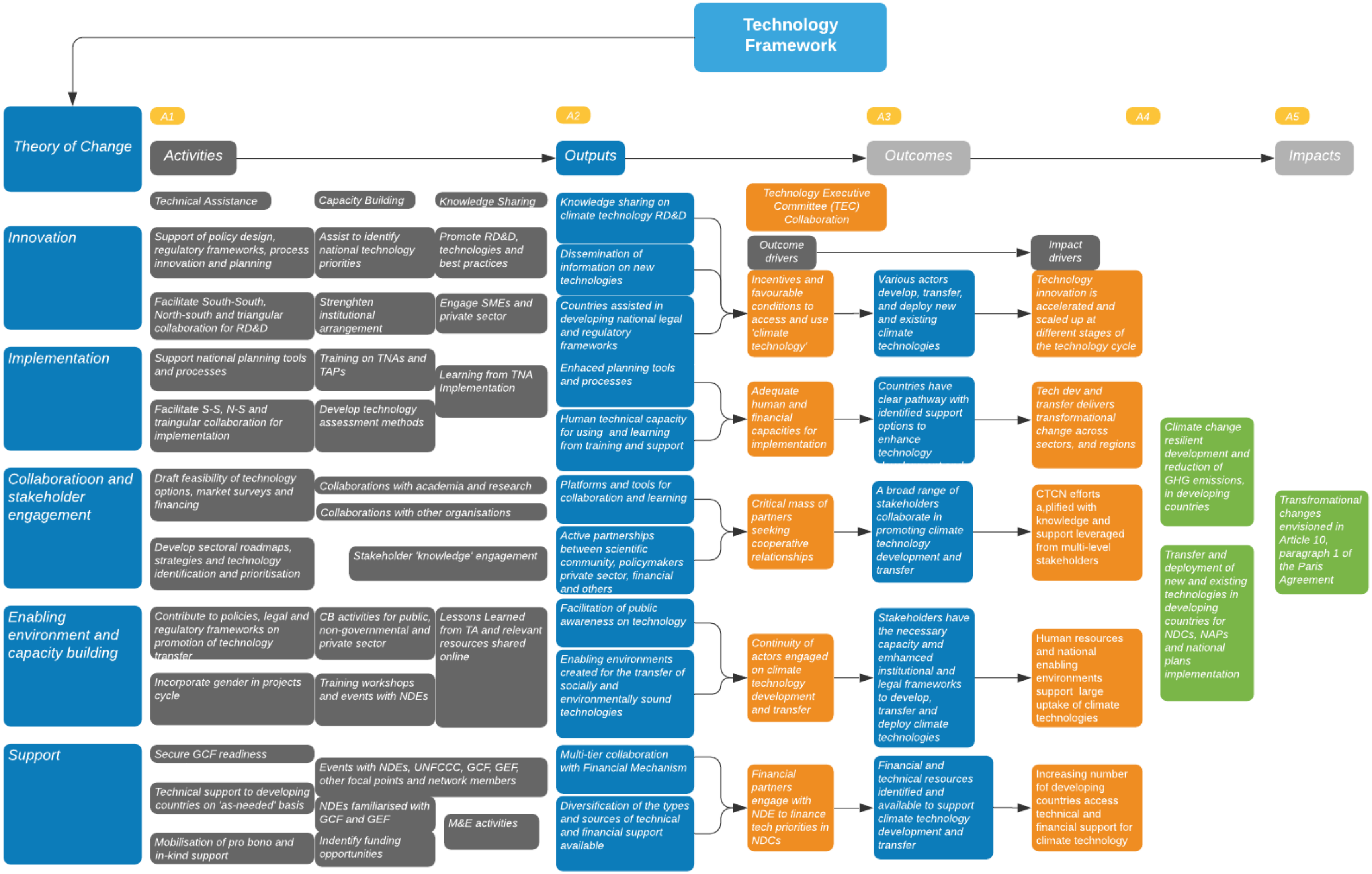


Source: Author, 2020

Consequently, the TF acts as the strategic document intended to articulate the system's management and define its role in improving the effectiveness of the mechanism. It assumes the theory of change of 'low carbon, climate-resilient development' by addressing the so-called 'transformational changes' envisioned in the Paris Agreement and a long-term perspective on technology development and transfer. However, there is much to understanding when it comes to actions, which the TEC and CTCN must take through their monitoring and evaluation system. The programmatic activities outline are to be undertaken in collaboration with the policy arm of the mechanism, the Technology Executive Committee, assuming coherence with and corresponding guidance from the Advisory Board and the Parties to the UNFCCC.

The Knowledge Management System previously developed a Monitoring and Evaluation System (M&E) to map, evaluate and communicate the activities leading to results and expected impacts. This system was originally developed by DNVGL, which also built the overall CTCN architecture. However, the Norwegian organisation no longer participates in the management of the CTCN knowledge system.[26] The activities outline in CTCN's theory of change and programme follow a rationalistic approach to most development programmes, seeking control over several activities, outputs, outcomes and impact. It is a means to an end: the delivery of transformational change to the Paris Agreement aspirations to low carbon climate-resilient development through technology transfer. From the outset, I can see why this could be problematic. Theories of change are always based on a set of assumptions. The questions if how are these assumptions ultimately treated and managed in order to advance the organisations towards the desired impact? Is the vision of impact even clear? For instance, CTCN relies on five main assumptions. The first assumption (A1) supposes that all activities are secured by reliable funding. The second assumption (A2), regarding outputs, assumes sufficient human capacity among the CTCN, NDEs, and other stakeholders to undertake their work (PoW), which I empirically explored in Chapter 4 and 5 it comes to implementing technology transfer in developing countries. The third assumption (A3) starts at the outcome phase and presupposes that the private sector has engaged in collaborative R&D and technology transfer under the CTCN. The fourth assumption (A4) imagines international and national political initiative, commitment to collaborative RD&D, and incentive are in place. Finally, the fifth assumption (A5) regarding impact is that the UNFCCC remains a crucial body for facilitating and supporting global climate solutions through technology development and transfer. See below Figure 12 CTCN's Theory of Change and Programme of Work.

[26] Analysis using data from interviews with CTCN Knowledge Specialist, UN-City, Copenhagen, Denmark, September 2017



Technology Framework
Theory of Change
A1
Activities
A2
Outputs
A3
Outcomes
A4
A5
Impacts
Technical Assistance
Capacity Building
Knowledge Sharing
Innovation
Support of policy design, regulatory frameworks, process innovation and planning
Assist to identify national technology priorities
Promote RD&D, technologies and best practices
Facilitate South-South, North-south and triangular collaboration for RD&D
Strenghten institutional arrangement
Engage SMEs and private sector
Implementation
Support national planning tools and processes
Training on TNAs and TAPs
Learning from TNA Implementation
Facilitate S-S, N-S and traingular collaboration for implementation
Develop technology assessment methods
Collaboratioon and stakeholder engagement
Draft feasibility of technology options, market surveys and financing
Collaborations with academia and research
Collaborations with other organisations
Develop sectoral roadmaps, strategies and technology identification and prioritisation
Stakeholder 'knowledge' engagement
Enabling environment and capacity building
Contribute to policies, legal and regulatory frameworks on promotion of technology transfer
CB activities for public, non-governmental and private sector
Lessons Learned from TA and relevant resources shared online
Incorporate gender in projects cycle
Training workshops and events with NDEs
Support
Secure GCF readiness
Events with NDEs, UNFCCC, GCF, GEF, other focal points and network members
Technical support to developing countries on 'as-needed' basis
NDEs familiarised with GCF and GEF
M&E activities
Mobilisation of pro bono and in-kind support
Indentify funding opportunities
Knowledge sharing on climate technology RD&D
Dissemination of information on new technologies
Countries assisted in developing national legal and regulatory frameworks
Enhaced planning tools and processes
Human technical capacity for using and learning from training and support
Platforms and tools for collaboration and learning
Active partnerships between scientific community, policymakers private sector, financial and others
Facilitation of public awareness on technology
Enabling environments created for the transfer of socially and environmentally sound technologies
Multi-tier collaboration with Financial Mechanism
Diversification of the types and sources of technical and financial support available
Technology Executive Committee (TEC) Collaboration
Outcome drivers
Impact drivers
Incentives and favourable conditions to access and use 'climate technology'
Various actors develop, transfer, and deploy new and existing climate technologies
Technology innovation is accelerated and scaled up at different stages of the technology cycle
Adequate human and financial capacities for implementation
Countries have clear pathway with identified support options to enhance technology development
Tech dev and transfer delivers transformational change across sectors, and regions
Critical mass of partners seeking cooperative relationships
A broad range of stakeholders collaborate in promoting climate technology development and transfer
CTCN efforts a,plified with knowledge and support leveraged from multi-level stakeholders
Continuity of actors engaged on climate technology development and transfer
Stakeholders have the necessary capacity amd emhanced institutional and legal frameworks to develop, transfer and deploy climate technologies
Human resources and national enabling environments support large uptake of climate technologies
Financial partners engage with NDE to finance tech priorities in NDCs
Financial and technical resources identified and available to support climate technology development and transfer
Increasing number fof developing countries access technical and financial support for climate technology
Climate change resilient development and reduction of GHG emissions, in developing countries
Transfer and deployment of new and existing technologies in developing countries for NDCs, NAPs and national plans implementation
Transfromational changes envisioned in Article 10, paragraph 1 of the Paris Agreement

At first, the ToC looks comprehensive. It follows the guidance of the Technology Framework. However, it is important to examine the assumptions and look for the baseline facts and indicators to illustrate the current gap between the actualised version of the CTCN's theory of change and the 'practice' of change five years after inception.

The strategic drivers set to change business as usual are based on a sequential pathway that follows the Technology Framework. A contributing factor is that the CTCN is under control' and expected to influence external stakeholders and actors. For example, it is engaged with countries, human resources and other resources needed for large-scale action in the pursuit of 'transformational change'.[27] On the other hand, the five main assumptions represent the areas where the CTCN supposedly has less control—or no control. In all themes covered by the Framework and ToC, the outcomes result from the direct outputs produced by the organisation's activities. The overall aim is to generate the conditions under which it is possible to pursue these 'high-level' outcomes. Since the CTCN carries out not all the actions, it is the global network and its partners that have to deliver new capacities for innovation and undertake research, development, demonstration and deployment of technologies (CTCN, 2019). The four 'stages' are frames for a cycle process that further assumes the idea of incremental progress in a technology continuum. For instance, the proposed outputs take the form of tangible materials, contents, persons or organisations engaged on specific tasks or actions. They aim, *inter alia*, to demonstrate the extent to which the needs of those seeking CTCN's services have been met. For these reasons, all CTCN activities revolve around its service areas and have a focus on outputs, as these are short-term gains that serve for monitoring and reporting (2/CP.17A.VII).

With regards to the Performance Measurement Framework (MFP) developed by the M&E consultants, the primary principle is 'results-based management', which guides the rest of the M&E activities. Although it is not possible to discuss all elements of the MFP here, it is important to note that the framework seeks performance information around indicators, baseline data, targets, data sources, frequency of collection, and responsibilities (CTCN 2019). While the list of all indicators is too extensive, certain key gaps are noteworthy, especially the recurrent lack of information regarding baseline data on indicators, followed by lack of targets. For example, Indicator 1.b. on impact, *anticipated increased economic, health, infrastructure, built environment, or ecosystems resilience to climate change impacts reported by CTCN participant countries*, has no baseline and no target. Another example

[27] Analysis using data from interviews with CTCN Knowledge Specialist, UN-City, Copenhagen, Denmark, September 2017

relates to the adoption and use of new and existing technologies in developing countries. Its indicator 2.a. *anticipated number of technologies transferred or deployed as a result of CTCN support,* again shows no baseline and no target. Further examples include, *number of countries receiving CTCN support for national institutional, legal and regulatory frameworks to encourage climate technology RD&D and take up*, or *number of countries that strengthen national systems of innovation as a result of CTCN support*, both of which have no baseline and no target. Many more indicators for this theory of change do not present adequate data or consistency in terms of Monitoring and Evaluation. Several other issues call for further inquiry. First, there is a gap between what the Mechanism has been doing over the past five years (2014-2019) and how it intends to continue. The M&E framework is supposed to provide information about previous baseline data, which has not yet been added, to clarify the previous outcomes from which the CTCN is progressing. Another, perhaps deeper issue is the vague meaning of such indicators and what they are intended to show. For example, the CTCN is supposed to 'strengthen national systems of innovation' as well as implement and mobilise finance, capacity building, and deployment of technologies globally—a complex and ambitious task in itself. In addition, its activities seek to generate innovation and deliver 'transformational change' across sectors and regions, as environed in the Paris Agreement. It is not yet clear what transformational change really means in practice, how it is going to be targeted, and ultimately what these transformational goals are when it comes to linking technology and sustainability, knowledge support, enabling environments, and financial aid for substantive changes in sustainable development.

3.4.3 The CTCN's Knowledge Management System (KMS)

The CTCN was originally designed to be a small organisation. It will normally receive requests directly or through colleagues in Paris and Vienna. Applications are reviewed and evaluated following the scope of CTCN and are normally slightly refined before a discussion with the NDE takes place. Once there is proof of concept, the CTCN and the NDE agree to bring it to the consortium partners, who then discuss it among the 11 partners, including the UNEP-UDP and the UNEP-DHI, to decide whether they have interest in taking it forward. As the CTCN Knowledge Manager explained to me, since there is a contract with the partners, it is the CTCN's right to determine who is best suited for implementing a given project. They develop a proposal in coordination with the national stakeholders, and from that point, it progresses to the bidding process with the rest of the network members. It then a task of managing knowledge between partners as well as providing evaluation and guidance of the process:

> *"Some of the Knowledge Management work that we have done on the internal side has been to support our processes and most of our technical assistance so that as the number of requests were growing the TA team could have a way of moving these things faster and also to be able to monitor the progress of different components."* (CTCN Knowledge Manager, UN-City, Copenhagen, Denmark, August 2017).

The Knowledge Manager shared that the company that created the CTCN's knowledge management system was initially DNVGL, an international accredited registrar and classification society based in Oslo, Norway. Therefore, an external private company was in charge of the content development strategy and planning, which has changed after the company finalised its contract with CTCN in 2018. DNVGL was also instrumental in all aspects of CTCN software and network system (DNVGL, 2018). The CTCN's KMS includes managing a growing network of more than 550 members; it provides content services and technical assistance opportunities and activities, events, capacity building, technology webinars, and technology information from network members and knowledge providers. Therefore, a well-functioning platform is essential to the delivery of technical assistance and tracking the progress and impact of CTCN.

All CTCN technical assistance and non-technical assistance must be reported on to the Convention. Individual donor countries have their own specific requirements and objectives that the CTCN has to meet to demonstrate that its contributions are effective, accountable and transparent. In addition, the CTCN is mandated to engage in collaboration, capacity building and knowledge-based activities beyond its technical assistance function. Particularly when sharing knowledge, the CTCN's mandate is to pursue the development of a functional KMS to facilitate access to a broad range of climate technologies and online information, and its operations require support via intranet. The Paris Agreements and the 2030 Agenda for Sustainable Development inform the context and framework within which the CTCN defines, develops and reports its activities and impacts. The scope of the CTCN encompasses three key services, and the SDGs have been selected as a broader measure of the CTCN's "intended impacts."[28] Such impacts will of course vary according to differing national realities and capacities. Through the CTCN's KMS, network members can access climate technology data and upload and share case studies and publications, allowing the system to categorise and tag keywords and sectors. In turn, this information is displayed in

[28] Analysis using data from interviews with CTCN Director, UN-City, Copenhagen, Denmark, September, 2017

each member's website profile, creating a battery of projects by country and sector to which stakeholders have immediate access. Consequently, when stakeholders and NDEs look for information, they can find projects, policy tools and case studies to inform their work.

The network should then be a platform for collaborating with and enhancing the work of the CTCN, its consortium, and member parties, thus serving the implementation of the Technology Mechanism. Members increasingly demand to be included as part of the network, and the network is readily expanding. However, the network architecture has not necessarily contributed to the successful alignment of its two central bodies, the TEC and the CTCN; instead, there is room for closer alignment in their work and collaboration and expanding their regional focus. From a management perspective, it has been challenging to coordinate a rapidly evolving global network:

> *"Once we started to expand, we realized quickly that in order to have a regional focus we needed people in those regions, because in order to keep us operative, you need almost day-to-day relationships, especially with the NDEs to help them make things go forward or address key issues. Also, local people will feel more at ease contacting people in their region than getting in touch with people from northern Europe, which can be intimidating."* (CTCN Knowledge Manager, UN-City, Copenhagen, Denmark, September 2017).

In addition, most technology transfer activities come from northern countries, even though there is a balanced membership of from both North and South organisations. As expressed by the manager, the process of outreach is not excepting from power structures which can make it less accessible or intimidating for developing country users, which is why there is a need to expand regional presence. Northern actors need to be more approachable and partner with local organisations and companies, not to mention collaborating with southern countries in the implementation of response plans. In these ways, capacity could meaningfully transfer through practice at various levels. This process is not yet underway. Northern bidders implement projects in developing countries covering only specific, targeted outcomes, and then leave. However, there has been a successful case of triangular cooperation developed by DHI, whereby the company transferred a hydrological model to Jakarta, the result of which has been a scaling-up of flood modelling to other cities in Asia, involving capacity building and knowledge sharing.

The fact that so much rests on the NDE can sometimes be problematic. National Designated Entities play a significant role in facilitating the CTCN's work. It is difficult for them to oversee each and every detail of a complete project, as they are also busy government officials responsible for several other tasks. Northern countries are able to implement climate technology transfer because they have the expertise and resources to work with the complex financial mechanisms of bodies such as the GEF and GCF. Might the platform then support the integration of a diversity of local partners, to enable them to finance their own solutions? In that sense, the CTCN could act as a central node and network management system, supporting the coordination of TNAs and financial mechanisms. More coherence between the TEC and the CTCN could support a direct line to fund projects. Creating a more dynamic system that reduces unnecessary bureaucracy, works with credible organisations and recognises the expertise in the Global North and South is a valid goal for such an organisation.

3.5 Discussions: Fragmented Bureaucracies and Global Knowledge Networks. Challenges Ahead

The world is increasingly interconnected. However, in an age driven by information and communication technologies, traditional global governance structures must adapt to the accelerated, interdependent landscape face by fragmented bureaucracies and divergent national interests (Flew, 2018). Furthermore, this increased connectivity and its dynamism stem from interdependencies that are inherently difficult to trace. Hence the persistence of unstructured, complex 'wicked' issues that characterise the contemporary world of climate governance (Bremer, 2013; de Bruijn & Heuvelhof, 2018; Lorrae van Kerkhoff, 2013). This fragmentation is linked to the problem of scale and is twofold. On the one hand, there is a growing multiplicity of actors, located at multiple scales of governance, attempting deliberate changes in socio-technical systems (Patterson et al., 2017). On the other hand, the existence of a global climate change regime has occupied the attention of most politicians and experts, as they continuously focus on renegotiating its boundaries, optimising it, and seeking to 'control' the dynamics of this large-scale socio-technical system under the UNFCCC (Clark, 2014). The fragmentation of global environmental governance has had the effect of reinforcing 'black boxes' of unknown feedback (Anderson & Parker, 2013a; De Oliveira et al., 2019). For example, institutional systems seeking strategic influence in global networks are growing in capability while facing unrecognised challenges to effectively delivering their desired changes. These socio-technical systems are large, complex and depend on global knowledge networks, which in the case of the Technology Mechanism are slow to react to changes and resistant to internal restructuring. Changes inside this Mechanism requires long-term institutional processes dependent upon fragmented power structures, incumbent actors, and closed protocols and procedures, which take a long time to get negotiated and implemented.

This chapter has explored the international formal response to climate change by means of global governance negotiations and arrangements adopted under the UN-system. The institutionalisation of climate policy by the intergovernmental structure has attempted to govern the integration of scientific evidence with the technical and socio-economic aspects of climate change. Over the years, however, the global response has proved disjointed and problematic to govern. For instance, despite the ongoing institutional process at the United Nations Framework Convention on Climate Change, the world has not yet succeeded in stabilising greenhouse gas concentrations in the atmosphere. As the Keeling curve shows, since the days of the Kyoto Protocol, concentrations of CO2 in the atmosphere have increased from over 359 parts per million to as high as 415 ppm in 2019 (UNFCCC 2019). The global response to climate change now involves a myriad of organisations from all sectors of society pursuing multiple agendas. As a result, what experts referred to as the 'global climate regime' under the Convention results, in practice, in a fragmented bureaucracy (Edler & Kuhlmann, 2008; van Asselt, 2013). Nevertheless, the negotiation of technical procedures under the regime continues to evolve, and more bureaucratic layers are added in the form of expert bodies, committees, and mechanisms that look to enhance its effectiveness and pursue 'bolder' visions of change. The Convention seeks to operationalise its most critical commitment: the Paris Agreement.

Despite the above conditions, many still seek to participate. Experts and expert organisations pursue involvement with the UNFCCC for various reasons, ranging from genuinely aligned agendas to strategic visibility and eligibility for funding. Increasingly, its development has included the private sector—now in the form of a network with lobbyists from many industries. Deliberative practices seek to steer specific agenda items, influence a negotiation, or advocate for a Technology Framework that sets 'yet to be defined' transformational goals. In this formalised setting, not everyone gets to participate. Demand for specific types of expertise and the formal accreditation process are selective for everyone, including political delegates, negotiators, and observers. Therefore, only a highly competitive and active network of experts manages to play a role in the formal climate negotiations each year at the COP's 'closed' negotiation sessions.

The technology and expert-based mechanism of cooperation is characterised by the constant mobility of representatives—incumbents who engage in the climate regime but also operate beyond its domain at different scales of governance. Their activity is not easy to grasp and requires following and mapping their activities and connections as they expand into a seamless web of interactions. Following particular rules and protocols, the Convention offers a highly technical space for science diplomacy and the negotiation of expertise in climate policy. Paying attention to the knowledge negotiations under the Technology Mechanism shows possibilities and challenges for unpacking dynamics and implications of one of today's most relevant global efforts to coordinate climate action.

As previously illustrated, technology transfer activities are salient and growing. They are perceived as the ultimate means to bring the business and public sectors into cooperation. From this angle, the strategy of developed country donors has been to negotiate the terms of reference through the finalisation of the Technology Framework and CTCN's theory of change. This has been observed in the incentive structures that guide its implementation. Many assumptions would need to be tested in order to ensure its functionality. For example, the model of 'transition' supposes that all activities have secured funding, or that sufficient human capacity is in place to deliver the changes envisioned in the framework. Or it assumes that the private sector is actively involved in the process, and that political action will lead to appropriate regulations and policies at the national level that encourage collaborative RD&D. A point of controversy, however, is that it has not been easy for developed and developing countries to agree to one vision, especially with regards to repository of resources, funding streams, and intellectual property rights and ownership. On another front, the technology framework is meant to provide overarching guidance and scaffolding for implementing technology-based solutions. For all its challenges, the international community recognises that a global network dedicated to enhancing collaboration is a functional means of spreading efforts across the stakeholder community and speeding up the goals of the Convention.

However, how does this happen in practice? Does such a framework support government across countries to deliver on the Paris Agreement? And does high-level guidance serve to steer governance dynamics in a way that influences socio-technical system changes of this scale? If global knowledge networks are scaling up, becoming more sophisticated and challenging to track, then networks—in the plural—build and change faster than the capacity to govern them. Furthermore, as noted before, a technology framework serving a formal global network requires that actors articulate visions, negotiate expertise, and agree on a common agenda that satisfies organisations on the ground.

The assumptions embedded in the Technology Framework that refer to 'innovation' through the 'technology cycle' frame this process as logical technical steps. The generation and advancement of technical knowledge are assumed to lead to positive innovations through technological maturation and the expansion of commercial applications based on technological diffusion. Consequently, the 'cycle' approach could be criticised for being overly simplistic, neglecting the diverse web of social and material conditions that play out in socio-technical systems (Gudowsky & Peissl, 2016; Stirling, 2019). Its assumptions offer a reductionist approach to the socially constructed conditions under which any socio-technical development takes place (Bijker et al., 2012).

Under the SBSTA, the elaboration of the Technology Framework was an opportunity to advance transformational change—on paper. The boundary practices across SBSTA have had the objective of 'generative effectiveness' (Young 20018). However, there is much to understand about how this objective translates into action. The SBSTA serves as the platform for translating a scientific assessment made by the IPCC into policy documents for the deliberation of the Conventions agenda items. More often than not, despite the formal arrangements under the SBSTA, deliberations on divergent matters about reasons and means—including cultural, economic and political motives—affect the terms of reference.

Over the last few years (2017-2019), several discussions took place at the climate negotiations about the problem of 'overlapping' efforts to deal with climate change in its various forms. For example, recent debates considered how to integrate the different agendas of the Paris Agreement with the Sustainable Development Goals and the Sendai Framework on Disaster Risk Reduction (AC/2018/13 &14). Even more recently, nearly four hundred experts met at the first Climate and SDGs Synergy Conference in Copenhagen (2019). The discussions pointed to two key themes: lack of coordination and need for integration. This included the urgency of building further consensus and stronger connections between the implementation of the Paris Agreement and the 2030 Agenda on Sustainable Development.

The conference participants agreed that this was one of the best opportunities to pursue 'systemic change'. A UN DESA and UNFCCC 'global knowledge network' could serve as a platform to build on the inputs of the conference that was supposed to take place at COP25 in Spain but did not go through. This situation poses challenges for integrating a climate action framework in general. The large-scale regime faces fragmentation, lack of coordinated policies, and inclusion of agendas. Significant challenges lie ahead as these organisations pursue the legitimacy required to implement these agreements. Related is the question of these systems' capacity to absorb and integrate complex knowledge while maintaining independent functions, structures and feedback mechanisms. Therefore, capacity remains one of the critical expectations these systems are supposed to meet. Furthermore, the institutionalisation of capacities should, in principle, lead to more empowered and knowledgeable decisions about finance, innovation, and strengthening policy instruments, as well as changes in behaviours and lifestyles (SR15, 2018). Therefore, institutional capacity should be able to effectively integrate complex knowledge to make decisions about uncertain climate futures.

The Technology Mechanism sees the ability to coherently formulate and implement environmental planning (i.e. National Adaptation Plans (NAPs)), technology roadmaps (i.e. Technology Action Plan (TAPs)) and mitigation planning (i.e. Nationally Determined Contributions (NDCs), Nationally Appropriate Mitigation Actions (NAMAs)), as well as other planning instruments as critical to its success. Evidence also points to the need for support from public and private sources and access to finance, technology development and transfer, and capacity building (these are cross-cutting themes). However, with all these international efforts from intergovernmental organisations, different countries still follow frameworks in different ways depending cultural context, political will and commitment, identified needs and priorities, funding access, and implementation capacities.

Efforts to address climate change involve a myriad of strategies, one of which is the building of formal arrangements between organisations at a global scale, generating globally networked responses. Such networks can potentially serve as knowledge platforms nurturing capacity to anticipate climate conditions and their effects (Galaz et al., 2018). There is much to understand about how organisations build such capacity over time, given a fragmented global climate regime (van Asselt 2013). In this complex and rapidly evolving context, the continuing development and spread of global networks of actors and organisations could be associated with the increasing need to mobilise expert knowledge in global environmental governance. The findings emphasise that global networks that build capacity are increasingly diverse, with changing functioning dynamics of which strategy and expertise have become the dominant drivers. What is more, global networks have produced noticeable effects and significant implications for decision-making and political processes in environmental governance.

The following chapters evaluate the tools and technologies used in future adaptation practice (i.e. climate models, hydrological models, early warning systems, and decision support systems). The rapid expansion of connectivity affects the development and mobilisation of networked actors, resulting in a loose structure with some organisations becoming central (as an indicator of strategic behaviour and influence), whilst others remain more fragmented. A closer examination of both the global patterns of network structures and the relational establishment of ties between organisations allows us to distinguish different strategies used to build the authoritative knowledge that steers environmental governance.

Chapter Four

Opening the Black Box: Mobilising Technologies and Expertise to Southeast Asia

4.1 Introduction

The travel of rationalities and transfer of artefacts encompass dense processes of long-term immersion into developmental settings and their globally interconnected networks. This chapter draws on empirical observations made between 2016 and 2019 and analyses the mobilisation of expert knowledge and technological transfer projects channelled through the Technology Mechanism to Southeast Asia. It examines how a formalised global network nurtures global policies and capacities to foster the transfer of mitigation and adaptation technologies to this region. In particular, it illustrates the realities of local experts involved in global development cooperation networks, describing the cases of Thailand and Myanmar, along with other relevant examples from the region. This chapter shows how the UNFCCC Technology Mechanism mobilises projects on the grounds and how Technology Needs Assessments are developed. It ends with a discussion about encountered realities of networked agencies, and the implications for the travelling of rationalities and mobilisation of artefacts in different contexts.

4.2 From Policies to Operations

Previously, Chapter 3 shown how negotiations based on expert knowledge lead to particular technological framings in pursuit of a coordinated global response under United Nations rules. This section describes the functioning of the Technological Mechanism, particularly in reference to the development of technology policies by the Technology Executive Committee (TEC) in tandem with the implementation of technology transfer projects through the global network managed by the CTCN. The policy arm of the Mechanism comprises a committee of twenty experts from different nationalities and backgrounds in science and policy. The committee meets biannually in Bonn, Germany to analyse policy issues emanating from the network and provide recommendations to the broader set of stakeholders working on technology policy challenges, businesses, and national entities seeking technical assistance through the Mechanism. Their work is strictly aligned with the ample vision of the Paris Agreement to support 'low-emissions and climate-resilient development' (TEC, 2017a) and the implementation of the Technology

Framework. The Committee's work plan focuses on supporting countries to incorporate the TEC's inputs and take direction from them as they build their Nationally Determined Contributions (NDCs) and National Adaptation Plans. Since the TEC's inception eight years ago, its work has evolved around the following areas: adaptation, mitigation, technology financing, research and innovation, development and transfer, technology needs assessments, and other cross-cutting issues (TEC 2019). Notably, these areas feed into the themes of the Technology Framework. Thus, over the years there has been closed policy feedback between the evaluation of the old framework, the strategic development of policy areas by the TEC, and the negotiation of the new technology framework that steers the Mechanism's global network. In order to fulfil its mission, the TEC establishes regular 'task force teams', which are groups of experts working on specific policy streams of the Framework, such as innovation and implementation. The task force teams largely consist of TEC member only, with occasional inclusion of stakeholder representatives—following the UNFCCC nomenclature—from business and industry non-governmental organisations (BINGO), environmental non-governmental organisations (ENGO), youth-non-governmental organisations (YOUNGO), research-oriented and independent non-governmental organisations (RINGO), and intergovernmental organisations (IGO). However, until 2019 there was still no available data showing evidence of real participation of wider stakeholder groups in any of the activities or inputs, apart from occasional formal representatives appointed by the Secretariat. Table 4 shows the TEC Task Forces in each area of the Technology Framework. The observer organisations include UNEP DTU, one of the CTCN consortium partners in charge of deploying TNAs globally. It also shows the CTCN and major donors acting as observers. Between 2012 and 2019, the TEC produced a series of policy outputs, which are technical policies containing strategic messages.

Table 4 Technology Executive Committee Task Forces (2019)

TEC Task Forces	Description	Observer Organisations
Innovation	Works on innovation and RD&D on mitigation and adaptation	No specific information
Implementation	Works on TNA, collaborative technology development and transfer, and uptake of existing clean mitigation and adaptation technologies	UNEP DTU Partnership
Enabling environment and capacity building	Work on creating creation enabling environments, including policy and regulatory environments, and to strengthen the capacity of developing countries.	No specific information
Collaboration and stakeholder engagement	Supports TEC collaboration with constituted bodies and stakeholders as well as engagement in the Convention process	No specific information
Support	Supports TEC work on drafting guidance to operating entities and linkages between Technology Mechanism and Financial Mechanism	CTCN, GEF GCF and AF

Table 5 Technology Executive Committee Policy Outputs 2012-2019

TEC Policy	Documents containing outputs	Number of outputs	Period	Type	Key recommendations
Adaptation technologies	TEC Brief#6 TEC Brief#5 TEC Brief#4 FCCC/SB/2018/2 FCCC/SB/2016/1 FCCC/SB/2014/3	5	2014-2018	Policy Briefs, Recommendations Conference of the Parties	→ Technologies for water and agriculture South-south cooperation, triangular cooperation, national adaptation plans, NDCs
Climate technology financing	FCCC/SB/2016/1 FCCC/SB/2015/1 FCCC/SB/2014/3	4	2014-2016	Policy Briefs, Recommendations Conference of the Parties	→ Collaboration between GEF, GCF, CTCN. Integrate TNAs with national plans (NAPs and NDCs). Facilitate market development and new business models. Capacity building for financing technology transfer. Share risk between private and public. Combine policies to attract climate technology finance. Enhance stakeholder collaboration
Enabling environments and barriers	FCCC/SB/2012/2	1	2012	Recommendations Conference of the Parties	→ Intellectual property rights and their influence in technology development and transfer. Public and private sector engagement. Engagement with international and national business communities. Access to technology finance. Activities related to technology cycle, policy and regulatory frameworks. Absorptive capacity.
Innovation, research, development and demonstration	TEC Brief#7 FCCC/SB/2018/2 FCCC/SB/2017/3 FCCC/SB/2015/1 FCCC/SB/2013/1 FCCC/SB/2012/2	6	2012-2018	Policy Briefs, Recommendations Conference of the Parties	→ The role of entrepreneurs in climate technology transfer. Challenges of innovation and technical capacity. Enhancing incubation models for entrepreneurs. Encourages GEF and GCF to improve information sharing of projects that lead to innovation. Encourages TEC, CTCN, GEF and GCF to collaborate and identify effective policies and instruments for collaborations with focus on developing countries. mobilise NDCs, NAPs and mid-century strategies. Protect indigenous and local knowledge and incorporate them in their National Innovation Systems (NIS). Enhance collaborative Research, Development and Demonstration. Strengthening technical innovation (cost-effective and better preforming). Strengthening NIS linked to climate change action. Generate links between TNAs, TAPs and NIS.

Mitigation technologies	FCCC/SB/2018/2 FCCC/SB/2017/3 FCCC/SB/2015/1	3	2015-2018	Recommendations at COP	→ South-south and triangular cooperation on mitigation technologies leading to NDCs and NAPs. Encourages research on development cooperation, including initiatives, mechanism and tools for planning and implementation. Setting standards, policies and laws that supports mitigation technologies, including industrial energy efficiency. Increased energy security. Enhance technology transfer on distributed renewable energy generation, increase efforts to reducing GHG emissions by generating low-carbon electricity, increase clean energy access and reduce dependence on imported fossil fuels.
Technology Needs Assessments	TEC Brief#2 TEC Brief#3 FCCC/SB/2018/2 FCCC/SB/2017/3 FCCC/SB/2016/1 FCCC/SB/2015/1 FCCC/SB/2014/3 FCCC/SB/2013/1 FCCC/SB/2012/2	9	2012-2018	Policy Briefs, Recommendations Conference of the Parties	→ Recognition of potential use of TNA and linkages with NDCs and NAPs. Phase I and II evaluated. Phase III (ongoing) with LDCs and SIDS to further focus on TAPs with a view to facilitate support and development of bankable projects. To mature methodology for TNA and TAP results for the international context. TNA process as added value for developing countries and in assisting the implementation of the Paris Agreement. Enhance collaboration and knowledge-sharing between national stakeholders and teams involved in TNAs and TAPS. Disseminate information on TAP implementation. Further close gap between planning and implementation of TAPs. generate a monitoring and evaluation system for TNA results. Expand funding beyond Global TNA project and implement results. NDEs are relevant players in linking prioritised technologies with technical assistance from CTCN.

Source: Author, 2019

Table 5 shows the outputs produced between 2012 and 2019. The TEC has developed a series of policy inputs to the global network by focusing on particular streams for analysis and recommendations. This stem from their programme of work runs in official meetings and events held at the Bonn headquarters. One of their main outputs is the so-called ‘TEC Briefs’, which are broad policy messages in the English language aimed to be used by a range of stakeholders at national and international levels. For example, the teams developed a compilation of best practices for southern cooperation on ‘adaptation technologies’, with specific attention to ‘knowledge-sharing’. Policy Brief Nº9, ‘South-south cooperation and triangular cooperation’, analyses how developing countries could harness development-cooperation models and generate platforms for sharing lessons learned, in order to accelerate collaboration on adaptation technologies and expert practices in the water and agricultural sectors (TEC, 2017c).

This policy brief highlights that the potential for south-south cooperation and ‘triangular’ cooperation on technologies for adaptation in the water and agricultural sectors remains mostly untapped (TEC, 2017b). In 2014, numbers from the Overseas Development

Assistance (ODA) showed total commitments in the OECD-DAC worth $US 135 billion, while south-south cooperation (SSc) was estimated to be worth $US 20 billion in 2017 (UNGA A/70/311). These numbers suggest that comparisons must be made carefully. The TEC advises governments to focus on 'knowledge and technology exchange' as the core strategy for scaling up existing aid and nurturing new forms. However, global estimates regarding SSc can differ significantly depending on the data source, and there is not yet an agreed international framework for assessing and monitoring SSc on adaptation issues (TEC, 2017). Expert consultations with developing countries emphasised the lack of access to financial resources, inadequate legal and regulatory frameworks, and insufficient organisational and technical capacity as the barriers to technology transfer on adaptation in developing countries (TEC, 2014a, 2014b). Their evaluation points to the lack of funding reflected, for example, in human resource 'gaps' and capacity to effectively engage in development cooperation activities. It outlines some of the common challenges ahead for the adaptation in water and agriculture. It acknowledges that while water and agriculture are essential for resilience and poverty reduction (and for development and well-being through improved sanitation), an estimated 60% of global agricultural output will need to rise to feed the global population by 2050, and water use for irrigation is expected to increase by at least 10% in the same period (TEC 2017). This recommendation was followed by the development of a 'blueprint' policy in combination with the UNFCCC Secretariat and the UN Office for SSc (TEC, 2018). The policy again evaluates the potential of different forms of cooperation 'from the Global South' dedicated to implementing technology transfer. In particular, it seeks to enhance coherence with the NDC and NAP processes at national levels. However, this integration is not straightforward. The recommendations were built following selected case studies. For example, one case shows the potential for scaling up the Cuban model for risk reduction through management centres and cooperation with another Caribbean island. Another analysis shows how Samoa adopted agricultural practices from China. Others describe cooperation practices at the city level between India, Indonesia and South Africa, and finally show prospects for a China-Ghana-UNDP triangular cooperation model for 'green' technology transfer for agriculture.

While the cases are valid, as they show cooperation activities under different models of aid, several challenges must be considered. First, the TEC shows general trends about the lack of regulatory frameworks and problems with intellectual property rights, and lack of transparency and certification systems, standards and precise technology 'priorities' in all these countries. From a policy perspective, it seems rational to try to target technical aspects that would create conditions for greater efficiency and efficacy for technology development and transfer in adaptation. Second, it assumes that creating the 'right' policies and 'incentive structures,' would significantly improve the problem of cooperation. Despite advocating the need to share experiences and build capacity for collaboration, the TEC—as a high-level policy committee—has no legitimacy to mobilise these policies in developing countries. In addition, its sophisticated messages and briefs might show generalised diagnostics of issues; however, they are tailored to task forces and formal members of the network, not necessarily to the policymakers and decision makers sitting in ministries in their home countries. Therefore, these briefs constitute recommendations on a broader sense, which feed into the black box of global technology transfer.

Another relevant example concerns the TEC Brief №10 (2017), 'Technological Innovation for the Paris Agreement'. Here the Committee generated insights on how innovation can accelerate the implementation of Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs). Notably, the brief includes a definition of technological innovation as:

> *"A complex process [that] involves the interaction of many actors, with multiple feedback loops across different stages. These loops may be due to trial and error, as actors' experiment with a technology to identify how it may solve the problem at hand. During the innovation process, technology may also need to be modified to suit local conditions. Furthermore, based on user feedback, it may be redesigned to have better performance, more features or new functions"* (TEC, 2017b, p. 7).

This understanding of innovation is one step ahead in interpreting the Technology Framework. The TEC places innovation at the centre of the Paris Agreement, suggesting its fundamental role in fulling the implementation of NDCs and NAPs at country levels leading to 'mid-century strategies' (TEC, 2017a). As an expert group, the TEC offers complementary support to the CTCN at the top level. For example, they suggest balancing short-term and long-term imperatives under the Agreement. They refer to 'short-term' as 2030, with attention on deployment and diffusion of technologies so as to respond to immediate mitigation and adaptation needs on the one hand, while taking time to tailor technology pathways on the other. Innovation, from this perspective, is supposed to build 'longer' time horizons (2050 and beyond), and thus the TEC recommends that, *"countries may focus on researching and developing a new generation of technologies that can enable deep or full decarbonisation, jump-start low-carbon development, facilitate resilience against climate change, or respond to societal needs that are not yet fully conceptualised."* (TEC 2017a p. 7).

The TEC offers messages from high-level COP participants such as the president of Fiji during COP23, which sent a political signal to harness innovation, enterprise and investment to fast-track the deployment of 'climate solutions' and build future economies. This allowed the arguments of the Paris Agreement on zero greenhouse gas emissions and limiting the rise of global temperatures to 1.5 ºC above pre-industrial levels. The messages show Uruguay as an example of sound energy governance, with 90% of its electricity from renewable energy sources; its 2030 energy policy framework serves as a critical enabler of the energy transition. They suggest the use of the Global Innovation Index to analyse and compare the performance of 121 countries and build indicators. Moreover, they suggest using these indicators to build on infrastructure, education, and business 'sophistication'. In essence, the TEC perceives innovation as about using systemic approaches, and understands building 'National Systems of Innovation' as a critical national challenge. In particular, the TEC considers TNAs to be essential enablers for mapping and assessing cost-effective ways to speed up technological transfer for innovation systems. This is interesting, since the approach suggests that irrespective of the challenges facing a country innovating socio-technical change, it is imperative to build systems of innovations linking actors, institutions and networks that drive innovation at the national level. Indeed, they assume that technology and knowledge transfer can catalyse innovation from the global to a national system.

The steps to build a more robust national innovation system that would eventually lead to more effective mobilisations of knowledge and technologies seem logical. The reality, however, is that most developing countries do not have such a system in the first place, and thus face a number of coordination constraints when it comes to innovation. These socio-technical elements cannot be assumed to be equal for every country. For example, some may have more capacity and fewer resources, or differing regulatory regimes with other priorities. Ultimately, these socio-technical transitions towards more efficient innovation systems take years, if not decades to build. On the one hand, the global aspirations show a universal pathway for removing barriers to the diffusion of innovations in the form of technology transfer projects. On the other hand, there are many more contextual conditions in play besides optimising the right technological 'push' through technical assessments and policy guidance.

The Technology Executive Committee plays a role in building linkages between the 'Financial Mechanism' and the Technology Mechanism. Its work is closely related to coordinating activities with the Green Climate Fund, exploring, for example, how to finance collaborative research and development by undertaking a leverage position at GCF board meetings. Their expertise serves as input to the Standing Committee on Finance, evaluating the effectiveness of the Financial Mechanism, drafting guidance to their operations, and building knowledge on the legacy of the Global Environmental Facility's Poznan Strategic Programme on Technology Transfer (PSP), which still funds the TNAs. In an outer formal layer, the TEC is perceived as playing an essential role as a boundary body that links expertise and technology policy to the implementation of technology transfer and its consolidation at a high level. However, the fragmented reality and distributed network conditions under which the Technology Mechanism must perform have also had an impact on the division of responsibilities amongst able bodies. This does not make the process easier to manage, but rather adds complicated layers of bureaucracies. As a committee, the TEC builds its insights on its 'technology dialogues', and its task force teams inform the working streams. If the main visible outputs are its policy recommendations, how do the different actors mobilise them? Who gets to read the policies, and which organisations use them as guidance?

Because of the large-scale socio-technical network beyond the Mechanism, it is not possible to know whether the policy briefs are put to good use by targeted recipients, such as ministries, municipalities, and other local actors in the national context. One way to understand the effects of these briefs would be to look at the synergies between the TEC and the work of the CTCN. However, observations and expert interviews suggest that these policies do not necessarily guide the CTCN's work. The rules set out in the technology negotiations have served to separate the bodies through mandates and physically locate these two entities in different countries. Consequently, they must collaborate indirectly, and it takes a year to address the feedback from the TEC through to the COP. Only then is the CTCN formally allowed to interpret such feedback as input for their work, this time only through the Advisory Board meetings.

Furthermore, TEC briefs neither guide nor inform the CTCN strategy in a way that increases coordination with the activities in the sites of implementation in developing countries. Ministries and organisations in participant countries could indeed use the briefs as guiding principles to support more coherent work. However, the briefs are only general outputs with 'key messages' that are not detailed enough, and they are the product of high-level negotiations that accommodate messages, rather than disseminate real technical expertise to the national stakeholders on the ground. For example, there has been an ongoing dialogue in the TEC about 'national innovation systems', which is a 'hot' topic for the technology negotiations, but which has given no detailed operational guides, due to conflicting interest with donors. This is reflected under the 'collaborative research and innovation' stream, which has been conflicting in efforts to support 'indigenous capacities'— mostly referring to local expertise. The managerial strategy of CTCN has initially been on nurturing expert discussion about generating technology 'packages' for countries:

> *"From a pragmatic way of working, you can still make your requests and not use a specific request package. This strategy is meant to be useful, to make it easier for countries to make requests to us and agreed on a pre-set, because we have to acknowledge the facts, that many countries have a difficult time prioritising their needs."* (CTCN Adaptation Specialist, UN-City, Copenhagen, Denmark, June 2018).

The packages, however, may risk a reductionist approach to technology-based solutions with overly simplistic based on techno-economic thinking. Further, the development of these technology 'packages' concept cannot be understood without first looking at the CTCN project operations. Hence, the next section focuses on its activities and analyses the projects that are have happened in the South East Asia region between 2015 and 2019. The following section introduces the Southeast Asian context, with a focus on its rapid economic development and its vulnerabilities to climate change. After describing the context, I will introduce a description of the main CTCN project activities.

4.3 CTCN Activities in Southeast Asia

Southeast Asia (SEA) is a sub region of Asia geographically located south of China, east of the Indian subcontinent and north-west of Australia. Mainly the climate in SEA is tropically hot and humid throughout the year, and rain is abundant. The majority of the region has a wet and dry season caused by seasonal changes in wind or monsoons. Because of its geographical location and geomorphology, SEA is one of the most vulnerable regions to the impacts of climate change in the world. Climate change will have severe effects on agriculture and water systems, which are particularly vulnerable socio-ecological systems (Kodali et al., 2009). In addition, some countries in SEA are embedded in large river deltas, which are complex socio-ecological systems that have been shaped by anthropogenic activities for centuries. Deltas are wetlands that form as rivers flow and carry their water and sediments into another more substantial body of water such as an ocean (Hoque et al., 2016; Nicholls et al., 2020). As the rivers move slowly, the deposit sediment into the delta, creating further sedimentation. Deltas in SEA cover vast territories, and although initially ungoverned spaces beyond state control, more recently they became the object of engineering interventions, including attempts to bring rivers under control through digging canal infrastructures for navigation and drainage (Preiser et al., 2017). Main deltas in SEA are the Chao Phraya delta in Thailand, the Mekong Delta in Vietnam, and the Ayeyarwady delta in Myanmar.

SEA cities, embedded mainly in river deltas, have seen a rise in economic growth and urbanisation over the past decades, with megacities such as Bangkok emerging to occupy large areas of land along the Chao Phraya delta. The region faces significant challenges, such as poverty and inequality. Its population is projected to approach 759 million people, with about 65% living in densely urbanised areas (World Bank 2013). The SEA region has high exposure to impacts associated with sea-level rise and acidification, as well as tropical cyclones, flash floods, and extreme heat. Due to these vulnerabilities, SEA countries have been the focus of international attention with regards to prioritising areas for new environmental planning efforts (Giosan et al., 2014; Zegwaard, 2016). CTCN operations have been running in the region for some years (2015-2020) and include the development of technology transfer activities in countries such as Vietnam, Indonesia, Bangladesh, Timor-Leste, Cambodia, Laos, Thailand, and recently Myanmar.

Table 6 The CTCN's Operations in Southeast Asia

Year	Title	Countries	Objective	Sectors	Phase
2019	Promoting data for climate change, drought and flood management	Myanmar	Adaptation	Early warning	Implementation
2019	Feasibility study for Carbon Mineralization by using CO2 issued from coal power plant for recycling ash slag in Cao Ngan coal power plant	Viet Nam	Mitigation	Carbon fixation and abatement, Industry, Waste management	Review
2019	Support for e-mobility transition in Jakarta	Indonesia	Mitigation	Energy efficiency, Infrastruct ure and Urban planning, Transport	Review
2019	Capacity building in Timor-Leste's renewable energy sector	Timor-Leste	Mitigation	Renewable energy	Design
2019	Development of low-emission mobility policies and financing proposal	Cambodia	Mitigation	Energy efficiency, Transport	Design
2018	Designing ecosystem-based solutions for building urban resilience	Laos	Adaptation	Water	Completed
2018	Technical assessment to enable up-scaling investments to achieve NDC energy efficiency goals in the building sector	Thailand	Mitigation	Energy efficiency	Completed
2017	Development of a certification course for energy managers and energy auditors of Bangladesh	Bangladesh	Mitigation	Energy efficiency	Completed
2016	Technology for Monitoring & Assessment of Climate Change Impact on Geomorphology in the Coastal Areas of Bangladesh	Bangladesh	Adaptation	Coastal zones	Implementation
2016	Saline water purification for households and low-cost durable housing technology for coastal areas of Bangladesh	Bangladesh	Adaptation	Water	Implementation
2016	Cost-benefit assessment of mitigation options in rice production for Vietnam	Viet Nam	Mitigation	Agriculture	Implementation
2016	Pilot demonstration of Energy Service Company (ESCO) model for greenhouse gases emission reduction in the cement sector	Viet Nam	Mitigation	Industry	Completed
2016	Promoting data for climate change, drought and flood management in Myanmar	Myanmar	Adaptation	Cross-sectoral	Implementation
2016	City Climate Vulnerability Assessment and Identification of Ecosystem-based Adaptation Intervention	Laos	Adaptation	Cross-sectoral	Completed
2016	Strengthening Bangkok's Early Warning System to respond to climate induced flooding	Thailand	Adaptation	Early warning and Environmental assessment	Completed
2015	Technology development for climate resilience and efficient use of resources in the agricultural sector in Thailand	Thailand	Adaptation	Agriculture and forestry	Completed
2015	High resolution regional climate model projections for Thailand	Thailand	Adaptation	Early warning and Environmental assessment	Review
2015	Fostering Green Building in Thailand for a Low Carbon Society	Thailand	Mitigation	Infrastructure and Urban planning	Design
2015	Benchmarking Energy & GHG Intensity in Thailand's Metal Industry	Thailand	Mitigation	Energy efficiency	Completed
2015	Assessment of energy efficient street lighting technologies and financing models for Thai municipalities	Thailand	Mitigation	Energy efficiency	Implementation
2015	Bio-waste minimization and valorisation for low carbon production in rice sector	Viet Nam	Mitigation	Waste management	Completed

2015	Hydrodynamic modelling for flood reduction and climate resilient infrastructure development pathways in Jakarta	Indonesia	Adaptation	Infrastructure and Urban planning	Completed
2015	The Development of Anaerobic Digester Technology for Palm Oil EFB Waste in Indonesia	Indonesia	Mitigation	Waste management	Completed

Source: Author, 2019

In the context of rapid urbanisation, **Laos** is an example of countries considered to be highly vulnerable to the impacts of climate change (Shrestha et al., 2018). Extreme events and disasters in the form of floods, droughts and soil erosion are expected to cause significant damage. The City Vulnerability Assessments and Identification of Ecosystem-based adaptation intervention is a technical assistance project coordinated by the CTCN and completed in 2016. The response involved conducting a vulnerability assessment at the city level in order to provide information and analysis about how people living in cities in Laos are experiencing risk from climate change and how likely they are to be impacted under future climate scenarios. The projected results included in the CTCN's 'closure report' pointed to the developed capacity of state and municipal authorities in Laos to address national and sub-national adaptation priorities and use data to inform the design of adaptation actions. This is expected to lead to environmental and social co-benefits such as enhanced provision of water and water treatment through improved ecosystem management.

In another project, the city of Jakarta is increasingly threatened by flooding due to socio-ecological dynamics leading to land subsidence, as well rising sea levels, and higher river levels resulting from increased rainfall (Mishra et al., 2018). Government authorities and the Jakarta Research Council, on behalf of the Provincial Government of Jakarta (PGJ), asked for Technical Assistance from the CTCN and its global network to build the capacity of stakeholders and decision makers in **Indonesia**. The intervention aimed at flood management and evaluations of technologies and methods for flood reduction and climate resilient infrastructure in Jakarta.

The CTCN mobilised the development of a high-resolution hydrodynamic model for the city and a system with which to govern floods, including flood hazard mappings, forecasting systems, and hydrological modelling:

> *"We created a set of tools such as the vulnerability mapping tool disseminating into 40 cities and they are now using it in city planning. The Hydrodynamic model of DHI for Jakarta, they now use it immediately in their 4-year programme. That*

was a success. However, that kind of process takes a lot of time" (CTCN Knowledge Specialist, UN-City, Copenhagen, Denmark, September 2019).

The successful project completion was a legitimate opportunity to strengthen new collaborations on water technology transfer for adaptation in the Global South. For instance, the project showed that even though there is a growing number of network members, most of the transfer was coming from northern countries such as Denmark. On the one hand there is a question of balance between North and South. On the other, there is an ongoing search for a different approach, with northern actors partnering with southern organisations on implementation. This would ensure that capacity be 'transferred' in more than one way.

Cases such as the modelling pilot project in Jakarta achieve their success through triangular cooperation between the CTCN, the PGJ, and the Danish Hydraulic Institute (DHI):

> *"We have a case happening right now on triangular cooperation with Indonesia looking at flood modelling, looking at a pilot study for a section of Jakarta. That was developed by DHI here in Denmark. They have really good expertise in this area, and the model that they developed felt it was so good that they wanted to move forward and started developing in other areas."* (CTCN Knowledge Manager, UN-City, Copenhagen, Denmark, August 2017).

There was a project cost of about $US 500,000 dollars to spread out into implementation. For this purpose, Jakarta received financing support from the Korean International Cooperation Agency (KOICA) to develop the rest of the city. By the implementation phase, Jakarta has invited the heads of governments from all the major cities in Asia to come and share information and lessons learned.[29] According to the project implementers, several lessons from Jakarta feed the spread of hydrological transfer models to other SEA countries. For example, the 'lessons learned' workshop that followed implementation in Indonesia was titled *Hydrodynamic modelling for flood reduction and climate resilient infrastructure development pathways in Jakarta* (CTCN, 2017). This dissemination workshop was organised by the CTCN and the DHI Water and Environment division and was hosted by the Bangkok Metropolitan Administration (BMA). The results showed Bangkok's technical assistance request was requested from Jakarta because the DHI promoted the idea of Early Warning System modelling 'packages' with a flood modelling system 'costumed' to the city of Bangkok. The hydrodynamic model developed utilised MIKE software, which has the capacity to input data into an 'operational Decision Support System' for city authorities. A

[29] Analysis using data from interviews with CTCN Knowledge Manager and CTCN Technology Consultant on TA Closure Report. UN-City, Copenhagen, Denmark, September 2019.

number of points can be observed here. First, the technological transfer of artefacts such as modelling technologies is a salient activity in SEA, as demonstrated by the technical requests to the CTCN by national authorities in Indonesia, followed by Thailand and Myanmar. Second, there is a strong push for these technological deployments to be made into replicable, cost-effective packages for other contexts. Finally, the Danish Hydraulic Institute deserves more attention. Their operations have rapidly expanded through the CTCN's network, and they have now formed the UNEP-DHI centre on Water and Environment. Hence, they now act as a Consortium Partner of the CTCN and are building regional presence and authority in water management through the deployment of technological packages. The way in which networked organisations build legitimacy and authority through project-based interactions is explained in detail in Chapter 5 for the case of Thailand and Myanmar.

It is important to mention here that the mobilisation of expertise in the form of hydrological modelling tools sets an important agenda for city planning in SEA. For example, both Jakarta and Bangkok, are built on large hydrological systems and infrastructures. Bangkok flood control systems were designed as an emergency response. This is reasonable, since Bangkok is situated in the Chao Phraya Delta and thus vulnerable to the overtopping of old canal and drainage systems. The city of Jakarta is near a mountainous area, which makes overtopping less relevant than it is in Bangkok. The system in Jakarta would apply flood monitoring for evacuation. Both cities use polder pumping systems for the most vulnerable areas. While Bangkok pays attention to hazards, the technical assistance they receive from the global network to the BMA uses flood damage analysis and the land-use 'stage-damage' function to model potential risks. On the other hand, Jakarta tailors its model to quantify potential damage and uses that as input for their decision support system. Whilst the hydrodynamic tools are customised to the particular needs of urban centres, there is a mobilisation process tied to specific skillsets and modelling technologies being deployed to these countries. Because of the transfer successes in both cases, the CTCN has considered them as key examples of how countries, guided through the Technology Mechanism process, can enhance their technical capacity to run models for adaptation in the water sector.

As is further explained in Chapter 5, the Danish Hydraulic Institute (DHI) has had a SEA network strategy for years. After the disastrous floods in the Chao Phraya in 2011, the presence and relevance of DHI technology solutions grew stronger. The DHI Project

Specialist explained how they have scaled up their operations across SEA to develop flood forecasting systems and scaling them throughout the region.

> *"Yes, for sure, we have Myanmar on the radar and have gained support from the World Bank. We had very good experiences in Thailand and we know they have the ambition to be a hub in the region regarding water management services. We are collaborating very closely with them."* (DHI Project Specialist, Bangkok, Thailand, Abril, 2017).

When it comes to implementing technology transfer projects, most activities of organisations such as DHI focus on capacity building for software technologies. DHI, together with the UNEP, conducts training sessions with local experts that provide knowledge to ministries and specialised staff in order to introduce their operation systems, as the DHI R&D Manager shared with me in an interview:

> *"As you can imagine, our knowledge is encapsulated in our software. Specifically, for climate change we have scenario tools included in the MIKE software where people have access to climate projections and use it in a relatively friendly manner, including for those who are not technical experts. They can use it to do scenario analysis. Specifically, we have developed climate guidelines, in water, urban and coastal areas for these countries."* (DHI R&D Manager, Copenhagen, Denmark, June 2018).

Therefore, the MIKE software runs hydrodynamic models in combination with climate models. Once these systems are mobilised and the transfer has been made, this provides continuity since the models' institutionalisation requires updates and continuous support. When combined with networking and stakeholder engagement, these activities lead to further business opportunities. The guidelines link well with the modelling tools and DHI's expert recommendations on flood management for cities, making these technological 'packages' significant and attractive for end users at the national level. They also become relevant artefacts with which to follow the travel of expertise.

4.4 Global Connections and National Realities: The Case of Thailand

Asia Pacific is the fastest growing economic region in the world. Its rapid development has been accompanied by population growth, urbanisation, and unsustainable production and consumption of goods and services. In this macro landscape, Thailand is no exception. Furthermore, climate change has posed significant challenges to water and agricultural systems (UNESCAP, 2017). In principle, the 2030 Agenda on Sustainable Development and the Paris Agreement represent a pathway towards improving well-being, water security, and climate action. They also point to the need for countries to foster resilient infrastructure that can withstand the impacts of climate change in cities like Bangkok. However, major issues remain in using science and technology to improve decision-making and environmental governance in Thailand.

The past decade has seen dramatic incidents unfold in SEA due to increased flooding and droughts (Tuitjer, 2019), with attention from the international development cooperation sector. For instance, the city of Bangkok was severely damaged in 2011. Floods are, however, common in delta landscapes (Zegwaard et al., 2015). The Chao Phraya delta has been shaped by human activities and more than a century of building environments and complex networks of water control systems such as dams, dikes, polders, and other artefacts (Molle & Floch, 2008). Thailand faces unprecedented seasonal variability due to climate change, and has a recognised need to improve its water management systems (Molle et al., 1999). According to the Rapid Assessment for Resilient Recovery and Reconstruction Planning, the floods of 2011 resulted in economic losses estimated at around $US 46.7 billion (World Bank, 2012). With climate change increasing the country's vulnerability to the impacts of flood- and drought-related disasters, it is uncertain how its infrastructure and socio-economic will bring about future prosperity. The problem of climate change adaptation is clear, and yet different countries' approaches to building resilience vary in complexity. We must also take into account that technologies for adaptation have received less international attention when compared to mitigation technologies (Olhoff, 2015), and there has been less space for these efforts. However, Thailand has been a regional advocate for adaptation technologies, in particular early warning systems with applications to water management and agriculture (STIPO, 2012). This is consistent, for instance, with the policy advice given by the TEC with regards to the challenges associated with adaptation efforts. Adaptation to climate change must consider social, economic, political and environmental contexts. The TEC suggests that countries dealing with these challenges examine their institutional systems. An insufficient understanding of the contemporary, context-specific settings can undermine the entire process of environmental planning from the 'outside', rendering the knowledge transfer ineffective, and the transfer of technologies conducive to "maladaptations" (IPCC, 2001, p. 378). Water management is complex, as it is intrinsically linked to other sectors such as energy and agriculture, and to the wider socio-ecological systems embedded in deltas. The case of Thailand shows that water governance, as opposed to 'controlling' managerial approaches, requires a multifaceted network of actors and further examination of the national context.

Over the past three decades, Thailand has focused on promoting industrial development in lieu of agriculture (UNCTAD, 2015). As a result, concentrated investments around the Bangkok metropolitan area have caused a rise in population numbers and fast infrastructure development in the Chao Phraya delta. This has been accompanied by an increase in slums, land subsidence, traffic congestion, and poor living conditions (Hara et al., 2008). The fast-growing city of Bangkok has flood 'seasons', which begin in September but can vary greatly depending on rainstorms at any time between May and October. The most severe floods are typically expected to occur in October, when rains in northern Thailand bring large amounts of water into Bangkok. In addition, tides are at their highest point at this time of the year and back water into the Chao Phraya delta, resulting in slow discharge and stagnation. The city *khlongs,* or canals, enter the city from various directions, mostly from the East, passing across the city and then into the Chao Phraya river. These canals receive water runoff from suburban areas of the metropolitan region sprawling east of the river and the rice fields beyond. There are hundreds of smaller canals feeding water into the main khlongs of Bangkok. When tides are high, water is sent back into the canals. Flood control infrastructure in the form of water gates is thus designed to prevent the river water from entering the khlong system. However, if the city gets flooded and the river is at its highest due to rainfall, the canal locks must be released slowly, over a period of time, before Bangkok can be drained of excess water. As a result, when storms produce heavy rain, it is necessary to remove a huge volume of water, exceeding the system's capacity. This series of knock-on effects produces heavy floods that can take many months to drain, with serious consequences for infrastructure, as well as socio-ecological impacts. In addition to the complex systemic feedback and uncertainty in weather patterns, there are other problems associated with managing floods. These concern broader national challenges that extend beyond water institutions.

For example, policies concerning water management in Thailand have been characterised by conflicting objectives regarding water storage, and a growing opposition to the construction of more dam sites (Netherlands Embassy Bangkok, 2016). The institutional framework is highly fragmented, with around thirty departments and bureaus supervising water management in eight ministries (Kanchoochat & Hewison, 2016). Water policies, laws, codes, frameworks and guidelines are used under highly fragmented conditions lacking both a single coordinated authority and a more integrated approach (Marks et al., 2020; Phien-wej et al., 2006). A lack of water resource legislation precludes any successful form of systemic integration, and none of the national and local agencies are specifically addressing coherent flood management. Initiatives seeking approaches to Integrated Water Resources Management (IWRM) in Thailand began in 1990, but there has been little progress (Anukularmphai, 2011).

The political system of Thailand is that of a unitary, parliamentary, constitutional monarchy and the country is *de facto* ruled by a military junta. According to a comparison of perspectives on public administration regimes made by the UNDP in 2015, Thailand is perceived internationally as stagnated in an 'old' public administrative system. Current research on Thailand's recent politics has shown that the *coup d'état* in 2014 has consolidated linear and hierarchical relationships between political executives and top civil servants producing a "network monarchy" that is vertical and closed (Kanchoochat & Hewison, 2016). The administrative tradition is characterised by vertical coordination and highly bureaucratic procedures with top-down authority and control of stakeholders (M. Robinson, 2015), creating effects such as institutional rigidity and slow implementation, limited accountability, and a lack of adaptive capacity and institutional learning (Denhardt & Denhardt, 2000; Swanson & Bhadwal, 2009). Citizens' interests and collaborative structures are hindered by a military-ruled government bureaucracy. A report from the United Nations Conference on Trade and Development (UNCTAD) describes the science, technology and innovation environment as hindered by political instability and short-lived governments, resulting in a lack of continuity between and within policies. In addition, it claims that, *"non-transparent bureaucratic procedures and a challenging regulatory environment (...) are also hampering innovation efforts by constraining the design and implementation of effective long-term development strategies"* (UNCTAD, 2015, p. 20).

Particularly in the water sector, this institutional rigidity and fragmentation became evident during the 2011 floods. Some 31 ministerial departments under 10 ministries, one agency and six national committees were ineffectual in drafting policy and acting; competition between institutions with conflicting priorities took precedence, and responsibilities overlapped (Netherlands Embassy Bangkok 2016). The response of the government was to draft a "Master Plan" on flood management, followed by the establishment of the National

Water Resources and Flood Committee (NWFPC) and the Water and Flood Management Commission (WFMC). These working groups are now entitled to formulate policies, approve further investment projects, and potentially monitor their development and impact. This being the case, an absence of unity and effective coordination persists, as well as insufficient long-term planning (Anukularmphai 2011). The need for an institution that can lead the process with an integrated vision has been recognised since the creation of the initial National Water Resource Committee back in 1988. However, despite being one of the most important advocates for water management, it does not yet have the real authority necessary to influence policy.

4.4.1 The Thai National Science, Technology and Innovation Policy Office

In this fragmented national context, 'climate' technological transfer networks are supposed to deliver on a number of fronts for mitigation and adaptation. That is why the national expert agency is the National Science, Technology and Innovation Policy Office (STIPO), under the Ministry of Science and Technology. This organisation is the main governmental think tank driving STI policy in the country. The STIPO therefore acts as an articulating agency in the science-policy interface, which nurtures the agenda for a Thai innovation system. Since 2008, the office has acted as a 'non-bureaucratic but government-owned' institution guided by the National Science Technology and Innovation Policy Committee (NSTIC), which is chaired by the Prime Minister of Thailand.

The STIPO's offices are located in Bangkok, and I had the opportunity to visit them to talk with their experts. The institution is considered a strategic organisation equipped with the necessary expertise to drive technology and innovation policy 'formulation' and coordination and foster its implementation nation-wide through a strategic plan to transition towards a 'knowledge-based economy' and enhanced socio-economic sustainability. As the national expert institution dedicated to, inter alia, collaboration and networking engagement, it is also committed to develop linkages at the international level and 'exchange programmes' with international stakeholders. Politically, it is a 'unique' moment in Thailand's history. Since the army took over after the *coup d'état* in 2014, there has been a push from the top to introduce reforms in every sector, including science, technology and innovation. In a dedicated conversation with the Senior Policy Expert at STIPO in Bangkok, he shared with me the strategy and national plan of Thailand as it was been developed in that moment by his team for the Minister:

"My department has the responsibility to formulate the national strategy. We are putting efforts to reform the regime on Science, Technology and Innovation. We call it Thailand 4.0" (Senior Policy Expert, Bangkok, Thailand, April, 2017).

In Thailand, policymakers have identified four 'development' eras. Conceptually, '1.0' was the agricultural economy that characterised the Siam expansion from the ancient city of Ayutthaya. 2.0 refers to an era of 'light industrial development. 3.0 refers to heavy industry, which indicates Thailand has passed this techno-economic 'phase' of development and is heading towards its 4.0 innovation-driven strategy. In practice, this means that science, technology and innovation will be the main area of policy development in Thailand over the next 20 years. Thailand STI Policy and 20-year Plan Strategy was consulted at STIPO with local officer during my fieldwork in Thailand in 2017. At the time it was an important, yet highly confidential documentation. The strategy is yet to be finalised, though it was due to be ready before the general elections in 2018. To date there are no signs of this report been made publicly available.

The STIPO initiated relations with the Technology Mechanism when it conducted its first Technology Needs Assessment (TNA) under the GEF in 2012. It received an offer from the GEF—in partnership at the time with UNDP—to formulate technology evaluations for the implementation of technology development and transfer under the UNFCCC. The STIPO held primary responsibility at the time to conduct the studies and hire local consultants to provide expert inputs for their TNA on mitigation and their TNA on adaptation. Following the completion of the TNAs, a National Designated Entity was nominated in 2014 to serve the purposes of the Technology Mechanism in Thailand. For the STIPO, the TNA process was an opportunity to prove they had the type of expertise the international community was looking for. In turn, it served them to 'prioritise' their technological needs to deal with climate change:

"We have used the TNAs to categorize four groups of technologies: water management, agriculture, modelling and mitigation technologies focusing on the energy sector. These are all climate change related technologies. Every technology can potentially address climate change either directly or indirectly." (NDE for Thailand, STIPO, Bangkok, Thailand, April, 2017).

For instance, the prioritisation of technologies in the case of adaptation included agriculture, water and modelling technologies, whereas mitigation focused on energy (TNA 2012). Thailand's TNA identified 'precision farming' as the key strategic technology for the agricultural sector, and decision support systems and capacity building as the main focus for technology transfer. Other inputs of the TNA were included in the Thailand Climate Change National Plan for 2015-2050.

Yet significant challenges and barriers to the implementation of these technologies remain, particularly at the institutional level. As explained previously institutional fragmentation characterised Thailand's water management systems. However, their TNA for adaptation points in a slightly different direction. Adaptation technologies for the water sector were prepared by a team of national consultants and examined by several rounds of public hearings (STIPO, 2012). Seven types of adaptation solutions were identified: environmental observation, weather and hydrological modelling, flood and drought risk management, operation of water infrastructures, community water resource management (CWRM), integrated water resource management for urban areas (IWRM), and finally early warning systems. Whilst the set of solutions shows a breadth of needs and actions to be followed, including the institutional and governance dimensions of water, these were not prioritised in the end. Instead, the Ministry selected those solutions which required one-off technological transfer projects, rather than knowledge transfer. For instance, the Technology Action Plan (TAP) emerging from the TNA results shows a preference for hydrological modelling technologies and precision farming. Although these are appropriate for disaster reduction in cities and increasing crop resilience in agriculture, this prioritisation shows how the travelling of rationale, as well as politics, affects the final solutions deployed. For instance, transferring knowledge related to water management and use can be seen as undesirable, due to the high political nature of water control in Thailand. This kind of solution would require deeper and more sustained forms of intervention in the institutional dimensions at the national and local levels, such as altering the way in which water is managed and by whom. This is inherently controversial, hence the reluctance of national incumbents to make it a priority. Instead, national decision makers prefer technological transfers that fit a criterion of 'tools and techniques' based on modelling technologies and smart tech. This is seen as bringing innovation to the country, without having to worry about the deeper political issues of changing institutional systems. Detailed examples of climate and hydrological transfer and its uses follows in Chapter 5.

Coming back to the TNA in 2012, Thailand had just faced one of the worst floods in history right in the city of Bangkok. And so, it made sense to choose to protect Bangkok's future infrastructure, as well as the country's main economic asset, agriculture. Consequently, the prioritisation was a salient decision for the Thai government. For example, the national Hydro Agro Informatics Institute (HAII) provided water statistics about the flood and its impacts, as was mandated at the time. Seeking combined efforts with the STIPO, the HAII made use of the TNA to request support in infrastructural investments to cope with the lack of water data in the country.[30] To demonstrate its willingness to support this initiative, the government of Thailand opened up bids for investments in sensors to detect flows of rivers and water channels. This resulted in more investments in 'telemetry' to send data to the HAII so they could generate 'predictive models' of extreme weather events and hydrological feedbacks from the Chao Phraya delta.[31]

However, Thailand faces important barriers in the water sector and the mobilisation of technology-based cooperation, due to the highly fragmented and internal competition of overlapping institutions. As an HAII explained to me in discussion in Thailand, the major department in charge of water in the country is the Royal Irrigation Department (RID). According to the National Designated Entity, the focal point of the network, the barriers are in knowledge and institutional capacities:

> *"Most of the personnel working in water are scientists but not engineers. This is quite a barrier, as there is a constant clash and lack of communication between our experts, because expectations and skills are different. This is the case for the RID and the Ministry of Science and Technology."* (HAII expert, Bangkok, Thailand, October 2018).

The STIPO has a boundary role between science and policy. It is mandated to articulate and mobilise expertise at the national and international level in order to advance policies related to Thailand's main challenges. The STIPO's 20-year strategy seeks to mobilise and integrate different mandates and generate budgets that align research and innovation in every sector, including water. The national strategy will be heavily focused on 'R&D and innovation', as it sees the potential of these sectors to boost competitiveness, economic development, welfare, and education.[32] However, problems such as climate change call for different 'incentive structures' than 'business as usual' when technology roadmaps are implemented in Thailand. The national vision focuses on mobilising top-down policy programmes for research, such that researchers may follow technology priorities set by the 'experts' and R&D can access international funding to advance knowledge in these areas.[33]

In terms of technological transfer, the STIPO is aware of the need to strengthen 'human capital' and the institutions involved in the mobilisation of technologies and resources. According to the NDE, for example, the Technology Mechanism, and the CTCN in particular, should be more focused on building capacity at national levels by supporting national

[30] Analysis using data from interview with HAII expert, Bangkok, Thailand, October, 2018
[31] Analysis using data from interview with projects expert, STIPO, Bangkok, Thailand, April, 2017.
[32] Analysis using data from interview with senior policy expert, STIPO, Bangkok, Thailand, April, 2017
[33] Analysis using data from interview with National Designated Entity for Thailand, STIPO, Bangkok, Thailand, April, 2017

strategies and shifting their technological approach towards institutions. Thailand already has good infrastructure and expertise, but faces challenges on the 'organisational' side, such as building more coordinated socio-technical systems. Overall, Thailand is an example of success in the eyes of international experts. They were the first to build TNAs, complete a technology transfer project through the CTCN network—the Early Warning System project to respond to 'climate induced flooding' (2016-2017)— present a high-resolution regional climate model project for Thailand for review (2015), and create a benchmark for energy and greenhouse gases (2015). More recently, the STIPO has also been engaging in Technology Executive Committee activities as part of the 'first of a kind' south-south cooperation through the Mechanism, mobilising transportation technologies and expertise from Thailand to Bhutan, with the support of the CTCN.

However, in practice, these are all one-off technological transfer solutions, which seldom deliver fundamental transformation on the ground. Officially, there are claims of south-south cooperation and knowledge sharing aided by the Mechanism, but there are many challenges associated with this model of cooperation, as the NDE for Thailand opened up in an interview:

> *"I think that south-south collaboration is quite difficult to achieve. Because most developing countries rely on technologies from the Global North. If southern countries have not an outstanding technology, there is no reason for that to happen. However, it could be happening much more in other sense, more simple types of technologies, and also on knowledge and capacity building."* (NDE for Thailand, STIPO, Bangkok, Thailand, April, 2017).

Although climate action is mobilised through the CTCN network, the projects prioritised in Indonesia and Thailand show a preference—expressed through the TNAs but ultimately 'prioritised' by experts—for technology-based solutions that align with technocratic narratives of management and control. This is the case of mobilising hydrological modelling tools without really attending to the deeper institutional problems that these countries face. The idea of a collaborative network system coordinated by northern organisations and northern technology providers has many complexities. On the one hand, the idea that developing countries could benefit from the network to arrange common projects, research programmes and learning mechanisms to build south-south development cooperation is interesting. For instance, countries in SEA share common challenges when it comes to the water sector. On the other hand, the way in which the TNAs are constructed, leading experts to value and prioritise what has been shown as cost-effective or replicable, in the case of modelling tools, builds dependency on northern providers while instilling a technical rationality of following 'best practices' to receive international funds.

So far, Thailand and Indonesia represent 'success' models of technology-based cooperation under the Mechanism seeking to be exported across SEA. For instance, the CTCN received the first Technical Assistance request from the government of Myanmar in 2016 to strengthen water management and increase adaptation to climate vulnerability with a focus on flood and drought management (CTCN, 2016). A response plan for the project promoting 'data for climate change, drought and flood management' entered a pilot implementation phase in 2019. The goal is to build a first-of-kind data portal that will inform planning, decision making, and management of natural disaster risks. The project has been taken on board by the UNEP DHI. The portal would use climate and hydrological data and is supposed to be downscaled to national and subnational levels. It is anchored in the Hydro Informatics Centre (HIC) within the Directorate of Water Resources and Improvement of River Systems (DWIR). The HIC is the national agency with expertise in hydrological modelling and forecasting and will receive training in DHIs MIKE modelling software. It is foreseen that 'significant investments are required to move from piloting to full project implementation at country level'.[34] After the pilot phase is complete, the project is intended to scale up to become a proposal to the GCF. The outputs of the activities leading to 'readiness' will be used to direct the design of future interventions through the GCF. It is yet to be seen how the project's pilot phase will unfold and whether officials in Myanmar will manage to strengthen effective climate finance planning and decision making that is acceptable to the GCF requirements.

Similar project packages are being replicated throughout SEA. This can be problematic, because it sets an agenda for other countries, such as Myanmar, that have not yet built their Technology Needs Assessments, nor received technology transfer from the network. These newly networked countries have to follow their neighbours, doing what has apparently worked before. There are many uncertainties associated with the replicability of technology-based solutions to complex problems such as climate change adaptation. These problems are opaque and cannot be controlled. Institutional fragmentation has proven to be a much deeper issue, tied to local realities, culture and politics, and has rendered external rationalities and visions of change ineffective. However, northern experts and donors persist in nurturing technological 'packages' that can deliver one-off projects across the network in the name of 'transformational change'. The reality, however, is more complex. The following section extends the analysis of the TNA processes to the expert meeting held in Bangkok, with a focus on Myanmar.

[34] Analysis usingdata from interview with CTCN Adaptation Specialist and UNEP DHI Operations Director, UN-City, Copenhagen, Denmark, September, 2017

4.5 Building Global Assessments in National Contexts: Least Developed Countries and Myanmar

Previous sections illustrated mobilisation and transfer from global policies to operations under the Technology Mechanism. They further analysed how global networks confront national realities in SEA, and the technology assessments and preferences fuelling interventions. This section continues the analysis of Technology Needs Assessments and the travelling of rationalities from Global North providers of expertise to southern nations when it comes to financing projects under the GCF. In particular, I focus on the case of LDCs and SIDS, of which Myanmar is a part.

Building on the legacy of the Poznan Strategic Programme on Technology Transfer (PSP), the Global Environmental Facility has approved a third round of TNAs to be conducted in LDC countries and SIDS with the purpose of accelerating programmatic activity related to the Convention. Since 2001, more than 80 countries have conducted TNAs focusing specifically on mitigation of and adaptation to climate change. Recently, several countries have reported to the Convention having successfully identified technology needs in their NDCs. At the aggregate level, prioritised sectors for mitigation include Energy (55%), Agriculture and Forestry (22%), Waste (13%), and Industrial Processes and Product Use (10%) (UDP 2018). On the other hand, countries have prioritised adaptation in Agriculture (34%), Water (34%), Infrastructure (14%), and Climate Observation (6%) (TT: Clear 2019). Since 2010, the UDP Partnership is the organisation responsible for supporting developing countries to undertake their TNAs. The Global Environmental Facility has been, thus far, instrumental in financially supporting 36 countries with their TNAs in Phase I (2009-2013), Phase II (2014-2017), and now Phase III (2017-ongoing).

Implementing technological transfer from one country to another can be difficult and time consuming. The mobilisation of technological expertise must have a coherent structure in place based on feasibility assessments of environmental conditions applied to socio-economic terms, coupled with technologies that must be both properly understood and culturally accepted. Technological systems from northern countries have flourished in a very different environment from that of developing countries, not only in terms of their technical specificities, but also in terms of policy. Following this rationale, TNAs encourage relevant stakeholders from government, research institutions and companies to work collaboratively to produce the report. The TNA expert from UNEP explained to me that

TNAs seek to increase the legitimacy and credibility of national ministries, due to the resulting cooperation activities of different national stakeholders during the process:

> *"During the process, stakeholders have to explain their position and arrange the technical elements in the categories of 'expertise' and 'capacity building' in order to build the reports together with the national consultants."* (TNA Expert, UNEP, Bangkok, Thailand, April, 2017).

The assessments constitute a starting point, or baseline, that generates boundary objects between national and international actors. The data shows that global initiatives are being undertaken to support the coordination of technology-related policy work in mitigation and adaptation. However, TNAs do not create a permanent platform, and it is difficult to assess the extent to which their outcomes, in the form of Technology Action Plans (TAPs), can be attributed to collaborative work and consultation with specific stakeholders. This is the case for consumers of technology and the financial sector of each country.

The case of Thailand exemplifies the kind of assessments TNAs build upon, and some of the socio-political realities when prioritising technologies. The TNA process (also regarded as a successful outcome of the PSP) has become instrumental in the eyes of global experts and northern donors to the continuation of technology transfer activities. On this occasion, the TNA III aimed to build capacity for technology prioritisation in the country's most socio-economically and environmentally vulnerable to climate change. Consequently, the third phase of assessments has developed financial and technical support to prepare TNAs leading to Technology Action Plans and seek synergies with Nationally Determined Contributions (NDCs) in these countries.

The 'TNA Phase III' was approved for implementation in 2018 for twenty new countries. Although the scope of this thesis does not allow for the full review of these countries, section 4.5 observes expert representatives from these countries and focuses on the TNA currently under development in Myanmar. The processes demonstrate how despite global and national recognition of the 'need' for technology transfer, there are numerous barriers to achieve its deployment. For example, the TNAs refer to the high cost of new technologies, as well as limited access to finance, lack of awareness of and access to technical information, restrictive government policies and regulations, and lack of institutions and human capacity in developing countries (GEF-6 PIF, 2018). Therefore, the TNAs attempt to address such barriers in order to leverage technological investments and accelerate the diffusion of technological solutions. Notably, the GEF-6 Project Information Identification Form (PIF), which constitutes the baseline for TNA III, uses the approach provided by the IPCC and

UNFCCC expert groups on technology transfer. It points out that barrier analysis and technological pathways must come from within countries and be 'technology specific'. It further notes that the barriers can be addressed by building capacities and institutionalising the TNA process at the national level. This is twofold. On the one hand, the TNAs are supposed to be country-driven, and yet they are nurtured externally from the outset. On the other hand, this 'PIF' baseline project under the GEF-6 stimulates planning processes and national dialogues between twenty selected countries, with policy makers and investors laying the foundations of further technology policies and investments in countries undertaking TNAs. From the start, there is acknowledgement of the lack of capacity and the need to externally support the scaling up of technological transfer.

The legacy of the TNA process is strong. These technical evaluations have been running from 2009 to 2020, and they continue to gain momentum. This means the TNA projects are considered fundamental to deliver on the Technology Framework and Paris Agreement, and so LDCs and SIDS are now up taking the initial steps to enter the globally networked ecosystem of technology transfer activities. Although the TNA process has been identified as an instrumental base for mobilising technological transfer, it does not play an overarching role in practice. Nonetheless, it must be articulated early on with other climate related targets such as NDCs, as well as dialogue with other national realities. Existing documentation in LDC countries like Eritrea, Uganda and Myanmar is not yet enough to provide robust planning for implementing technology projects under the Financial Mechanism of the UNFCCC. Under this narrative, the TNA appears to be the 'national participatory process providing in depth analysis of technology options and actions' to these countries (GEF-6 PIF, p. 5, 2018). However, this process is in itself highly technical; in practice, it is developed by experts, outsourced by the national institutions commissioned to build these assessments.

The case of Myanmar introduced interesting dynamics in the third round of TNAs. For instance, Myanmar represents an LDC country considered by UNDP to have a low Human Development Index of 0.584 and a rank of 145 out of 189 countries and territories (UNDP 2019). The nation relies heavily on food production for income and economic growth and faces increasing vulnerability to climate change. Similar to Thailand, its key strategic sectors in adaptation are agriculture and water, with a large river delta, the Ayeyarwady. About 75% of Myanmar's rural population relies on agriculture for their livelihood, combined with livestock and fisheries (NAPA 2012). Many of the country's problems are rooted in the tension between poverty and economic growth since the country opened its borders in 2011. The economic opportunities offered to Myanmar by the global market depend on how well the country can build and manage its water infrastructure to support agricultural development. Concrete challenges to advancing sustainable development in the country relate to increasing crop production and trade. Its vulnerability to the impacts of climate change lies in the increasing frequency of extreme floods and droughts, similar to its neighbour, Thailand. Likewise, the Burmese government identified the need to improve weather forecasting, early warning systems, and water management after Cyclone Narguis in 2008. The country's critical infrastructure in communications is weak, and there is a general lack of access to data and information. These issues particularly affect national agencies' ability to assess and manage extreme flood and drought events on time.

The ministry of Environmental Conservation and Forestry of Myanmar (MOECAF) is responsible for the ongoing TNA assessments under the GEF-6. According to one of the TNA experts supporting Myanmar, the process is moving forward in the country, as they signed the MoU with the UDP in Denmark. The inception TNA meeting in Bangkok in 2018 included the national focal point for the GEF, who is the person coordinating the TNA. There has been a selection of national consultants in Myanmar following the terms of reference in the TNA guidelines of UNEP DTU, which require meeting the expert's criteria on, for example, sectoral technologies and policy expertise at the national level. The expert stressed the importance of steering Myanmar's TNA in the right direction, using the guidelines and building an internal institutional practice monitored by UDP, which in turn ensures that the process functions normally. In terms of implementation, there should be a realistic approach—for instance, use of barrier analysis and creation of an enabling environment for technology options prioritised by Myanmar's MOECAF. These include cost-benefit analysis addressing risks and incentives to attract external funders and investors. The TNA can serve to bridge the gap between national policy targets, bringing together technology, policy, and the investor community. In order to build a strong TNA, Myanmar must improve methodologies and tools to build robust action plans that can facilitate finance. In principle, this is the same as the criteria for the other countries. There are already many 'packages' and tools to guide the national consultants in this process, such as the TNA guide (2015), the stakeholders guide for identifying stakeholders at the national level, the Multi Criteria Assessments for Adaptation and Mitigation (2015), and the guide on how to prepare a Technology Action Plan.[35]

These tools are meant to support the experts in building, inter alia, connection with funders and investors, and transforming initial project ideas into ready-to-submit concept notes for

[35] Analysis using data from interview with TNA expert at UNEP DTU, UN-City, Copenhagen, Denmark, June, 2018.

a strengthened technology transfer network. The TNA system enables inter-country cooperation, such as that between Thailand and Myanmar, by showcasing best practices from countries that already conducted TNAs and providing mentorship and future collaborations in the form of capacity-building packages. For example, countries with more experience, such as Thailand, could potentially support Myanmar to develop its capacity to conduct cost-benefit analysis, identify financial incentives, assess information and technology risks, and remove institutional barriers (GEF-6 PIF, 2018). To this end, projects should seek to build implementation capability using a global network comprised of existing partnerships involving financial institutions such as regional development banks and donors, as well as national, regional, sectoral and international technology centres across the TNA process. It is important to note that Myanmar conducted a 'preliminary' TNA in 2015 under the MOECAF as part of their initial national communication to the UNFCCC. It was evaluated in advance that Myanmar has a clear need for the transfer of Environmentally Sound Technologies (EST), such as renewable energy and energy efficiency technologies, and a strong focus on flood control and early warning systems for adaptation. Whilst the country had no official TNA, efforts were made to introduce the importance of technology transfer and additional support from international expertise (GEF-6 PIF, p. 22 2018). Consequently, the foundations were already set for Myanmar to identify its technology needs before the official TNA inception in 2018. The TNA expert from Myanmar shared with me some important information regarding the long-term technical process of TNAs as very bureaucratic, sometimes difficult to manage, and carries expectations from national experts that it will lead to implementing projects on the ground:

> *"In terms of implementation there has to be a critical reflection based on reality. TNAs are a very first stage of understanding where the countries want to go and sometimes there is a lot of expectation that TNAs will lead to implementation. In reality they are just terms of reference. Guidance for local stakeholders to develop more concrete and realistic proposals to implement technology transfer projects and have more chances on getting access to climate finance."* (TNA Expert for Myanmar, UNEP, Bangkok, Thailand, April, 2017).

Expert perspectives on the TNA process in Thailand and Myanmar indicate that the TNA is a very first step toward building capacity for technology development and transfer. It is, therefore, out of scope to think of these boundary objects as a means to deliver transformational change in countries. However, the politics around the development of these artefacts suggest they can be instrumentally aligned with a country's visions of change and give strategic direction to technological-based socio-technical transitions. This would align with the UNFCCC process and the strategies of northern donors and technology providers, such as those under the CTCN network. But there are many more tools available than those financial instruments set out by the Convention to implement technological projects. The GEF, GCF and Adaptation Fund (currently the Financial Mechanism) are one set of operating financial organisations. The ecosystem includes a broader financial landscape, with stakeholders in SEA including the Asian Development Bank and the World Bank. The TNA is in itself another instrument to facilitate country driven import of global technology products and expertise. However, the process is enormous. It takes about three years to completed if everything goes as expected. This means a country ends up with the 'terms of reference' for this activity. Over three years, the travelling of expertise flows continuously to the national focal points in order to finalise the product. In parallel, these countries must begin applications for Technical Assistance to the CTCN and build pilot projects that can lead to demonstration and ultimately transfer through the network. In addition, another process must take place to build Green Climate Fund readiness:

> *"Good time for execution involves several structural challenges to the post-approval process that we highlighted and that we asked the secretariat to look at. Looking at the second part of how long it takes to get to the GCF dollar, remember there's accreditation but then there's the project cycle as well. You get the funding proposal in, it gets approved and then we found that in overall if you include accreditation as well as project approval cycles, it takes about 1,100 days to get to the first GCF dollar if everything goes well" (*GCF Coordinator, COP23, Bonn, Germany, November, 2017).

To this end, the National Designated Authority (NDA) for the GCF in Myanmar would need to develop several financial policies and resolve compliance issues when they come to the GCF as an agency. This involves several bureaucratic steps—from high-level negotiations to internal approval systems, technical and commercial requirements, and country regulations such as 'fiduciary standards' and 'environmental safeguards'—before moving forward to accreditation.[36] With good timing, the TNA process would take about three years to achieve those results and for TAPs to be ready to implement. In addition, it is necessary to fulfil the CTCN Technical Assistance requests and pilot projects for several more years. In parallel, the GCF takes a considerable amount of time and poses several institutional and regulatory challenges at the country level. There is another important caveat when it comes to the GCF. Once NDAs have been accredited, they do not have to re-accredit for another five years. However, there is still the project cycle, meaning there is distance between accreditation and the first 'GCF dollar'. There are critical gaps in the coordination of overburdened national experts and policy makers to mobilise this highly formal, fragmented and complex network process in the desired direction. There are currently long

[36] Analysis using data from interview with GCF Coordinator, COP23, Bonn, Germany, November, 2017.

waiting times from the TNA process and the CTCN transfer and piloting, all the way to GCF accreditation, project bidding and first disbursement of funds. This in itself is a challenge for LDC countries and SIDS. The levels of policy burden 'mobilised' in the countries by the 'new' model of technology-based cooperation under the UNFCCC is clear.

4.6 Discussions: Travel of Rationalities and Implications for the Mobilisation of Artefacts

This chapter has focused on understanding the mobilisation of expertise and technologies from a formal global knowledge network into Southeast Asian contexts. Efforts made through global technological transfer schemes under the UN-system encounter numerous challenges. First, there is a great distance between high-level technocratic policies intended to guide governments toward implementing technological solutions to advance international commitments. This strategy faces challenges from national realities—regulatory regimes and politics different from ideals of change held by the Global North. Second, the mobilisation of technology-policy artefacts through networked organisations, and in particular to Southeast Asian nations, tends to be simplified by leveraging 'packages' in attempts to fit different realities into standardised solutions. Third, by means of techno-economic assessments and long-term commitments guided by incumbent actors in a network, authoritative evaluations become the very boundary objects through which the travelling of rationalities are legitimised and made 'successful', creating, in turn, a locked-in systemic black box effects. The social process leading to 'black boxing' (Latour, 2005) is characterised by the invisibility created by scientific and technical success. Similarly, the socio-technical nature of technology transfer networks explained in this chapter shows how highly formalised settings are characterised by a complex institutional machinery that runs effectively by means of deepening its inputs. For example, the global technology policies and techno-economic advice developed through the work of the TEC are inputs made available for national experts driving the process in their ministries back home. Similarly, the Technology Framework appears to provide overarching governance through its five strategic themes, whilst the transfer of pilot technology packages and the building of technological assessments occur inside specialised ministries. These practices are complemented by other activities built over years of networked cooperation, with an eye to enhancing financial structures and 'readiness' to legitimise business models for the full scale up of technological deployments.

However, the assumptions displayed in CTCN's theory of change signal the inherent complexities of these connected developments and paradoxically bring to light the process's opaque nature. For instance, it assumes that all activities are to be secured through new funding structures that rely heavily on having sufficient human capacity on the ground and that national political agendas will develop the right policies and incentives in a timely manner. However, such scenarios belong to general categorisations that are part of intrinsic category system, and specific instances required grounding and contextualisation to its interpretation, as has been shown in the case of Thailand and Myanmar. In this case, context-specific dynamics are socially and culturally different in each setting and have implications for how such knowledge transfer activities are institutionalised. For instance, Thailand showed highly fragmented cultures of governance regarding managing water resources and disaster prevention. Furthermore, local institutional systems diverge in their approach to management activities and are far from those high-level technocratic aspirations of generalised models of change developed in norther European contexts. In contrast to the technocratic control-based functions of external expert networks, national institutions in Southeast Asia display different contextual conditions and point to the deeply ingrained political realities of sustainability transitions (Meadowcroft, 2011).

When it comes to policy coordination efforts by globalised expert communities, the focus in this case is on incremental inputs in the form of high-level policy briefs and general guidance to stakeholders. Since policy coordination is ultimately based on building consent and mutual expectations (Haas 1992), the policy process of the articulation of the Technology Mechanism involves mobilising diplomatic messages for national ministries, national authorities, and designated incumbents to support the institutionalisation of the transfer process. For instance, there is the case of task forces and the production of technology policy documents. Whilst these governance strategies seek to nurture enabling environments at the local level, they are built mostly as inputs. High-level inputs are vague about expectations and outcomes. But the long-distance interpretative process—from the global policy formulation context to the local implementation of assessments on the ground—corresponds to distributed socialisation practices that make sense of the technological changes proposed. In addition, when globalised networks of experts, boundary objects, resources and artefacts intersect, they function in reality through vast and ungoverned spaces. Consequently, the travel of input-based rationalities is confronted with the fact that the transfer of knowledge cannot really be monitored in distributed knowledge systems. Instead, knowledge organisations, such as those under the Technology Mechanism, tend to reproduce models of ‘transformational solutions’ to complex and contextualised dilemmas by means of traditional, 'universalised' economic thinking that assumes common motivations. This bias, product of the often-unidirectional flows of knowledge, ignores the possibility of diverse agencies, as well as the uncertainties which abound when the transfer of expertise remains oblivious to the intangible elements of technology. This applies equally to the CTCN deployment of 'packaged' solutions, as well the construction of technological assessments. In both cases, there have not yet been inside the Technology Mechanism, substantive alternatives to technology-driven modernisation visions of change which could form part of this global solution.

Chapter Five

How Networked Organisations Build Capacity for Anticipatory Governance through Project-based Interactions

5.1 Introduction

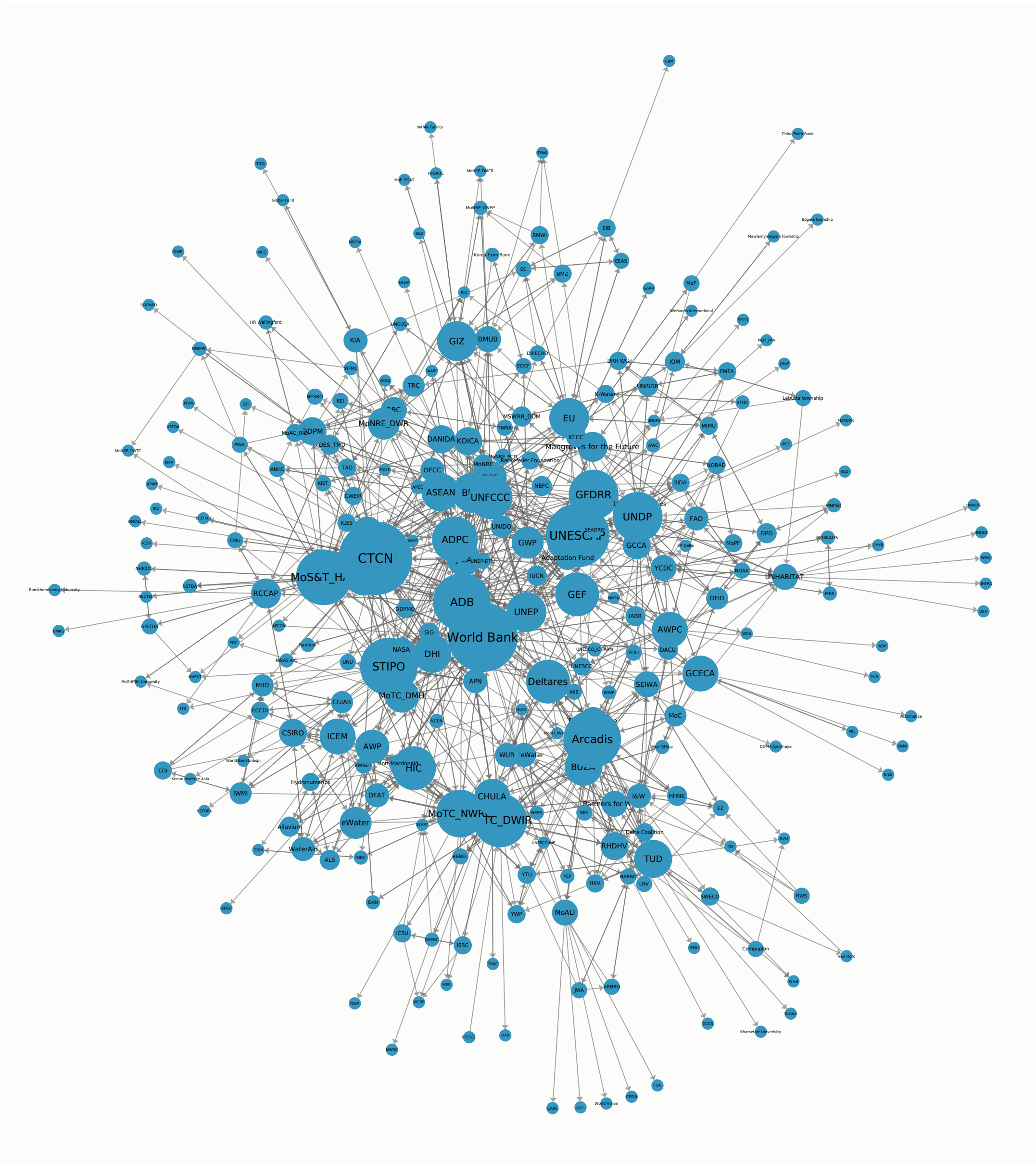
Connected developments through formalised global knowledge networks have proven to be complicated matters. Previously, Chapter 3 dealt with the intended functioning of formalised global knowledge networks through the negotiation of technology and expert-based cooperation systems under the UN. The analysis showed the fragmented realities of global bureaucracies under which the Technology Mechanism is intended to function. Chapter 4 dived into the network and analysed some of the muddied realities associated with the mobilisation of technologies and expertise from Europe to South-East Asian contexts. Chapter 5 will analyse in greater depth how networked organisations cluster around climate and hydrological modelling affairs to build and use 'capacity' on the ground. For this purpose, the chapter draws on social network analysis and fieldwork data to show how networked ecosystems formed in their endeavour to bring about those authoritative practices associated with anticipatory governance in Thailand and Myanmar. Building capacity for governments to make inferences about future developments should, in principle, enhance their ability to anticipate and plan for climate change adaptation. The analysis suggests that networked organisations manage to effectively consolidate technology and knowledge transfer through network arrangements. However, their governance effect in enhancing anticipatory decision making is found to be marginal at the local level. Evidence is found confirming the travelling of technical rationalities requires the balancing of tools and techniques with local institutional practices in order for them to be conducive to more robust forms of anticipatory governance. Consequently, technological deployment efforts need to consider more seriously the social and strategic elements of capacity at the local level in order to nurture robust institutional systems. Further considerations are given to uncertainty signals when absorbing external expertise and associated artefacts into different contexts of use. The chapter ends with a critical discussion about the lack of substantial integration practices; uses which do not necessarily lead to better response measures to risk and uncertainty, nor build more diverse institutional cooperation for long term environmental planning. Finally, it shows the need for preventive actions and more transparent operational response frameworks if these networked mechanisms are to significantly improve resilience and adaptability of local knowledge systems and institutions dealing with climate change adaptation in South East Asian contexts.

5.2 Global Climate and Hydrological Networks Operating in SEA

While global knowledge networks are often associated with the rapid mobilisation of knowledge in environmental governance, futures research has given little attention to how worldwide expertise and their associated tools —in this case, modelling technologies— influence the practices of environmental governance in national institutional contexts. Since there are unresolved questions about the effectiveness of the transfer of western knowledge to other non-western settings, this calls for further analysis, in particular where climate change adaptation is concerned. In this case, the concept of 'expertise' is associated with anticipatory governance (Sardar 2010; Fuerth & Faber, 2012). Hence, the chapter pays attention to particular actors' use of capacities to envision, imagine, evaluate and strategically respond to anticipated events (Boston 2017).

It is clear from previous chapters that the transfer of climate and hydrological modelling technologies is a salient activity across SEA. Climate change is very likely to severely impact the flood risk of coastal cities, for example in Bangkok and Yangon (Aerts et al. 2012). In particular, delta regions are dynamic and densely populated environments characterised by intense agricultural practices, the rapid development of cities and vulnerability to climate change. For example, prioritised technologies under the TNAs and through CTCN's technical assistance shows that forecasting technologies are shown as 'needed' by national organisations in Indonesia, Thailand and more recently, Myanmar. Forecast modelling technologies intend to enable anticipatory capacities and allow organisations to make more elaborate and robust inferences on matters playing out at different temporal and spatial scales, in order for them to plan and adapt to climate-induced flooding and droughts. For instance, A high-resolution regional climate model tool for Thailand has been under review by the CTCN since 2015. The project focuses on Adaptation using climate models for inputs to Early Warning Systems and Environmental Assessments. The project aims to factor in the model in the planning and management of irrigation and agriculture. The necessity of such capacities can be observed in the case of institutions dedicated to water governance and agriculture in these two countries. Global knowledge networks attempting to deploy climate and hydrological expertise and technologies to the region comprise a much larger ecosystem than those organisations connected to the Technology Mechanism. This requires a closer look into the actions of agencies consolidating transfer efforts at national levels.

Figure 13 Global Knowledge Networks in Thailand and Myanmar 2016-2019.



Source: Author, 2018

Data collected between 2016 and 2018 show SEA is a rapid development region, with many forms of agency collaborating and competing to settle ties and offer their expertise. The active presence of cooperation networks enables a higher degree of interactions at different levels of governance. This results in a dynamic and dense set of ties across a sizeable global knowledge network ecosystem.

Figure 13 is the visual output built using the Social Network Analysis software KUMU. The graph represents a global knowledge network operating in Thailand and Myanmar between

2016 and 2019 when fieldwork data was collected. The inter-organisational context, where many organisations interact, offers an overall, explicit view of the network mapped. It used qualitative measures based on interview data and reports to generate links between them. While the visual representation validates network formation across interinstitutional spaces, the application of multi-sited ethnography enabled the study of actors connected to organisations through space and time and represent their knowledge sharing activities linked to technology development and transfer. Figure 13 also shows a representation of active organisations involved in hydrological and climate-related practices in Thailand and Myanmar. This dense web of agencies shows 193 organisations, ranging from government, private sector, intergovernmental organisations, research institutes and non-governmental organisations with a presence in both countries. Technically, these are communities of nodes characterised as 'networked organisations' for analysis. These organisational nodes are autonomous, geographically distributed, and are heterogeneous in their operative environment, social capital and goals. They have, over the years, established formal ties and collaborative activities supported by information and communication technologies. Figure 13 shows the directionality of connections and the size of organisations according to the number of incidental nodes and their network connectivity. Directionality represents connections "from" and "to", meaning that the direction indicates the relation's nature. Formal ties refer to the relationship's character and the focus of links, such as active projects and collaborations, described and analysed in detail in this chapter.

The most connected organisations are visualised larger than others, as they have a more significant operational reach and tend to cluster towards the graph's centre. Smaller organisations are visualised in the network periphery and have significantly less connectivity than their larger counterparts. In this case, organisations are intertwined by common interests which are formalised via concrete official documentation. These communities formed when agencies create ‘formal’ ties with other agencies. Their formal ties belong to technology transfer projects. Sustained connections occur by developing official MoUs for cooperation, which defines their relationship, directionality, and role in expert-based collaboration. For instance: mapped organisations maintain official platforms for capital investments in water infrastructure, give loans, and act as donors for technology transfer projects. This is the case for UN-agencies such as UNEP, UNDP and the World Bank Group, the Association of Southeast Asian Nations (ASEAN), and the Asian Development Bank (ADB). Each of these groups has grown a regional presence. As opposed to its neighbour Thailand, the case of Myanmar shows more direct interventions of development agencies, which are running programmes in the country. Decades of military rule had led the country into political turmoil and a distancing from the ASEAN, the regional forum of SEA countries which aims at improving regional governance and cooperation, leaving Myanmar in a position for donors and other external affairs to more strongly intervene in its affairs. Over the last ten years, the World Bank has increased its significant presence in Myanmar. According to the Country Partnership Framework for Myanmar (CPF 2018), aid is strongly focused on the following areas: Human capital, peace and the introduction of private sector-led growth and economic opportunities, while promoting resilient infrastructures in order to cope with natural disasters and foster sustainable development for the period 2020-2023 (World Bank 2018). In the case of UNEP, the agency started playing a more active role after cyclone Narguis in 2008, through the establishment of an "environmental desk" though which to provide support in the recovery phase, which leads into a UN disaster recovery programme from Myanmar. A regional competitor of the World Bank is the Asian Development Bank, with which it competes in the strategic areas of infrastructure, connectivity, human capital capacity building, and institutional reform to improve economic growth. Myanmar faces serious problems when it comes to peace, governance and sustainable development according to the UNDP. Therefore, their role has been to position a UNDP country programme which will support the implementation of the 2030 Agenda on Sustainable Development, at the same time monitoring and helping to establish political dialogues.

On another front, national organisations dealing with water act as recipients of donor aid and engage in capacity building and technology transfer projects. For example, the Hydro Agro Informatics Institute (HAII), Hydro Informatics Centre (HIC) and Myanmar's National Water Resources Council (NWRC). Initial analysis based on data collected during fieldwork suggests some organisations have strategic roles. For example, the Hydro Informatics Centre (HIC) in Yangon is the national expert organisation receiving capacity building from organisations such as UNESCO-IHE in the Netherlands, and in collaboration with the Hydro Agro Informatics Institute (HAII) in Thailand. For instance, in conversations with the UNEP Adaptation Specialist for Myanmar, she shared that many agencies catalyse public and private interests, often competing for donor funds to implement technology and expert-based cooperation. The UNEP officer explains:

> *"I have to coordinate funding proposals and there is a lot of competition between agencies, national and international because there is only a certain amount of money available for each country and each agency have their contacts and their proposals. The same applies to public and private sector agencies in the region, sometimes inside the same agency."* (UNEP Adaptation Specialist for Myanmar, UNESCAP, Bangkok, Thailand, April, 2017).

For instance, after the tsunami in 2004, which came crashing ashore at Koh Raya, parts of Thailand's territory around the Andaman sea were severely hit, requiring international cooperation for post-disaster recovery and raising the presence of international aid in Thailand. This was followed by the disastrous Bangkok floods of 2011, which focused the attention of organisations dealing with water in Thailand.[37] Northern companies such as the Danish Hydraulics Institute (DHI), Deltares and Arcadis subsequently appeared on the map. The three companies have expertise in hydrological technologies and expertise in environmental planning for cities. In particular, DHI developed earlier strategic ties with such national agencies in Thailand as the Royal Irrigation Department (RID), the Department of Water Resources (DWR), Thai's HAII, the Provincial Water Authorities (MWA and PWA) and the EGAT; the department in charge of managing the country's hydro dams.[38] Additionally, DHI was in conversation with the Bangkok Metropolitan Administration (BMA), the authority responsible for managing the city's 'khlong' systems. DHI also developed ties over time with regional and global agencies including the World Bank, the ADB, and the UNEP and its Global Water Partnership, making it an influential organisation across the network. Given the number of agents and potential activities, centrality measures allowed the identification, cluster and analyse the composition of the network to understand the position of critical nodes as influencers and gatekeeper of knowledge.

[37] Analysis using data from interview with Disaster Risk Reduction Expert, UNESCAP, Bangkok, Thailand, April, 2017.
[38] Analysis using data from interview with DHI operations officer in Bangkok, Thailand, March, 2017.

5.3 The Hydroclimate Cluster

The social network analysis findings point to a group of organisations with the highest-ranking centrality values based on three different centrality measures (Table 7 shows centrality results). The data shows existing organisations with the highest degree of connections between nodes, representing hubs for analysis. A closer look indicates that the most incidental nodes in this network cluster are as follows: The World Bank, the Climate Technology Centre and Network (CTCN), the Danish Hydraulics Institute (DHI), the Thai Hydro Agro Informatics Institute (HAII), the Thai Science, Technology and Innovation Policy Office (STIPO), Department of Water Irrigation from Myanmar (DWIR), the United Nations Environment Programme (UNEP), the Bangkok Metropolitan Administration (BMA), National Water Rivers Committee of Myanmar (NWRC), the Hydro Informatics Centre from Myanmar, the Global Water Partnership (GWP), and the United Nations Framework Convention on Climate Change (UNFCCC). Other organisations were included, such as the Asia Disaster Preparedness Centre (ADPC), the Green Climate Fund (GCF) and Arcadis, given their relevance in interviews and secondary data. The interviews, reports, and social network analysis indicate that such organisations are formally connected through ongoing technology transfer interventions. They also have control over the flows of project information, as observed during fieldwork and in interviews. Because of fieldwork rapport and interviews, project officers were willing to share their project information and MoUs for analysis.

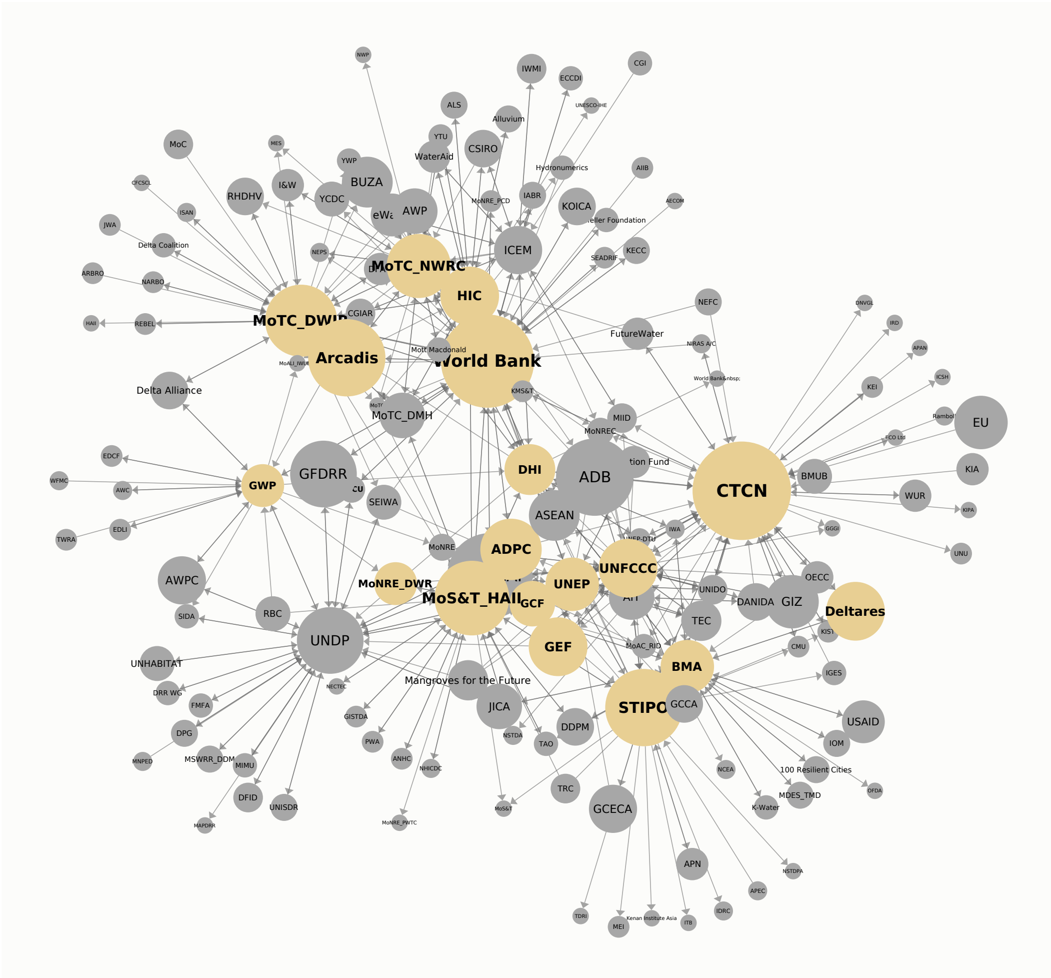
Table 7 Centrality results

Closeness Centrality			Betweenness Centrality			Eigenvector Centrality		
Rank	Label	Value	Rank	Label	Value	Rank	Label	Value
1	World Bank	0.576*	1	World Bank	0.247*	1	World Bank	0.041*
2	CTCN	0.559*	2	CTCN	0.243*	2	DHI	0.035*
3	DHI	0.556*	3	DHI	0.195*	3	CTCN	0.034*
4	MoS&T_HAII	0.533*	4	MoS&T_HAII	0.176*	4	UNEP	0.031*
5	STIPO	0.523*	5	UNDP	0.158*	5	MoTC_NWRC	0.03*
6	MoTC_DWIR	0.518*	6	STIPO	0.156*	6	HIC	0.03*
7	UNEP	0.516*	7	MoTC_DWIR	0.147*	7	MoTC_DWIR	0.028*
8	BMA	0.496*	8	BMA	0.112*	8	MoS&T_HAII	0.027*
9	MoTC_NWRC	0.493*	9	GWP	0.096*	9	TM_UNFCCC	0.026*
10	HIC	0.491*	10	UNEP	0.081*	10	STIPO	0.024*
11	UNFCCC	0.484	11	HIC	0.072	11	BMA	0.019
12	UNDP	0.474	12	ICEM	0.061	12	AIT	0.018
13	GWP	0.466	13	MoTC_NWRC	0.061	13	MoTC_DMH	0.017
14	ADPC	0.462	14	UNFCCC	0.046	14	UNDP	0.017
15	UNESCAP	0.462	15	AIT	0.023	15	ICEM	0.017
16	AIT	0.461	16	ADPC	0.018	16	TEC	0.016
17	ADB	0.461	17	UNESCAP	0.018	17	DFAT	0.015
18	MoNREC	0.451	18	KMS&T	0.015	18	GCF	0.015
19	ICEM	0.446	19	SEIWA	0.011	19	UNESCAP	0.015
20	Adaptation Fund	0.435	20	GCF	0.01	20	Mott Macdonald	0.014

Source: Author, 2019

Table 7 shows closeness centrality, betweenness centrality, and eigenvector centrality results from SNA engine KUMU with data inputted the data into R Studio to get a random value sample of 100 organisations (See Chapter 2, p. 73). This was followed by building a network structure and pre-selected the first 20 organisations with the highest rank and value for each metric, of which ten within the highest ranks were clustered, aggregating a total of 15 organisations across the metrics (the most incidental, the direct and indirect nearness between nodes, the information bridge nodes, and the most influential nodes). Based on this selection, for analytical purposes, I named it the cluster: *Hydroclimate cluster*.

Figure 14 The Hydroclimate Cluster



Source: Author, 2019

Figure 14 shows a visualisation output of the most central organisation in the network based on centrality measures. The results indicate marginal variations between centrality, betweenness and eigenvector centrality. The ranks for each measurement correlate in direct and indirect nearness. The levels show the leading organisations in information flow and the nodes that act as crucial knowledge share points. Also, ranked organisations represent the most prominent, given their incidental characteristics. As expressed in the methodology, I did not consider the results of social network analysis in isolation, and they are not sufficient on their own to explain influence. The data's explanation is also combined with ethnographic information, interviews, and policy reports from each organisation, as it is expanded in this chapter.

In Figure 14, the Hydroclimate cluster points to central nodes of interest. For instance, the CTCN network, which has grown over the past five years (2015-2020), indicated formal ties with agencies with previously set relations in Thailand and Myanmar, such as Deltares. For example, Deltares is now a CTCN network member registered in the Netherlands with sectoral expertise in coastal zones, water infrastructure, and urban planning, focusing on deltas, coastal regions, and river basins worldwide. However, Deltares had built previous connections in the region. The network dynamic is related to the fact that some international organisations have had historical ties to South-East Asia. For example, Dutch engineers have formulated 'delta plans' in Myanmar and Vietnam and have ongoing delta planning activities in these countries. The famous 'Mekong Delta Plan' is an example of Dutch 'delta' enterprise travelling and shaping institutional relations in Vietnam (Zegwaard, 2016). The continuous presence of external experts, such as water engineers and European planners, has influenced the development of infrastructure and institutions including banking systems and telecommunications across SEA. For example, Myanmar shows administrative ties to the British colonial history, where external institutional systems ended up making the Ayeryawaddy delta an object of environmental planning by European experts together with the World Bank (Hogendoorn et al., 2018).

Although Thailand remains a focus of international attention, it has retained its independence from those external institutional models which were largely shaped during extended colonial periods. For instance, by the Dutch over the "East Indies" (Indonesia), French "Indochina" (Vietnam, Laos and Cambodia), Portuguese Timor and British Burma (Myanmar), Malaya and Borneo. In contrast to its neighbouring countries, Thailand was never colonised by European powers, and thus retained its independence and most of its traditional institutional systems. For example: Thailand's tradition of water institutions reflects this legacy, having had a flood management system since the fourteenth century (Takaya, 1987). However, contemporary means of expert travels have gently landed water governance agendas in Thailand. The country's legacy of water institutions has not been an impediment for new global arrangements to set ties in the modern capital of Bangkok, and from there spread their influence through the involvement of development-cooperation on water and climate change. For example, the Hydroclimate cluster showed that between 2016-2019 significant activity was linked to the consolidation of formalised inter-agency agreements: a signal of concentrated efforts in the region. While large-scale global knowledge networks emerge, smaller 'formalised' networks are nurtured through 'closed' cooperation mechanisms; these connections which in turn become centralised and legitimised by national institutions. For example, the cluster shows how more particular, incidental actors create central nodes which pull information and resources. For instance, the figure of the NDE inside a ministry seeks to structure the flows of technologies and expert knowledge through by making formal connecting gates. Another example, the NDE for Indonesia, sits at the Directory General of Climate Change under the Ministry of Environment and Forestry, the NDE for Myanmar sits at the Environmental Conservation Department at the Ministry of Environmental Conservation and Forestry; Vietnam's NDE at the Ministry of Natural Resources and the Environment. Finally, Thailand's NDE occupies a science-advisory role at the National Science, Technology and Innovation Policy Office (STIPO) (CTCN, 2016a). In the case of Thailand, the national focal point under the NDE serves as the nodal entry point for the Hydroclimate cluster.

Earlier in Chapter 4, STIPO was characterised as a specialised agency bridging science, technology and innovation at the governmental level that provides strategic planning in areas related to climate change. For example, the organisation developed the National Science, Technology and Innovation Policy Review in 2015 and a National STI Policy and Plan (2012–2021). These efforts are aligning STI planning objectives with climate strategies. There are clear indications that STIPO acts as a central coordinating node for the mobilisation of technologies, and also for the use of expert networks in the context of climate change. Through a formal network mechanism, STIPO catalyse other formally connected actors, such as technology providers. This national boundary organisation plays a strategic role in connecting international organisations from the CTCN network, and makings links, in this case, with the Danish Hydraulics Institute (DHI), with the Thai Hydro Agro Informatics Institute (HAII), the Bangkok Metropolitan Administration (BMA), the Green Climate Fund (GCF) and the World Bank.[39] At the very centre of the Hydroclimate cluster, there is a highly networked ecosystem of organisations serving as a platform to enable relationships with national and international partners through focal connections. In South East Asia, the institutional dynamics driving knowledge applications in water governance shows that the use of technological packages is perceived as salient by this network. Technology packages in this case refer to encapsulated climate and hydrological modelling tools which are ready to deploy and use by expert government organisations.

[39] Analysis using data from interview with STIPO officials in Bangkok, Thailand, 2017.

Table 8 Hydroclimate Cluster in Focus

Nodes	Type	Activity	Scale	Location	Description of main activities
ADPC	IGO RI	Policy and Planning Capacity Building Development and Aid	Regional	Bangkok	→ International centre that builds capacity of institutions to anticipate and deal with disasters and climate change impacts in Asia and the Pacific. Supports countries in Asia and the Pacific in building their DRR systems, institutional mechanisms and capacities to address hazards, such as floods, landslides, earthquake, cyclones and droughts.
Arcadis	PSO	R&D and innovation, Technology transfer Implementation & Capacity building	Global	Amsterdam	→ Engineering and management consulting in a range of areas, including cities, energy, transport and water management.
BMA	GOV	Policy and Planning Implementation & Investing	National	Bangkok	→ The local government of Bangkok. The BMA administrative role includes to formulate and implement policies to manage Bangkok. It also manages part of the city's wastewater and flood control systems.
CTCN	IGO KN	Capacity Building Technology Transfer Implementation	Global	Copenhagen	→ UN organisation under UNEP and UNIDO that acts as the operational arm of the Technology Mechanism under the UNFCCC. It fosters technology development and transfer, and provides technical assistance on mitigation and adaptation technology, as well as capacity building and manages a global network of 500+ organisations.
DHI	PSO	R&D and innovation Technology transfer Implementation Capacity building	Global	Copenhagen	→ International software development and engineering consultant firm with expertise in hydraulic and hydrological technology. DHI implements technology transfer projects and capacity building on a range of water management areas such as modelling, forecasting and flood control.
DWIR	GOV	Policy and Planning Implementation	National	Yangon	→ Public organisation responsible for water management under the Ministry of Agriculture and Irrigation in Myanmar.
GCF	IGO	Financing Development and Aid	Global	Songdo-dong	→ Fund established within the framework of the UNFCCC as an operating entity of the Financial Mechanism to assist developing countries in adaptation and mitigation practices to counter climate change.
GWP	IGO KN	Capacity Building Policy and Planning	Global	Stockholm	→ International network that fosters integrated water resources management (IWRM) in developing countries and operates with governments, UN agencies, research institutions, NGOs and the private sector.
HAII	GOV RI	R&D and innovation Technology transfer Implementation Capacity building	Regional	Bangkok	→ Public organisation under the Thai Ministry of Science and Technology that develops and applies science and technology to support agricultural and water resource management.
HIC	GOV RI	R&D and innovation Technology transfer Implementation Capacity building	Regional	Yangon	→ Public organisation under the National Water Rivers Committee (NWRC) that applies science and technology to support water resource management in Myanmar.
NWRC	GOV	Policy and Planning Implementation	National	Yangon	→ The committee develops an integrated water management system and a national strategy, policy and framework for drafting water laws in Myanmar. It promotes international collaboration on water.
UNEP	IGO	Development & Aid Capacity Building Policy and Planning	Global	Nairobi	→ UN Environment Programme is the global advocate for the environment with a range of programmes focusing on sustainable development. It coordinates environmental and climate-related activities and assists developing countries in implementing environmental policies and practices.
UNFCCC	IGO	Policy and Planning & Implementation	Global	Bonn	→ International environmental framework with 197 parties and 165 signatories. It pursues efforts to stabilise greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Important milestones include the Kyoto Protocol (1997) and the Paris Agreement (2015). Its secretariat works together with multiple stakeholders to implement these accords using a range of governance mechanisms, such as the CDM, the Technology Mechanism and the Financial Mechanism.
STIPO	GOV RI	R&D and Innovation Policy and Planning Capacity Building	National	Bangkok	→ Public organisation that works together with the National Science Technology and Innovation Policy Committee, chaired by the Prime Minister of Thailand. It provides support to the government in science, technology and innovation policy.
World Bank	IGO	Financing Development and Aid Implementation Policy and Planning Investing	Global	Washington D.C	→ International financial institution that provides loans and grants to developing countries. It provides financial and technical assistance with the aim to reduce poverty and support development.

Source: Author, 2019

Unmistakably, the Danish Hydraulics Institute (DHI) is an influential node in the network. Both UDP (officially the UNEP DTU Partnership) and DHI have consolidated their organisations as consortium partners of CTCN. While UDP leads the TNA process under the

GEF, DHI transfers hydrodynamic models with support from CTCN donors. In particular, DHI plays an active role by offering services on modelling tools for rivers, deltas, cities and oceans. Their main source of expertise lies in the software development of MIKE models (e.g. MIKE 11, 11 GIS, 21C, Hydro basin, and MIKE 2019), which hydrological engineers globally use in public and private organisations (DHI, 2006). From Denmark, DHI operates a research department, where they engage in collaboration with SEA universities in different countries, conduct basic research on modelling and develop product portfolios. For years, DHI and the Asian Institute of Technology have closely collaborated to address challenges such as sedimentation, soil erosion and environmental pollution in SEA. DHI provides technology transfer, training and research support to AIT continuously; the connection between the organisations is nurtured by the active exchange of staff and students. Recently, they have developed a range of studies on natural hazards in water infrastructure (Oliver et al., 2018), hydrodynamic data assimilation (Schneider et al., 2018) as well as multi-stakeholder scenario tools for decision making using the SIM4NEXUS approach (Sušnik *et al.*, 2018). A critical network connection is their formal partnership with UN Environment, in which the UNEP-DHI Centre on Water and Environment has become an essential part of their water policy and implementation strategy (UNEP-DHI, 2017). Together with UNEP, DHI collaborates with the Global Water Partnership (GWP) to advise on the role of Decision Support Systems (DSS) for Integrated Water Resource Management (IWRM). In a technical report, they have provided seven cases of DSS application for water-economic modelling and planning in Asia, South East Asia, Africa and Latin America (GWP, 2013). Since 2017, UNEP-DHI started to follow the UNEP Fresh Water Strategy 2017–2021, which includes a strategic focus on policy and technical advice, capacity development, implementation and strengthening of national legal and institutional arrangements on water management (UNEP, 2017). Consequently, the centre created a mandate to provide policy advice and technical assistance on water management at the global, transboundary, national, basin and subnational levels. As the implementing agency of UNEP's IWRM Programme, the centre developed national reports and technology roadmaps for 19 countries to date; of which five are in South East Asia: Cambodia, Laos, Thailand, Vietnam and Myanmar.[40]

The UNEP-DHI partnership consolidates a platform for technology transfer. Specifically, their expertise travels with their modelling software. MIKE models enable water engineers to prepare forecasts, as well as scenario analyses for project-specific future conditions, in

[40] Analysis using data from interview with UNEP DHI officer. UN-City, Copenhagen, Denmark, September, 2017.

order to support decision-makers on environmental planning. Following this logic, the organisation has developed specific guidelines for climate and water system interactions in urban and rural contexts and coastal areas. The guidelines combine DHI's modelling approach with recommendations of how to deal with water resource management challenges through project-based interactions, considering future climate projections and operational challenges for decision making. For example, UNEP-DHI had worked for the past ten years in Thailand with different organisations, including AIT, and supported the BMA when the Chao Phraya flooded in 2011. Their response on that occasion was to establish collaboration with the government and agree to build a climate and water forecasting system for the Bangkok Metropolitan Administration (BMA). Succeeding in its strategy, DHI delivered an operational MIKE system for the city. Through a capacity building scheme, they deployed a tailored software and trained local staff under the CTCN's Technical Requests services (CTCN, 2015).

On another front, the Hydro Agro Informatics Institute (HAII) is also a recipient of DHI modelling technologies and training. During the government's response plan after the 2011 floods, HAII began collaborating with the BMA in the building of water statistics. The HAII considers itself to be an important "data keeper of Thailand". The HAII is a government agency operating as a national data centre. They are mandated to safeguard data and provide expertise on policy issues that involve significant amounts of data, such as country statistics on water and agriculture. HAII started as a cooperation project with the Massachusetts Institute of Technology (MIT) due to King Rama IX's previous royal links during his studies in the US. The Thai Royal family had maintained ties with MIT and Harvard since King Rama IX was born in Cambridge, Massachusetts, in 1927, when Mahidol Songkla, the previous king, was studying. Consequently, HAII was founded in 1994 in efforts to bring more consistent data analysis tools for decision-makers to Thailand's two critical sectors. They have received support from DHI concerning water modelling technologies, and they also provide data and policy advice to institutions such as the BMA, as the HAII lead officer shared in an interview with me:

> *"We know DHI well. We use some of their models. They come and implement technology with the Bangkok Metropolitan Administration. We support BMA since we hold the data and information. We supply them with data required to ran simulations"* (HAII Lead Officer. HAII, Bangkok, Thailand, April, 2017).

According to the HAII, the BMA is one of thirty-four Thai institutions with data-related water management needs. For instance, Bangkok city monitors water with "hundreds" of water level sensors stationed across the Chao Phraya. HAII uses these data to analyse the behaviour of the delta, which is then used to engage with the government at the policy level, promoting their national expertise. However, when it comes to the CTCN network, there is apparent competition for resources. HAII is the 'local' expert institution providing data and modelling based expertise in, for instance, the case of the BMA early warning systems and flood monitoring. As such, it would make sense for them to receive funding from requests to the CTCN network to further deploy their skills in particular areas of agriculture and water data across Thailand, or through south-south cooperation. After all, they have the data, expertise, and know the regulatory and policy environment of Thailand. They also have the national legitimacy to use their expertise in these areas.

For example, HAII competes with DHI in the bidding process leading to the deployment of the early warning system for BMA, which already existed in Thailand. The HAII shared with me their frustration when tried to get funding from UNEP and the CTCN to become the national implementer, although DHI had a 'stronger' bid in the end due to their international recognition as water modellers:

> *"We try several times (with CTCN). Now we have other ongoing bids with the Asian Development Bank to study flood risk in some of the basin in Thailand. It's actually an initiative of the Thai government, it sounds funny, but this is finally happening. Thai government requesting money from the ADB to do a study of this nature. We are the local partners since they invited us and then we together joined the application."* (HAII Lead Officer. HAII, Bangkok, Thailand, April, 2017).

However, the HAII continues to focus their attention on structuring pre-existing but fragmented data in Thailand. They also have a deep connection with the Kings' ideas of Sufficiency Economy, which they have incorporated as a framework for working with rural villages in Thailand. The Sufficiency Economy philosophy emanated from Buddhist practices and beliefs. According to the Chaipattana Foundation created by King Bhumibol in 1988, the sufficiency economy is a social methodology for the development of Thai society, with principles based on moderation, prudence and social immunity, one that uses knowledge and virtue as guidelines for living. This philosophy—some argue, comes from Schumacher's "Small is Beautiful" (1973): a critical view of Western economic theory which resonates with Buddhist worldviews. Thus, the uses of expert knowledge emanating from the HAII are articulated within the visions of change embedded in Thai economic philosophy. Their approach, for instance, includes projects on *"Kaem Ling"* Monkey's Cheeks, a method of flood control. *Kaem Ling* is the practice of storing excess water when flat areas of Bangkok cause floodwaters to drain slowly from one gradient to the next. Many canals have small hill gradients, and other are silted. The canals are used temporarily as reservoirs and filled up when heavy rain occurs. Floodgates are then opened to allow the water to flow out to the sea or be used for irrigation. Hence, the concept of Monkey Cheeks is a popular term in Thailand since it is easy to understand by local farmers and local water authorities. According to the institution, improving approaches to community-based natural resource management (CBNRM) is the future for Thailand's resilience to climate change:

> *"It is very important to understand local weather as well as local knowledge, the local wisdom, and the local way of handling things. Rural communities, as well as here in Bangkok, are faced with this (water) challenges every day, every year. They have done that for hundreds of years, so they know how to run their agriculture when they have droughts or floods. Develop this type of activities (CBNRM), we believe is the way to survive in the future."* (HAII Specialist. HAII, Bangkok, Thailand, April, 2017).

However, there was a turn towards outward-looking, technology-based solutions after the 2011 floods. Both the government and organisations such as STIPO prioritised the technological transfer encapsulated in the TNA assessments. The government sees it as a priority to import expertise and associated technologies in water and agriculture to ensure critical infrastructures can be better monitored against environmental hazards. The problem is twofold. On the one hand, there is a narrative of "technology deficit", which discredits what local organisations such as HAII have in terms of technology and capacity. On the other hand, this legitimises those external companies from the Hydroclimate cluster in stepping in once more and further consolidating the technology transfer processes. While it is not necessarily wrong to have up-to-date modelling technologies to enhance structural resilience at the city level, the authority of well-networked external actors has a much stronger advantage when compared to local implementers when it comes to accessing funds. This has been shown by the hegemony of DHI, and the consolidation of closed networked arrangements through project-based interactions across SEA. The next section explains the UNEP DHI strategic implementation of the BMA project through network means.

5.3.1 Strategic Operations and Uses of Expertise

The establishment of strategic alliances is at the core of activities inside the hydroclimate cluster. The operations of DHI, in combination with UNEP partners, consolidate the transfer of hydrological modelling technologies by winning and implementing projects. The global knowledge network coordinated by the CTCN matches demand and supply and provides technical guidance on technologies and funding. The strategic position of the UNEP-DHI partnership allows proximity on interactions with CTCN and other UNFCCC-related agencies, including those of the Financial Mechanism (e.g. GCF). These strategic linkages are means of transfer of tailored packages and portfolios of expertise. These portfolios export project ideas and concept notes arising from network clients (e.g. BMA).

The process involves the pairing of potential solutions to requests with funding and prioritised sectors and technologies (e.g., through Technology Needs Assessments). For example, the BMA needed to obtain hydrological modelling software and build local capacity to operate such technology. Consequently, the BMA selected DHI to be the implementer of an Early Warning System for the city of Bangkok (CTCN, 2015). While other organisations such as HAII, Arcadis and Deltares made bids for the same project, there was a previously legitimised interaction between DHI and BMA. Hence, there is a perception that DHI would effectively supply the service, and feasibility studies went immediately to technical details of implementation.[41] In this particular case, the interactions between DHI and the BMA are based on a combination of formal governance arrangements, as well as the relational mechanisms that evolve through project-based interactions. As a result, established links of centralised, networked organisations maintain institutional dynamics that are legitimised through formal and relational strategies.

Formalities develop into concrete Memorandums of Understanding (MoUs) which increase the likelihood of funding. The collaborative networked capability of DHI and the BMA allows for technical knowledge to be exchanged and produces a concept note and implementation plan together with the CTCN. The operations continued with DHI and STIPO working together, enhancing the legitimacy of the project.[42] DHI engaged closely with the NDE from the initial project description phase all the way to the drafting process a year in advance of the bidding process for funding.[43] The practice suggests higher coordination exists in organisations which are centralised—and to some extent authorised by peer nodes, to perform strategic behaviour and influence; whilst other local organisations such as HAII remain marginal to the process. In turn, their expertise comes in once the project has been implemented and they can be of service by providing data. This dynamic shows important patterns in the structuring of formal global networks and the relational setting of ties between organisations through the use of tools and techniques. It suggests strategies and uses of expert knowledge by incumbents to gain influence and legitimise technological

[41] Analysis using data from interview with CTCN Adaptation Specialist, UN-City, Copenhagen, Denmark, June 2018.
[42] Analysis using data from interview with UNEP DHI Officer, UN-City, Copenhagen, Denmark, June, 2018.
[43] Analysis using data from interview with Policy Officer. STIPO, Bangkok, Thailand, April 2017.

transfer. This example illustrates how an organisation uses access to the network to maintain its operational reach. The strategic positioning offers network members a direct line for project implementation at city levels, such as in Bangkok, Jakarta and Yangon. Project-based interactions can take the form and length of short training sessions of two weeks, up to technology transfer implementation trajectories of two years. For example, to update the MIKE software and train local staff or when deploying and implementing a new technology. This strategy combines a broader portfolio of technology options and includes policy and implementation phases.

The network interactions described represent long term engagement through project-based interactions that link technical engineering aspects of tools (e.g., in the case of modelling technologies), with policy advice to ministerial agencies and capacity building to local staff. This combination of formal arrangements with relational mechanisms makes the UNEP-DHI partnership one of the most active hydrological modelling companies in Thailand. The use of modelling tools are attempts to reduce the risk of flooding by means of instrumental rationality, however, ignore the more complex institutional aspects of local politics, which render anticipatory skills affected by governance elements which are not addressed. However, the uses of expert tools say little about the real complex socio-technical-environmental tensions, which could have different future implications for climate change adaptation in the context of SEA's cities.

In the case of Myanmar, the strategy emanating from globalised arrangements shows that DHI is in the process of opening doors. The company started feasibility studies for promoting data on climate change, drought and flood management. Similarly, the World Bank and Asian Development Bank are actively engaged in in-country projects. In Myanmar, DHI has a contract with the World Bank to help set up the Hydro Informatics Centre (HIC). The HIC is part of the Ayeyarwady Integrated River Basin Management Project (AIRBM), administered by the Burmese National Water Resource Committee (NWRC) and other local authorities, such as the Directorate of Water Resources and Improvement of River Systems (DWIR), both currently following the Dutch Delta Plan for the Ayeyarwady (IADS). The DHI started building a decision support system in 2018, and is training Burmese staff in hydrological modelling—similarly to in Thailand, although this project is beyond the scope of CTCN activities. The modelling system carries institutional integration with the HICs practices and policy frameworks. Arguably, DHI's legitimacy also comes from training new generations of modellers with skills in their hydro informatics systems, which also specialised their technical knowledge toward DHI MIKE models. This strategy seeks to ensure long term future projects, software updates, and technological upscaling can take place not just at the city level, but potentially across the entire delta.

Myanmar is a new, evolving market for competitors across the Hydroclimate cluster. The World Bank's funding dominated most hydrological projects in Myanmar from the 1990s until recently. Networked organisations such as Arcadis and Deltares are actively trying to position themselves against their main competitor DHI. However, Myanmar is still uncharted territory. After British imperial rule, the Burmese have been profoundly impacted by anti-democratic forms of power since the 1960s. The military also closed several technical universities for decades (Walton 2017-check). After Cyclone Narguis devastated the Ayeyarwady delta in 2008, there was another type of flooding— that of aid organisations. Most of the knowledge brought from external experts has only touched capacities at the local level, since studies and reports are tailored to northern donors. This started with Myanmar's Initial National Communication (INC) under the UNFCCC, with the participation of MOECAF in Nay Pyi Taw, GEF and UNEP (2012), all of which followed by the development of their National Adaptation Programme of Action (NAPA) in 2015. Another entry for cooperation and aid in Myanmar, for instance, is through the now-established Myanmar Climate Change Alliance (MCCA) together with the Ministry of Natural resources and Environmental Conservation. They develop "together" the Myanmar Climate Change Strategy & Action Plan, a fifteen-year road map for Myanmar's 'strategic recovery', while maximising market opportunities for low-carbon and climate-resilient development (UNHABITAT 2017). This was followed by an assessment made by the WWF, in alliance with MCCA and the Centre for Climate Systems Research from the Columbia University, on Climate Risk in Myanmar, together with other vulnerability assessments, the ongoing TNA process, and other technical "transfers" through the assessment and deployment of experts. Global agencies' primary focus has been on improving recovery options for Myanmar while strengthening networks with local organisations. While this might be needed and sound, it also generates competition, since they offered points of entry supported by donor funds and direct foreign investments. It is through these very means that water companies used their organisational links to advance their interests further: for example, DHI recently established a new office in Yangon.

Over recent years (2016–2019) their operations have focused on building relations with the national government and developing a project portfolio together; while Myanmar is requesting technical assistance from the CTCN to build data for climate change, drought and flood management for the country. with DHI as the technology implementer (CTCN, 2016b).

From a financial point of view, the Green Climate Fund (GCF)—the new aid donor in town, requires that countries reach a readiness status achieved through a combination of capacities that, together, enable the development of bankable concept notes for technology transfer funding (GCF, 2018). For example, one of the projects most in demand by the government of Myanmar has been the development of capacity for climate change adaptation, through systems that combine real-time climate data with hydrological data in a type of "knowledge portal" which can then guide decision makers.[44] The government is pursuing efforts to combine strategies for resilient agricultural development using such tools. As this section has shown, networked organisations take key operational strategies to build technology and expertise portfolios which can then be replicated and used in a similar manner over time, based on continuous project-based interactions. The mobilisation of technological packages, in the form of modelling technology, comes with designed capacity building schemes that can be replicated and scaled up from country to country, standardising knowledge use through tools and software applications to deal with climate change adaptation.[45]

5.4 Anticipatory Governance, Political Realities and Uncertainties

As seasonal variability increases in deltas, as demonstrated in the 2011 floods in Thailand, anticipating events requires sufficient preparation: paying attention to cumulative events and systemic feedbacks from the environment, as well as effectively managing institutions. For example, in 2011 the Asian Disaster Preparedness Centre (ADPC)—an expert, networked organisation in matters related to disaster in the region, anticipated a potential increase in storm frequency and changes in rain patterns that year. Warnings of insufficient preparation for disaster scenarios were not considered by the government, particularly on draining water upstream of the delta, which was suggested by the ADPC at the time.[46] The reservoirs were at their maximum capacity before the rainy season, and when storms came, the infrastructure could not hold more water. Furthermore, the institutional management of the problem was characterised by poor coordination amongst government departments, with several competing agencies trying to do the same activities, without guidelines or instructions; the Department for Disaster and Mitigation had no decision-making role, but merely that of an advisor.[47]

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[44] Analysis using data from interview with UNEP DHI Officer, UN-City, Copenhagen, Denmark, September, 2017.
[45] Analysis using data from interviews with DHI Consultants in Bangkok, Thailand, April, 2017.
[46] Analysis using data from interviews with ADPC Officers in Bangkok, Thailand, April, 2017.
[47] Analysis using data from interviews with ADPC Officers in Bangkok, Thailand, April, 2017.

The Asian Disaster Preparedness Centre (ADPC), as a regional disaster management agency, has a role in producing tools based on technologies such as GIS, water modelling, weather forecasting, remote sensing and satellites to support governments in South East Asia at both the national and subnational levels to deal with decisions under uncertainty. The ADPC provides scientific evidence and policy advice to decision makers, for example in Thailand and Myanmar, for floods, droughts and cyclones. Their activities include analysing historical data, building models, and trying to predict the likelihood of particular events, considering the potential impact on infrastructure and population. Financial support for this organisation comes from the United States Agency for International Development (USAID), and it receives technical assistance from the National Aeronautics and Space Administration (NASA). As a networked organisation, the ADPC is in charge of building evidence to inform decision making in the region by analysing multiple forms of data, and translating results to non-technical audiences. Their expertise focuses on disaster risk management and, for instance, uses DHI's MIKE models for hydrology in combination with ground motion modelling (for earthquakes) and other tools such as General Circulation Models (GCMs). The agency is, therefore, well equipped to monitor and report risk to other specialised national agencies in the region. Together they liaise with government organisations, such as the Thai Hydro Agro Informatics Institute (HAII) and more recently with the Hydro Informatics Centre (HIC) in Myanmar.[48]

When it comes to climate models, there are many challenges associated with relying on climate change scenarios and downscaling them at the project level in a specific context, especially as regards climate change impacts. In recent years, there have been efforts in R&D to purposely design such downscaling of global climate data, and to try to match this with local climate and water data (Okkan & Fistikoglu, 2014; Teutschbein et al., 2011; Xu, 1999). One of the main challenges is the reliance on GCMs and then interpreting such data in different contexts. This statistical downscaling requires different methodologies. For example, DHI and the ADPC use the input of new climate conditions into MIKE models to study their interactions. Their starting point is to observe the chain of different data inputs from global, regional and local scenarios; they then combine impact assessments and adaptation analyses. In each step, different uncertainties must be considered: these are tested through simulations and models that allow data to be translated into statistical terms by determining probability distributions. The results are then used as a 'knowledge chain' for bias correction when applied to hydrological models.[49] Expert organisations such as DHI

[48] Analysis using data from interview with HAII Officers. HAII, Bangkok, Thailand, April, 2017.
[49] Analysis using data from interview with DHI Officer. UN-City, Copenhagen, Denmark, June 2018.

and ADPC recognise that the knowledge chain quickly becomes a chain of uncertainties. For example, in Bangkok, the implementation of MIKE required demonstrating what the software can and cannot do, by showing the BMA how the model works. The capacity building requires explaining both its potential as well as its limitations, reflective workshops with local experts, and overcoming some of the anticipatory myths surrounding modelling technologies. Reflecting on limitations enables the local organisation's inferential capacity to develop by deploying the technology, together with the institutional guidelines, in its operations. One of the DHI experts in Bangkok shared with me about implementation challenges:

> *"Some of the main challenges of implementing such [modelling] tools are the overall accuracy of the model. If it is not accurate, predictions will not be accurate either. Then there is the driving input, such as rainfall data, which is a challenge. The information we get here [Bangkok] is delayed in time. If you are trying to anticipate what could happen in the next 6 hours and the data you used to make such prediction has latency, by the time it reaches your computer it is already 5 hours old. Then the whole forecast is unreliable, if at all relevant to a particular decision. It is key to explain these potential dynamics when you are training local engineers."* (DHI Consultants in Bangkok, Thailand, April, 2017).

Moreover, the technical challenges are multiplied through the institutional dimensions fundamental in performing anticipatory governance. One of the ADPC experts explained to me:

> *"The problem is that there is no integration of different agencies dealing with water management in South East Asia. It is the same in Thailand, Vietnam and Myanmar. Because water is such a key asset, everyone wants to be involved and have a say. There are so many overlapping mandates in Thailand for example, regarding water management. Same in Myanmar. A lot of players claiming that they are capable of doing this big job alone, which is not the case. You need to collaborate with other agencies, not compete. Collaboration, data access and interpretation are one thing, then acting based on evidence is another."* (ADPC Officers in Bangkok, Thailand, April, 2017.

It is clear then that certain situations, like the flooding of Bangkok, suggest an organisational conflict where the competition, fragmentation, and politics of agencies concerned are involved, resulting in conflicts of interests and duplication of policies. For example, national institutions take time to respond to this kind of emergencies, as discussed with a Climate Data Expert at UNESCAP in 2017:

> *"Water is complicated, too many agencies. One is the BMA, another is the Department of Water, and another is the Prime Minister's Office. Wait, there is more. The Royal Irrigation Irrigations Department, HAII (…) unlikely, they don't like each other and so no one would like to be the first to take any action, be the face of the mess. Later, if someone did something, the other will try to prevent it. It*

> *is like a conflict of interests among concerned agencies."* (Thai Climate Data Expert. UNESCAP, Bangkok, Thailand, April, 2017).

According to other experts, what happened in 2011 in Bangkok was that people tried in vain to find correct data about water; for instance, the Prime Minister at the time wanted water data, saying that although he was able to make a decision, the many competing agencies, different sources of data and different mandates made the process chaotic and uncertain.[50] Situations which are characterised by divergent values or conflicting politics might well bring greater uncertainty. This is a signal that government officials at the time acted in an uncoordinated and competing manner. Some argued that the flooding was caused by climate change, whilst others pointed out the problems of data. The available data, however, indicated something different: that the situations could have been prevented, for instance by appropriate dam management, early communication among stakeholders, and more coordination.

In essence, these contextual conditions bring uncertainty in times of crisis, and when political conflict is combined with an absence of scientific consensus when the information is presented, all kinds of problems emerge. Some would argue that, unless uncertainty is reasonably reduced, it is difficult to develop meaningful policies for practical adaptations to climate change. However, there are many unknown situations of deep uncertainty when it comes to disaster governance, in particular when an economic crisis is likely to be triggered as a result of these "black swans" (Taleb, 2008). In this case, more technology or data does not seem to enhance anticipatory decision making on the ground when dealing with socio-political uncertainties. National institutions in Thailand are convinced that technological improvements are almost a necessary when deploying modelling tools to 'enhance their capacity'. However, experience suggests that the development of climate change models and hydrological models must be tailored to local conditions, not just in their calibrations or technical capacities to run simulations, but also in supporting local institutions to harmonise their frameworks and practices. On the one hand, there might be a lack of data "harmonisation", for instance, on how to apply data to make sense and use it as reliable input to generate reasonable scenarios. On the other hand, there is a clear need for tools to critically assess ex-ante, and give appropriate characterisations of uncertainties, including those posed by politicians—although this is very difficult to achieve in countries which have non-democratic institutions.

[50] Analysis using data from interview with Thai Programme Manager, Water and Agriculture. UNESCAP, Bangkok, Thailand, April 2017.

This context shows clearly the complexity of building the capacity to manage climate and hydrological data, as when building evidence and using such knowledge to inform decision making in South East Asian countries. When it comes to governing the processing of raw data and transferring it from one platform or institutional context to another (from the scientific to the policy context), how the knowledge boundaries are maintained through performative expertise becomes critical. Therefore, there is a need for concrete frameworks to guide policymakers: frameworks which must be both technically articulated and widely intelligible at the same time. This is something that expert agencies typically fail to do. Besides, in Thailand and Myanmar, very few want to claim the authoritative knowledge necessary to make final decisions when it comes to disaster prevention and management. However, when protocols are established ex-ante, a governance arrangement follows involving anticipation and scenario planning, as clear instructions protect individuals and allow them to make sound decisions. The relational component, as ADPC has shown, involves not just building the technical expertise, but convincing the decision-making level to trust a guided response that has been anticipated and coordinated at the institutional level. On the technical level, the capacity to enable those standardised mechanisms that speed up data flow between organisations was one of the recommendations taken up by the BMA when DHI implemented the Early Warning System for Bangkok. The issue of data accessibility would need to be overcome by further coordination between the BMA and the HAII. However, the evident institutional fragmentation makes the governance of climate and hydrological data difficult, as it still needs to be translated from one system to another before it is ready to use. As a result, chains of data stations have to be aligned to the correct data flow. As "learning for future projects", DHI concluded that the BMA could recalibrate and use weather radars to improve data flow and accuracy and upgrade their infrastructure. They also suggested continuously running simulations and using scenario tools to anticipate what potential outcomes should particular patterns emerge and learn how to proceed if conditions are not met in the system.

5.5 More Than Tools and Techniques

Using a strategic engagement process through continuous capacity building, networked organisations provided local organisations with the possibilities, challenges and roadmaps for future project interactions. However, focusing only on technical expertise does no more than add the use of tools to management procedures. Anticipatory governing practices require coherent governance capacities in order to enable coordination and data sharing between stakeholders. It will continue to be challenging for government agencies to use such tools and techniques effectively if they are not combined with sound institutional coordination. The results show that local governance dynamics make it harder for expertise to reach authority, ultimately rendering inferential capacities insufficient to influence decision-making processes aimed at managing risk. Possessing forecasting tools and techniques to represent the likelihood of hazardous events is only beneficial if the relevant organisations also have clear operational response guidelines to steer preventative action. One of the weakest points in the development of inferential capacities, indeed, is the ability to access, downscale and integrate reliable climatic and hydrological data in real time in order to anticipate near future events, especially when such data belong to various sources with fragmented mandates that overlap or compete.

The analysis shows how the hydroclimate cluster, composed of globally networked organisations, develop project-based interactions to deploy tools and techniques. The data also suggest that particular forms of expertise––the development of inferential capacities to anticipate and plan disaster management–– is a salient activity in Thailand and Myanmar. However, capacity building for anticipatory governance in climate change adaptation is twofold. On the one hand, it requires the development of technical capacities to operate tools such as climate and hydrological models. On the other hand, in order for governance to have an effect, inferential capacities require a degree of legitimacy sufficient to produce institutional action. By 'institutional action', I refer in the short term to concrete responses via specific protocols and guiding principles from national organisations, and in the long-term environmental planning. Furthermore, anticipatory practices which use combined modelling tools depended on climate, weather and water data as combined inputs in order to make robust risk assessments. In principle, these inputs allow national agencies in South East Asia to infer short-term interactions of socio-ecological systems in their deltas (e.g., to monitor flood risk). However, their success depends on the balancing of tools with expertise, of preventive actions with operational procedures in order to act when is required.

Project pipelines from networked organisations in water and agriculture in South East Asian deltas are only increasing. So far, identifying organisations belonging to a formally arranged global network has enabled us to track and analyse examples of how capacity building for anticipatory governance operates in practice, and to illustrate the complex interactions between actors, technology, and institutions. The analysis also illustrated many limitations and lessons regarding the capacity to manage knowledge boundaries in order to build a legitimate transfer of operational frameworks for risk management.

5.6 Discussions

Capacity building to make inferences about future development is relevant in environmental planning. The adaptive capacity of government organisations varies from context to context, both in their technical ability to use modelling tools, as in their institutional capacity to generate authoritative responses. The chapter examined how networked organisations attempt to build capacity for anticipatory governance through project-based interactions in Thailand and Myanmar. Findings suggest that, although particular organisations manage to centralise the mobilisation, transfer and operational capacity of modelling technologies due to formal and relational mechanisms, their governance effect at the local level is limited. As the analysis shows, the use of anticipatory governance tools continues to spread across the hydroclimate cluster in South East Asia, and yet the institutional challenges at the local level, the political conditions and the ability of local organisations to elaborate the robust inference with which to inform decision making continue to be challenging factors. The persistence of particular forms of networked organisations explains the presence of *de facto* governance practices (Rip, 2010; Gupta and Möller, 2018). It reveals the generation of legitimacy in relational mechanisms through project-based interactions and shows how a cluster of organisations build a collaborative platform. However, the consolidation of such practices does not yet guarantee its effectiveness with respect to dealing with climate change adaptation and its associated uncertainties. It further demonstrates that technology transfer projects need to be backed up with social and strategic capacity building in order to nurture consistent anticipatory governance in different cultural contexts.

The study shows that expert knowledge and skills are not easily transferable in the context of climate and water governance. Cases from Thailand and Myanmar illustrate some of the real challenges when dealing with anticipatory governance tools and techniques in different cultural settings. For those reasons, I argue that consolidated networks that *de facto* legitimise expertise in climate and water governance fall short in effectively building capacity to govern future climate change risks. The mismatch happens in part because of short-term, one-off technology transfer projects that are unbalanced in practice, especially concerning their complex institutional dimensions (van Kerkhoff, 2013; Van Kerkhoff and Szlezák, 2016). Consequently, current technology transfer programmes in South East Asia do not necessarily translate into an enhanced institutional capacity for environmental planning. Furthermore, project-based technological fixes continue to be high on the agenda of development cooperation networks as the way to solve adaptation challenges. However, continuing to favour such practices over enabling local institutional capacities undervalues the complex social dimensions of technology, and thus hinders the adaptability of organisations dealing with climate change and water governance. Adaptation governance should therefore pay more attention to institutional dimensions. In this context, the mobilisation of expert tools and techniques needs to re-consider the inherent differences between the sites of knowledge production and the sites of knowledge use.

These problems critically inform the expanse of new forms of technology-driven (Haselip et al., 2017) and market-based mechanisms that continue to be seen as the instruments of choice when it comes to development and aid, to the detriment of alternative or localised perspectives, or other forms of governance systems for dealing with the global climate crisis (Fairhead, Leach and Scoones, 2012; Mosse, 2013. Because these solutions are often model-based, they continue trying to fit Eurocentric rationales (Haraway, 1988; Harding, 2009; Crewe and Axelby, 2013), while remaining oblivious to the consideration of intangible elements of technologies in localised contexts, and particularly to the political realities of local expert knowledge when dealing with natural disasters or human-made disasters. Any transfer of such kind continues to deepen modernisation narratives about technological fixes and assumes incremental improvements will lead to transformational change in sustainability (Gillard *et al.*, 2016).

There is still much to be said about the framings of paradigm shifts. This chapter analysed attempts to modernise decision making; utilising one-off technological undertakings and its numerous contradictions embedded in more profound processes. Since these technical realisations depend on local conditions, transformations are not about making the city's infrastructure smarter by installing a modelling tool, but about redefining priorities and regulatory frameworks that will lead to long term strategies adequate to local conditions, human resources and institutional capacities, most of which are already present. There is a need, in the practice of "transitions" to take circumstantial means more seriously than they at present appear to be taken: specifically, that that expertise tends to be valued and gains authority not by its applicability or adequacy, but by reinforcing the historical, colonial factors and socio-political contexts from which they emerge (Mosse, 2004, 2013; Tsing, 2005).

Localised dynamics demonstrate some of the problems of navigating knowledge boundaries, since they are supposed to be the product of negotiations between epistemic communities (Haas, 1992; Robinson and Wallington, 2012; Cash *et al.*, 2014; Galaz *et al.*, 2018). The uses of knowledge in spaces where adequate control is assumed, but uncertainty abounds, makes the reliability of this knowledge doubtful. Also, it becomes even more challenging to understand if this knowledge has been co-created and made fair, clearly communicated, or if uncertainty has been acknowledged or even discussed (Shackley and Wynne, 1996; Van Wyk *et al.*, 2007; Stirling, 2011). There is at least now a more precise understanding of how these expert knowledge exchanges occur, and how boundary objects are produced in these different contexts.

Indeed, formal global knowledge networks that generate strategic centrality toward their aims allow for the analysis strategic behaviour; analysis which can be applied to expert networks and the technologies and policy tools they employ. Strategic activities show how expert networks use knowledge and technologies to try to influence environmental governance at transnational levels. However, evidence has shown that anticipatory capacity is dependant up on the deployment of modelling tools without appropriate institutional arrangements at the local level. Consequently, they do not necessarily enhance the capacity of local actors to envision, imagine, evaluate and strategically respond to anticipated events (Fuerth and Faber, 2012; Guston, 2014; Galaz *et al.*, 2018). Robust environmental governance requires dealing with planning and anticipating possible futures, rather than merely reacting to consequences. Current activities show that when floods happen, local organisations are flooded with external aid, flooded with modelling tools and flooded with uncertainties. It has been argued that value diversity and evaluating choices that emerge from biased groups contribute to the scientisation of politics and generate tensions between modernist adjustments versus precautionary realities (Read & O'Riordan, 2017; von Krauss et al., 2005). This is particularly the case when deep uncertainties —which cannot be expressed through models— and more data belong to real social, cultural and political constraints (Workman *et al.*, 2020).

Global knowledge networks allow for the study of uncertainties as signals spread across different communities of practice. Global knowledge networks enable the study of uncertainty in the boundary of science and policy, as well as inside agencies dealing with complex socio-technical-environmental issues. The heuristics of 'signals' supports the understanding of how knowledge travels, and how knowledge is used, by highlighting underlying assumptions of policy actors involved in the delivery of expertise in interconnected but distinct cultural realities. The analysis suggests that processes intensified by informatics and lack of collective decisions can, in turn, generate uncertainty when the application of knowledge through means of transfer is not negotiated, co-created or translated from one context to another (Jasanoff, 2004; Robinson and Wallington, 2012; Jasanoff and Kim, 2015). The boundary objects encapsulated in modelling tools bring new uncertainties with them; these then travel and spread through the network as if to reinforce chains of cost-effective but unfit knowledge artefacts. Consequently, they become the very signals which allow the identification of uncertainties spanning the mobilisation of bias and the travelling of rationalities contained in technological packages. This phenomenon can be explained through identifying assumptions brought by experts—in particular, when more technological capacity is framed as needed in order for good environmental governance to happen. Furthermore, global policy thinking which advocates for the transfer of such rationality also promotes their own visions of change, for instance, through the theory of change already explained in the case of CTCN.

Attempts to operationalise changes through technology projects that put their efforts into incrementally reaching transitional momentums also seek to be categorised as transformational. However, there is no clear link between a theory of change promoting technology transfer of this nature and substantive changes which will lead to, for instance, more resilient societies, more robust and transparent institutions or knowledge systems more prepared to withstand the impacts of climate change. These are still in doubt.

Furthermore, capacity building schemes and knowledge applications through this formalised network also have other relational components performed on a project-to-project basis. This tends to legitimise the very incumbent structures to which they belong, creating path-dependency (Geels, 2014; Stirling, 2014). Subsequently, *de facto* governance practices emerge through repeated interactions under the centralised hydroclimatic cluster, and produce generative effectiveness in deploying artefacts, not in building substantial capacity. This legitimised transfer is conducive to mechanic and closed spaces of knowledge exchange and becomes more authoritative over time.

Achieving substantial changes in sustainability policy and practise continues to be challenging when dealing with complex environmental issues. There is a North-South tendency to frame innovative solutions based on technical rationality and technical fixes; thus, the problems of governing globally connected spaces of sustainable development become opaque and must still be exposed and debated. It is demonstrated that driving science-policy and boundary work across spaces of global connection is problematic across formal global knowledge networks. In particular, socio-technical networks are complex and moving spaces. They challenge Western ideas of governability and control since unknown drivers tend to intervene in socio-technical network interactions in ways transition managers hardly notice. These are not problems that can be solved solely by applying managerial lenses but rather represent complex governance challenges. The contexts of transitions become somewhat blurred when deeper contextual elements arise. This belongs to the social and political elements of change, which emerge when the urgency of large-scale transformations becomes more evident and more pressing. Finally, there is a mismatch between narratives of change enacted by incumbent powerful agents which advocate for transformative approaches through technocratic means, and the extent to which their agency reinforces the very systemic problems they try to overcome. This contradiction suggests the need to continue interrogating the very meaning of change.

Chapter Six

Assessing Transformations in Global Policy Networks: Implications for the Response to Climate Change

6.1 Introduction

Chapter six contributes to understanding which framings of expert knowledge featured in global policy networks' discussions inside the climate negotiations drive global responses to climate change. It specifically addressed the question: *which framings of expert knowledge, futures and uncertainty feature in global policy networks' discussions of transformations and anticipation?* (Research Question 5). In this chapter, I travel back to European contexts to research global policy network affairs during three of the UN's climate change conferences. For analytical purposes, data was extracted through participant observation, field notes, rapport, interviews, and from coded and analysed IPCC documentation. Science-policy spaces under the IPCC and the boundary work that the IPCC-SBSTA produced has gradually incorporated salient notions of transitions and transformations. The IPCC assessments (1995, 2007, 2014 & 2018) are contrasted with emergent narratives from the 'global response' encountered at COP negotiations and events.

While travelling back to the high-level spaces of policy fora, I encountered narratives of transformation at the IPCC-SBSTA interface, situations of techno-economic optimism, and increasing ventures of "smart" futures leveraged by companies influencing socio-technical changes by means of disruptive technologies. Following narratives and pledges for accelerating climate action, global institutions are themselves looking for radical transformative strategies. Observed forms of agency linked to transformational claims and technology-oriented strategies, show how interest groups leverage to introduce disruptive technologies into the climate change agenda. Several solution-narratives were encountered, including digital transformation to address climate finance, smart city packages, and the case of geoengineering. The chapter finds that pursuing transformative changes is likely to be required in order to overcome future social and environmental challenges. However, Collaborative capability across observed formal spaces of networked climate governance is not found to be leading a global response that performs realistic collective efforts to transform business as usual substantially.

While formal global knowledge networks may be a legitimate form of cooperation, they do not show signs of solving critical problems of coordination inside the global climate regime under the UNFCCC. While the IPCC-SBSTA interface has done significant work to integrate the rational of transitions and transformations in their assessments and boundary work, science diplomacy spaces inside the Convention respond to a large apparatus characterised by the practice of divergent political and economic interests. In the case for more radical "transformative lenses", these get diluted in techno-economic discussions and highly technocratic frameworks. Furthermore, precautionary narratives of the future tend to disappear when they encounter narratives of technological possibilities such as with the case of technology transfer, negative emission technologies and the digital revolution. Such narratives obscure original efforts of science diplomacy through their reiteration of technocratic vision of change. Findings confirm that the politics of business interest use transformational framings but are elusive to uncertainty, and seek fast, optimal, universal––and economically sound strategies instead. The chapter finds strongly suggest that policy networks which are not open or reflexive about uncertainty may spread uncertainties across knowledge networks. Government officials and other incumbent actors who focus efforts to solve climate issues based on control-based imaginaries of change may generate path dependency in their institutions and deviate alternative efforts towards unrealistic outcomes.

The problem of choice is critical. Climate change is rooted in social practices, institutions and cultural habits. Similarly, when it comes to developing future responses to climate change, the problem of choice shows assumptions of control over-large-scale complex phenomena and are biased towards reductionist views of transformations, since this these problems are largely ungoverned in reality. Seeking to reduce unknowns to measurable risk and reinforce pre-existing bounded rationalities about management and control may be a common obstacle to effective climate action. These critical findings contribute to open up a broader debate about what sustainability transformations mean in these contexts and to rethink epistemic and methodological assumptions about how to support scientific and technological innovation meet more humble and realistic visions of change.

6.2 Transitions and Transformations in the IPCC-SBSTA Interface

This section analyses how the IPCC and UNFCCC processes have integrated the concepts of "transitions" and "transformations"—and other derived notions— in their assessment reports, and utilised them at science-policy fora at the Subsidiary Body for Scientific and Technological Advice (SBSTA). Famously, the Intergovernmental Panel on Climate Change (IPCC) has been in charge of assessing the scientific, technical and socio-economic knowledge relevant to the understanding of climate change and its associated risks and impacts (Biermann et al., 2014). As an experts' body of the UN-System, it incorporates its work into reports and summaries that are widely used by policy experts during UN climate negotiations. This "science diplomacy" is used as a governance tool to stress problems about divergent and plural views and provide robust knowledge on climate change (Kouw & Petersen, 2018). For example, the Conference of the Parties (COP) uses the IPCC's work as a critical input to negotiate science into policy discussions concerning the implementation of accords such as the Kyoto Protocol (1997) and the Paris Agreement (2015). For more than twenty-five years of interactions, the scientific body and policy community have formed an IPCC-SBSTA interface to communicate systematic assessments of climate change to policymakers, as well as establishing a permanent dialogue between the scientific and political streams of environmental governance. The IPCC is globally recognised as the most authoritative scientific and technical voice on climate change, and its assessments have had a profound influence on the negotiators and Secretariat of the UNFCCC. The institutional framework of both bodies ultimately responds to the UN General Assembly, although the IPCC host institutions are UNEP and the WMO. The IPCC and UNFCCC work in direct communication through the SBSTA and their Systematic Observation (SO) process. In addition to producing reports, and giving official presentations during COP events, the IPCC hosts a special pavilion during summits, and IPCC experts participate in several science-advice official activities through the Systematic Observation meetings of the UNFCCC.

The collaboration between the IPCC and UNFCCC generated a process of institutionalisation between the two bodies. Today, their joint efforts are instrumental in providing science advice to the Convention and all participants involved in climate change science and policymaking. The interface has been attributed with "generative effectiveness", for SBSTA has been capable of absorbing scientific knowledge and using it to inform and influence policy processes at the climate negotiations (Young, 2018). However, there is a difference between the expert knowledge provided by the IPCC and the way it is utilised in the science diplomacy space under the SBSTA, where many networked forms of agency participate. For this reason, the boundary work of this interface is constantly challenged by global policy networks, which ultimately decide whether or not to incorporate the SBSTA's advice into decision making, whilst simultaneously being influenced by other incumbents and business interests. As observed during COP23 and COP25. The negotiations of the Technology Framework under SBSTA reflected matters of divergent values, for example regarding the role of gender in innovation, financial commitments to implementation and the lack of support by member countries such as Saudi Arabia among others, which consistently blocked negotiation meetings. Climate governance in formal science-policy spaces are the result of cumulative attempts to build authoritative knowledge, along with messages to negotiators and the policy networks driving responses to climate change. For these reasons, it was important to observe them and unpack how such an interface assesses, integrates and communicates knowledge on policy pathways nurturing transitions and transformations. Further, it was critical to analyse how this knowledge is interpreted and utilised by global policy networks together with the wider global response of businesses and other stakeholders. For example, global policy networks and government representatives use the scientific input of the IPCC through the SBSTA to leverage for climate policies and pathways for change both nationally and internationally. Similarly, the private sector captures these narratives and uses them as input to leverage for market-based and technology-based solutions aligned with their own interests—as already seen across the CTCN network. With regards to the Technology Mechanism as the implementation arm of the Paris Agreement, it has been shown that the theory of change used by the CTCN presents significant gaps in terms of understanding their transformational goals under their current monitoring and evaluation system. However, both, the Advisory Board to the CTCN as well as the Technology Framework under the UNFCCC steer transformational change in ways which are difficult to operationalise in practice. While the CTCN is working to better understand and address transformational change —for instance by conducting ICAT assessments— it is very much dominated by incumbent discussions about endogenous versus exogenous technology impact strategies, and by the techno-economic assessments required to comply with higher level frameworks. Transformational change discourses, such as in the Technology Framework, are tactics used to legitimate the implementation of the Paris Agreement's functions. However, the Accord does not have a clear definition of what transformational change really means, despite indicating it's need. Thus, the political nature of such transformational framings can only be unveiled through the agency of actors and revealed through these subsequent visions of change. Since transformations to sustainability can be interpreted in multiple ways, policy experts cover its meaning under the notion of "low-carbon and climate resilient development" —another wide concept which is repeatedly stated in the Paris Agreement, in IPCC reports, and widely used by advocates of technology development and transfer policies. The Paris Agreement seeks to strengthen the global response to climate change in the context of sustainable development and poverty eradication. Thus, it aims to holding the increase in global average temperature rise––"well below to 2ºC", and pursuit efforts to 1.5ºC above pre-industrial levels. This is pursued through making "financial flows" ––or efforts, consistent with pathways toward "low greenhouse gas emissions and climate resilient development" (Paris Agreement, Art 2, p. 3).

Different notions of transitions and transformations have been found in the IPCC reports. Both concepts evolved throughout the assessments, and dominant narratives are found. For example, the IPCC second assessment report (AR2) addressed the concept of "transformations" in the economic sense, referring to it in the context of cost-benefit analyses and "no-regret potential" for long-term horizon planning of technology gains as a way to combat climate change via mitigation (IPCC, 1995). Additionally, AR2 used the concept of "economies in transition" to refer to developing countries and assessed barriers to the diffusion of technology development and transfer, finance and capacity building and to reflect on the lack of integrated assessment models that included specific social and economic dynamics of developing countries able to shows market imperfections and institutional barriers (see table 9).

Table 9 IPCC AR2 Content Tree Analysis Results

IPCC Report	Themes	Analytical lens	Narrative	Content Tree Analysis
IPCC SAR (AR2) 1995	Transition(s)	Structural analysis (techno-economic)	♦Countries with **economies in transition**. ♦Current integrated assessments models do not reflect on specific social and economic realities of developing and **transition economies**. Development of methodologies that address market imperfections, institutional barriers and informal sectors is needed. ♦Global assessments are biased when mitigation options and impacts on **transition economies** are valued in the same way as developed countries. ♦Success depends on reducing barriers to the diffusion and transfer of technology, as well as allocating	Annex A

			resources and capacity to assist the implementation of behavioural changes and technological opportunities. (pp. 7, 9, 11, 13, 16, 30, 53, 54, 55)	
IPCC SAR (AR2) 1995	Transformation(s)	Structural analysis (techno-economic)	♦Longer time horizons allow a more complete turnover of capital stocks and gives research and development and market **transformation policies** a chance to impact multiple replacement cycles with much higher potential. (pp. 16, 53)	Annex A

Source: Author, 2020

AR2 shows the period in which academic and policy discussions revolved around the limiting—mostly "structural" —factors— that acted as barriers to mitigation actions: in particular around market imperfections. Salient 'economic' narratives at the time paved the way for science-diplomacy discussions leading to the Kyoto Protocol in 1997. For example, that parties should focus on reducing greenhouse gas emissions, based on the scientific consensus that global warming was happening due to human-made CO_2 emissions. Debates were largely centred on mitigation: in particular, on how to generate a cost-effective and "responsible" global carbon market (UNFCCC 1998). For instance, AR2 considered the extent to which global market inadequacies could be removed through cost-effective policy initiatives. The narratives of AR2 point to developments in climate policy already targeting some equity issues; for instance, that policy options and impacts for mitigation were mostly valued equally across developed and developing countries. These findings had implications that advanced questions about justice and equity in environmental policy, for the reason that future generations cannot directly influence past decisions. Although mainly from a techno-economic "structural" analysis, AR2 reflected the original pledges of the 1992 Rio Earth Summit, where the notion of "common but differentiated responsibilities" emerged (Aglietta et al., 2015). Consequently, AR2 earlier showed the lack of integrated assessment that would include these differences, for instance in terms of factoring the context-specific social and economic realities of different countries. However, the context of transition captured by this assessment was framed largely as a linear economic progression—from developing to developed—and offers a transformational outlook almost exclusively based on market-based policies. The report fed the idea of transition economies into the UNFCCC negotiations, in light of what came to be the Kyoto Protocol a few years later. The idea of transition economies strongly suggests focusing on removing market barriers to advance technology development and transfer, a premise that would go on to thrive in the current global climate regime. As the evolution of climate negotiations has shown, this policy narrative has become dominant.

Later on, the Third Assessment Report (AR3) shows a continuation of the themes of transitions and transformations, both in terms of structural and techno-economic analyses, suggesting not only the focus of the scientific research at the time, but also what narratives started to become salient in global policy discussions on climate change action. For example, this was the time in which the IPCC was requested to provide a special report on technology development and transfer (2000), and when discussions following the Kyoto Protocol would lead to the Poznan strategic programme on Technology Transfer (2008). Thus, finding the means to remove economic barriers was central to policy debates at the time. The analysis of AR3 shows transition approaches were primarily concerned with economic modelling associated with mitigation, together with the transformation of energy systems, as the central techno-economic strategy to overcome further lock-in of fossil fuel infrastructure investments. AR3 was also a pivotal moment in linking the term "environmentally sound technologies" to the context of "alternative development pathways" (see table 10).

Table 10 IPCC AR3 SRY Content Tree Analysis Results

IPCC Report	Themes	Analytical lens	Narrative	Content Tree Analysis
AR3 SPM 2001	Transition(s)	Structural and socio-technical analysis (techno-economic)	♦Economic modelling studies completed since SAR indicate that a gradual, near-term **transition** from the world's present (1995) towards a less carbon emitting economy minimises costs associated with premature retirement of existing capital stock. There are several reasons why this is so. A gradual near-term **transition** from the world's energy system minimises premature retirement of the capital stock, provides time for technology development, and avoids premature lock ins (pp. 24-28, 85, 94, 110, 122, 144).	Annex B
AR3 SPM 2001	Transformation(s)	Structural and socio-technical analysis (techno-economic)	♦Energy **transformation**. Energy efficiency, as the ratio of energy output of a conversion process or of a system to its energy input. The change from one form of energy, embodied in fossil fuels, to another, such as electricity, links them with the concept of environmentally sound technologies EST (taxonomy). ♦Alternative development pathways should be analysed with different patterns of investment in infrastructure, irrigation, fuel, mix, and land use policies. ♦Macroeconomic studies should consider market **transformation** processes in the capital, labour and power markets. Informal and traditional sector transactions should be included in national macroeconomic statistics. (policy recommendation). ♦Energy use and carbon emission in residential and commercial building fall into categories such as voluntary programmes, building efficiency standards, equipment efficiency standards, state market **transformation**, financing programmes, government procurement, tax credits, energy planning) production, distribution and end use), and accelerated R&D. (pp. 337, 372, 386)	Annex B

Source: Author, 2020

Table 10 shows a socio-technical narrative of transitions being applied in assessments to evaluate near-term transitions in energy systems as a preventive measure against a systemic path dependency on fossil fuels. Additionally, the need to explore transformations in mitigation options through processes of capital, labour and power markets. Finally, that such transformation should be pursued as “state transformation”, for instance, through programmatic activities, financial reforms, procurement systems and accelerated R&D. While the literature had already expressed the need to transform energy systems and policy structures to overcome systemic path-dependencies, up to this point, the subject of transformations was almost exclusively addressed as structural change, indicating a modernist rationale strongly biased towards management of the economics of mitigation. The narratives of AR3 correlate with the scale up of international environmental agreements under the Convention in together driving the direction of technology-driven solutions in global sustainability policy and practice.[51]

The progression of science-policy assessments (AR4) in relation to transitions and transformations points to the emergence of a stronger voice in narratives using socio-ecological lenses at this science-policy interface. For instance, more attention started to be given to the role of adaptation to climate change and vulnerability. In AR4, the concept of "pathways" became an articulating notion. Nevertheless, the pre-established techno-economic narrative of transitions dominated assessment. For instance, structural analysis indicates the need to understand "adaptation costs" in economies in transition, and the need to implement adaptation metrics. In the case of transformations, these are largely framed as encompassing systemic changes of industrial, agricultural and other various sectors of the economy (see table 11). Interestingly, the notion of pathways appears to articulate both mitigation and adaptation policy options. For example, in the broader sense, AR4 maintains that sustainable development can reduce vulnerabilities to climate change, although climate change might generate further barriers to achieve sustainable development pathways. Similarly, it sustains that the utilisation of adaptive and mitigative capacity depends upon the "underlying" socio-economic uncertainties present in development pathways. This is significant since, for the first time, there is a clearer acknowledgement in the IPCC's assessment of knowledge barriers which relate to both mitigation and adaptation, highlighting the interdependencies of context and local conditions. This appeared as part of the earlier SRES scenarios (SRES 2000) which explored alternative development pathways for mitigation; however, these included a wider range of demographic characteristics, together with economic and technological drivers. AR4 identified and included narratives from the literature on socio-ecological resilience and adaption. Consequently, the impact of climate change started being framed at the interface as a more pressing issue in the Summary for Policymakers, expected to have adverse effects on natural as well as human ecosystem interactions; specifically, the kind of impacts that would largely depend on the specific characteristics of socio-ecological systems, sustainable development trajectories and their locations.

[51] For instance, Kyoto Protocol (1997) and Poznan Strategic Programme on Technology Transfer (PSP) 2008.

Table 11 IPCC AR4 SPM Content Tree Analysis Results

IPCC Report	Themes	Analytical lens	Narrative	Content Tree Analysis
AR4 SPM	Transition(s)	Structural analysis (techno-economic)	♦Countries included in Annex B of the Protocol (most Organization for Economic Cooperation and Development countries and countries with economies in **transition** (Annex B of the Kyoto Protocol)) agreed to reduce their anthropogenic greenhouse gas emissions (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride) by at least 5 % below 1990 levels. ♦The IPCC has been especially successful in engaging in its work a large number of experts from developing countries and countries with economies in **transition** through the Trust Fund and the cooperative spirit of government delegates. ♦Adaptation costs of planning, preparing for, facilitating, and implementing adaptation measures, including **transition costs** of capacities, resources and institution of a country or region to implement effective adaptation measures. ¨Adaptation and mitigation options and responses, and the interrelationship with sustainable development, at a global and regional levels (pp. 14, 54, 76-83, 88-90).	Annex C
AR4 SPM	Transformation(s)	Structural analysis (techno-economic)	♦In the relative share of Gross Domestic Product produced by the industrial, agricultural, or service sectors of an economy; or more generally, **systems transformation,** whereby some components are either replaced or potentially substituted by other ones (p. 87).	Annex C
AR4 SPM	Pathway(s)	Socio-technical & socio-ecological systems analysis. Adaptation and Vulnerability, Sustainable Development	♦Broader environmental and sustainability issues: sustainable development can reduce vulnerability to climate change, and climate change could impede nations' abilities to achieve sustainable development **pathways** [WG II] SPM. ♦It is very likely that climate change can slow the pace of progress toward sustainable development, either directly or through increased climate change (pp. 8-22, 26, 44-70, 80, 85).	Annex C

AR4 SPM	Pathway(s)	Socio-technical & socio-ecological systems analysis. Adaptation and Vulnerability, Sustainable Development	♦The evolution and utilisation of adaptive and mitigative capacity depends on underlying socio-economic **development pathways** (as key uncertainties) (p. 73). ♦The barriers, limits and costs of adaptation are not fully understood, partly because effective adaptation measures are highly dependent on local variability. ¨The SRES (SRES 2000) scenarios explored alternative **development pathways** covering a wide range of demographic, economic and technological driving forces and resulting GHG emissions. ♦The magnitude and timing of impacts that will ultimately be realised will vary with the amount and rate of climate change, emission scenarios, **development pathways,** and adaptation. ♦Altered frequencies and intensities of extreme weather, together with sea level rise, are expected to have mostly adverse effects on natural and human ecosystems. ♦Climate change impacts depend on the characteristics of natural and human systems, their **development pathways** and specific locations (pp. 7-44, 64, 73).	Annex C
AR4 SPM	Pathway(s)	Socio-technical & socio-ecological systems analysis. Adaptation and Vulnerability, Sustainable Development	♦It takes several decades to materialise mitigation actions. If applied in the short term, they would avoid locking into both long-life carbon intensive infrastructure and **development pathways**, reduce the rate of climate change, and reduce the adaptation needs associated with higher levels of warming. [WG II]. ♦Scenarios with alternative **emission pathways** show substantial differences in the rate of global change (pp. 19, 66).	Annex C
AR4 SPM	Pathway(s)	Socio-technical & socio-ecological systems analysis. Adaptation and Vulnerability, Sustainable Development	♦Future human induced climate change, and its associated impacts, are determined by human choices defining alternative socio-economic futures and mitigation actions that influence **emission pathways.** (pp. 70).	Annex C

Source: Author, 2020

On the one hand, AR4 brings another perspective into the SBSTA's science-policy negotiations, as it shows evidence that materialising mitigation transitions are long term processes that can take several decades; thus, appropriate policies should be implemented in the near term in order to avoid systemic rigidity and lock in of long-life, carbon-intensive infrastructures, while reducing adaptation needs through reducing vulnerability, and by enhancing resilience via capacity building. On the other hand, that human-induced climate change may strongly be associated with choices and behaviour, thus changing the focus on the need to define policy pathways that consider choosing alternative futures may be critical.

The data from the IPCC reports indicate that the themes of "transitions" and "transformations" are utilised as strategic narratives, a boundary tactic that has gently been introduced into climate negotiations as common lexicon. For instance, science-policy discussions arising from this interface show the Fifth Assessment Report (AR5) as a major advancement in the research and politics of transformations at global levels. Indeed, AR5 dedicated a whole chapter to conceptualising and evaluating what the IPCC experts conceptualise as transformation pathways. This was done in order to advise policymakers about future trajectories and implications of mitigation actions, but also with attention to the limited knowledge of "transformational adaptation" (IPCC, 2014). Given the trajectory of the IPCC-SBSTA, there are reasons to think that the political momentum and science-policy negotiations which led to the Paris Agreement were at least partly influenced by AR5. Although it may not be possible to establish a direct correlation, it is conceivable that the science-diplomacy that built the Paris Agreement drove the transformational claims that are "envisioned" in the agreement. For example, AR5 was formative in establishing that the stabilisation of GHG concentrations in the atmosphere will require: "*large scale transformations in human societies, from the way that we produce and consume energy to how we use the land surface. A natural question in this context is what will be the 'transformation pathway' towards stabilisation; that is, how do we get from here to there?*" (IPCC 2014, p. 418). Thus, the report suggests two things with regards to transformations: firstly, it indicates the need for a significant shift in the way socio-technical and socio-ecological systems interact, and secondly, it indicates the need to find a policy route conducive to this shift. For this endeavour, experts evaluated transformation pathways — from a strongly mitigation angle— using more than 1,000 scenarios from peer-reviewed science (IPCC, 2014). The IPCC considered ambitious mitigation goals, as well as a range of assumptions about technological development and the barriers to international coordination.

Table 12 IPCC AR5 SPM Content Tree Analysis Results

IPCC Report	Themes	Analytical lens	Narrative	Content Tree Analysis
AR5 SPM	Transition(s)	Socio-technical, socio-ecological analysis and agency.	♦The institutional dimensions of adaptation governance, including the integration of adaptation into planning and decision-making, is critical in the **transition** from planning to implementing adaptation [robust evidence, high agreement]. ♦The most common barriers to this goal include multilevel institutional coordination between different political and administrative levels in society, key actor involvement, mainstreaming, and sustaining momentum for adaptation. ♦Lack of horizontal interplay between actors, policies, and sectors, and coordination of formal governmental agencies with the private sector and society {WGII 15.2, 15.5, 16.3, Box 15-1}. (pp.)	Annex D
AR5 SPM	Transformation(s)	Socio-technical & socio-ecological systems analysis, and agency.	♦ *"**Transformation** is used in this report to refer to a change in the fundamental attributes of a system. Transformations can occur at multiple levels; at the national level, transformation is considered most effective when it reflects a country's own visions and approaches to achieving sustainable development in accordance with its national circumstances and priorities."* {WGII SPM C-2, 2–13, 20.5, WGIII SPM, 6–12}. ♦**Transformations** in economies; social, technological and political decisions and actions can steer adaptation and promote sustainable development. ♦**Transformation** is most effective when it reflects a country's own vision to suitable development according to national realities and priorities. ♦Focusing on adaptation actions as incremental changes to existing systems and structures, without considering **transformational change**, may increase costs and losses and missed opportunities. ♦Planning and implementing **transformational adaptation** could reflect strengthened, altered or aligned paradigms, and position new demands on governance structures to bring together goals and visions for the future, addressing equity and ethical implications. {3.3} (pp.20, 27, 80).	Annex D

AR5 SPM	Pathway(s)	Socio-technical & socio-ecological systems analysis, and agency.	♦Future and equity and ethical implications: **Adaptation pathways** are enhanced by iterative learning, deliberative processes and innovation. ♦*"Effective decision-making to limit climate change and its effects can be informed by a wide range of analytical approaches for evaluating expected risks and benefits, recognizing the importance of governance, ethical dimensions, equity, value judgments, economic assessments and diverse perceptions and responses to risk and uncertainty."* ♦Countries have different past and **future pathways** to GHGs. Countries face different challenges and circumstances and have different capacities to address mitigation and adaptation. This raises questions of equity, justice and fairness. ♦The design of climate policies is influenced by how individuals and organisations perceive risk and uncertainties and take them into account. There is no a single best balance between mitigation and adaptation. ♦Climate change is a global collective action problem and cooperative responses are required. Mitigation, adaptation and impacts can all result in **systemic transformations** in human and natural systems, ecosystems, food systems, infrastructure, coastal, urban, and rural areas, and human health and livelihoods. ♦**Adaptation pathways** require actions that balance incremental changes with more **fundamental transformational changes**, including the way humans produce and use energy and land, but also beliefs, values, and worldviews. (pp.)	Annex D

Source: Author, 2020

Even though it is possible to observe the inherited techno-economic narratives relating to transitions and transformations in AR5, the assessment is more comprehensive, and includes other perspectives. Firstly, when referring to transitions, it stresses the need to focus on the institutional dimensions of adaptation governance, and the problem of integrating adaptation into planning and decision making. AR5 also shows a clearer assessment of the barriers toward realising transitions in adaptation, relating to the lack of multilevel institutional coordination and involvement of critical actors. Finally, it considers research advocating more horizontal interplay between actors, policies and sectors. Thus, AR5 represents a significant step away from techno-economic framings being legitimised at global policy levels and suggests the need to incorporate the roles of agency and society in order to realise transitions in the case of adaptation. Furthermore, it is the first IPCC report to fully classify "transformations" by giving the concept appropriate characterisation and definition. It identifies both the role of diversity and the need to pay attention to socio-technical as well as socio-ecological issues, with critical attention paid to balancing incremental changes with transformational change. The report further highlights the importance of planning and implementing transformations to paradigms and the demands for governance systems and visions for the future in addressing the issues of equity and justice. Lastly, AR5 represents an important contribution to policy debates about adaptation pathways by showing the need to integrate iterative learning, deliberative processes, and innovation. With regards to decision-making, the assessment stressed that decision making is affected by governance, ethics, equity, value judgements, and diverse perceptions and responses to risk and uncertainty. Since all countries have different pasts, so too will they shape the future in different ways. This is critical when rethinking the equity, justice and fairness of historical development trajectories and interventions. Similarly, the design of climate policies is highly influenced by how individuals and organisations perceive and deal with risk and uncertainty. This will have consequences for both mitigations and adaptation pathways and impacts, all of which combined have transformational potential. These transformations are assessed as being both systemic and relating to a range of issues, for instance, human and natural ecosystems, infrastructures, human health, energy, and livelihoods. In sum, transformational pathways require those actions that balance incremental changes with transformational changes, not just in energy and land use, but also in culture, values and worldviews.

Not exempt from critiques and controversy, the IPCC launched the Special Report on Global Warming of 1.5ºC on October 2018 (SR15). The proposal to welcome the special report at COP24 in December 2018 was blocked by oil giants The United States, Russia, Kuwait and Saudi Arabia. This report marked a significant shift in the politics of climate change by intensifying the "climate emergency" narrative. Its content speaks to wider issues concerning transitions and transformations to sustainability, and thus requires attention. SR15 brought into the science-policy space of climate negotiations deeper questions in relation to the need for substantive change, and its fast and unprecedented nature. For example, the assessment refers to transitions by means of techno-economic analysis —since it is the legacy of the global climate regime— but also includes socio-political dimensions and the role of agency, using socio-technical as well as socio-ecological systems analysis, vulnerability assessments, and sustainable development policy (see table 13). When referring to transitions, the analysis points to the need for shifting global investments into renewables and developing non-market-based instruments, among other measures, to secure the equity of the energy transition. For example, in relation to the implementation of clean energy transitions and their associated costs, and in maximising trade-offs. The transition is likely dependant on its pace and magnitude, as well as the composition of the global mitigation portfolio and its management. It also signals the urban and infrastructural transition consistent with 1.5ºC with no limited overshoot as radical changes in urban planning and land use. Furthermore, renewables, such as solar energy and wind, along with technologies for energy generation could contribute significantly to accelerating the pace of a transition to a low-carbon economy.

Table 13 IPCC SR15 SPM Content Tree Analysis Results

IPCC Report	Themes	Analytical lens	Narrative	Content Tree Analysis
SR15 of 1.5ºC	Transition(s)	Structural analysis (techno-economic). Socio-technical systems analysis	♦Through shifting global investments and savings, and through non-market-based instruments, as well as accompanying measures to secure **the equity of the transition** acknowledging, the challenges related to implementation including those of energy costs, depreciation of assets and impacts on international competition, and utilising opportunities to maximise trade-offs. Their net effect will depend on the pace and magnitude of changes, the composition of the mitigation portfolio and **the management of the transition** (High Confidence SPM). ♦The **urban and infrastructure transition** consistent with limiting global warming to 1.5ºC with no or no limited overshoot would imply, for example, changes in land and urban planning practices. Solar energy, wind energy and electricity storage technologies have substantially improved over the past few years (high confidence). These improvements signal a potential system transition in electricity generation. (pp.15–23).	See Annex E
SR15 of 1.5ºC	Transformation(s)	Earth system analysis, socio-ecological systems analysis. adaptation and vulnerability, sustainable development	♦Approximately 4% (interquartile range 2 – 7%) of the global terrestrial land area is **projected to undergo a transformation of ecosystems** from one type to another at 1ºC of global warming, compared with 13% (interquartile range 8 – 20%) at 2ºC (medium confidence). ♦Trajectories that strengthen sustainable development at multiple scales, and efforts to eradicate poverty through **equitable societal and systems transitions and transformations**, while reducing the threat of climate change through ambitious mitigation, adaptation and resilience. ♦Sustainable development supports, and often enables, the fundamental societal and **systems transitions and transformations** that help limit the global warming of 1.5ºC. ♦Such changes facilitate the pursuit of climate-resilient development pathways that achieve ambitious mitigations	See Annex E

			and adaptation to climate change. (pp. 8, 22–24).	
SR15 of 1.5ºC	Pathway(s)	Agency, socio-technical, socio-ecological systems analysis. adaptation and vulnerability, sustainable development	♦The potential for climate resilient development pathways differs between and within regions and nations due to different development contexts and vulnerabilities (very high confidence). ♦Social justice and equity are core aspects of climate resilient development pathways that aim to limit global warming of 1.5ºC, as they address challenges and inevitable trade-offs, widen opportunities, and ensure that the options' vision is equitable. ♦Climate resilient development pathways [the paradigm] related to CRDPs trajectories that strengthen sustainable development at multiple scales and efforts to eradicate poverty through equitable societal and systems transition and transformations while reducing the impacts and vulnerability to climate change. ♦Improve air quality resulting from projected reduction. It is important to reduce the trade-offs of with respect to sustainable development and the SDGs (high confidence). ♦Such pathway would reduce dependence on CDR (pp. 17, 19, 22–24)	See Annex E

Source: Author, 2020

In relation to transformations, the analysis finds that global land area is projected to transform significantly, impacting ecosystems of different kinds. Thus, national policy trajectories that implement sustainable development at multiple scales need to focus on poverty reduction through equitable societal systems and look for transformative approaches while reducing the threat of climate change by means of ambitious mitigation, adaptation and resilience. The SR15 stressed the importance of sustainable development as the key global policy framework that would enable transitions and transformations to occur. The political aspiration of the report frames transformations to sustainability towards limiting global warming to 1.5ºC, a degree agreed by the international community to be 'desirable' in pursuit of climate-resilient development pathways. In an already heated debate over how to solve problems of implementing the Paris Agreement, the SR15 added extra pressure to nations, as the report concludes that humanity has twelve years (ten as from 2020) to rapidly deploy ambitions on curbing emissions to achieve stabilisation at 1.5ºC, at the same time than pursuing the sustainable development agenda and efforts to poverty eradication before the end of 2030. The political effect of this report has led to more controversy about the feasibility of such a global response. It was observed at COP25, the sour discussions on solving "market" and "technology" barriers to achieve progress in this global quest. The assessment also signals the challenge to achieve climate resilient development pathways across, for example, regions and nations due to different development contexts and vulnerabilities. It further highlights the importance of equity and justice as core elements that could together address emergent opportunities and trade-offs of viable options. The report sets the paradigm of transformations under the global climate regime as climate resilient development pathways that increase efforts to eradicate poverty through equitable societal and systems transitions and transformations, while reducing impacts and vulnerability to climate change, and reducing the reliance on Carbon Dioxide Removal (CDR) technologies (See Table 13). The Special Report came the same year that the Paris Rulebook for implementation was adopted at COP24. However, the ambitious message of transformational change communicated by the report to the SBSTA and in the climate negotiation is currently politically contested.

The evolution of the term's "transitions" and "transformations" in the IPCC reports clearly shows an increasing trend. This strongly relates to the concept of "transitions" having become a paradigm in academic research and policy discourse over the past 20 years. Consequently, these concepts have been picked up and interpreted by the IPCC and used at the IPCC-SBSTA interface to leverage and recommend decision-making pathways to collective climate action. Moreover, their policy momentum has continued to drive decision making responses both at the UNFCCC and at the global level. While the main articulating narrative at the IPCC-SBSTA boundary has advocated a techno-economic rationality — characterised in AR2, AR3 and AR4— AR5 included analysis beyond economic-centric evaluations and started to include the need for paradigm shifts aligned with equity and justice. On the one hand, it recognises the epistemic labour of researchers on these issues; on the other, it incorporates these policy problems into the Summary for Policy Makers (SPMs). The results of this analysis show a gap between what the climate regime pursues in terms of technology-based solutions, and what is being advice to consider on other matters. As is shown next, there is a decided mismatch between the science advice performed by the IPCC through the SBSTA, decisions adopted, and the further pledges of negotiators and politicians to continue escalating instrumental transfer solutions both for mitigation and adaptation to climate change. Following lessons from previous assessment cycles and the growing evolution of the literature regarding transitions, transformation pathways under AR5 were made considering explicitly that measures of aggregate economic modelling — which are often considered key factors for decision making— where to be read cautiously, as one of many elements, when considered as a basis for good decision making (IPCC 2014). AR5 states that transformations involve synergies and trade-offs for national policy objectives; including, but not limited to, energy, water and food security, and other socio-environmental economic factors closely connected to technology. The arrival of AR15 marked the stronger connotation to the role of politics and values involved in transformations to sustainability. The way in which this has been taken by global policy networks and the global response to climate change is controversial.

The production of science-policy knowledge at this interface, and its mobilisation, is subject to the political stream of climate policy. For example, policy statements about feasibility tend to have a bounded rationality which leads to subjective criteria when it comes to COP decisions. The rationality of climate negotiators and decisionmakers is bounded by the availability of data and information to support deliberations, as well as by their institutional roles, mandates and timelines which are determined. For example, in the negotiations of "agenda items" which have specific themes and a short time to come up with final decisions. Similarly, other criteria involving the degree to which these accords are to be pursued in practice, as with the Technology and Financial mechanisms, are subject to value-laden choices. For instance, the socio-political elements influencing policy include not only the social acceptance of new technologies (e.g. with the case of negative emission technologies), but also insights on the socio-economic, technical and environmental dimensions underpinning substantial policy transformations at multiple scales. Thus, the potential tension between material constraints and the desired changes could be a matter of significant uncertainty. For example, this is the case of policy initiatives which are bounded by political or economic interests and are coupled with other national public priorities which differ from country to country.

Similarly, science-policy network negotiations of technological change —changes which, in the stream of climate policy have been informed by the IPCC-SBSTA boundary— lead to divergent policy pathways and outcomes. For example, technological visions of change are sometimes assumed to be exogenous —as with economic 'forces. In other words, techno-economic assessments can, in some cases, follow deterministic perceptions of how technology evolves as an independent force. Determinists views on socio-economic development and technology were developed by Karl Marx (1867), who argued that changes in technology are the primary influence on human social relations of production and organisational structures. Interestingly enough, this approach, used to understand socio-material transformations, is still applied today––although not necessarily in a Marxists sense, to refer to the inherent power of new and disruptive technologies, such as digital technologies. Other narratives treat technological change as a response to endogenous forces; forces that can be steered via the planning of future incentive structures. For instance, the persistence of seeing technological transfer issues as management problem of ensuring economic legitimacy in the eyes of donors and northern technology providers in order to work. The case of the Technology Framework that guides the Technology Mechanism ultimately responds to incremental views of transitions seeking to manage global technology markets over time. However, this model appears oblivious to the many forms of agency which influence technological development and innovation processes. Thus, the techno-economic narrative becomes instrumental, and, at the same time, ineffectual. For instance, such practices were found in the CTCN's theory of change: and thus, throughout its implementation. Similarly, the Technology Needs Assessments follow, in the same category. The TNA ought to be, by the Convention and funding organisation, the most effective way for analysing the technology needs and barriers of countries, identifying enabling conditions for technology development and transfer as a key component in the implementation of NDCs. Their guidelines also advocate including transformational change as input into the technology prioritisation process. While these are important efforts in attempts to build national capacity, the paradigm of the technology transfer process itself is not questioned, rendering the whole approach to transformational change a matter of compliance with high-lever frameworks, rather than building up from on-the-ground substantive transformations. Consequently, both the CTCN and the TNA processes respond to old, interventionist models which assume the management of incremental interventions leading to socio-technical change. These are, however, not necessarily consistent with the diverse and complex national realities.[52] The problem of framing transformations also falls on larger, integrated assessments that rely mostly on techno-economic modelling tools as the principal techniques to guide their evaluations. These are characterised by simplification and optimisation models which try to reduce the inherent complexities of large-scale systems.

[52] As previously observed in the case of South East Asian countries.

The data from the IPCC reports, and the development of climate policy on mitigation and adaptation technologies, suggest a relationship indicating which framings of expert knowledge are influenced by techno-economic rationality, and point to the need to highlight and evaluate their transformational claims. For example, various assumptions were found in the case of the Technology Mechanism under the UNFCCC, which shows the consolidation of the technology transfer preference towards implementing transitions in sustainability. This problem also responds to the IPCC-SBSTA interface and their collective advice in such matters over the years. In addition, the kind of transformation pathways influencing policy discussions contained in the assessments and leveraged in the negotiations can never fully represent the structural, systemic and agency dynamics affecting decision making at the global level. This was observed during negotiations at COP23 and COP25, every form of agency–––whether a single negotiator representing a minister, an alliance of politicians or a business network, can be very different in their aspirations, and in the way they perform and try to influence negotiation outcomes. For these reasons, it is salient to reflect on the now-solidified technology-based implementation of the global climate regime which articulates a narrow interpretation of change, seeking incremental transitions whilst claiming transformative potential. The instrumental rationality which has gained structural deepening over the years forgets those other suggestions made by the IPCC and the SBSTA on matters relating to social and political uncertainties in realising effective global climate action. Despite the reliability problem inherent in seeking sustainability transformations by means of technology-based solutions, policy networks continue to produce socio-technical imaginaries that tend to be normative in regard to economic-centric accounts of the future.

The results suggest that communicating and mobilising knowledge for policy at the IPCC-SBSTA interface requires efforts of a kind of science-diplomacy to addresses complexity and communicate plausible futures particularly sensitive to uncertainty. Scenarios that emanate from the IPCC are generated by experts who judge the most salient drivers of change in light of plausible futures and how systemic dynamics and agency may play out in realising change, whether incremental or transformative. On the political side, involving the negotiation process as observed in the COPs, the travel of rationality across different forms of agency may generate value-laden uncertainties; especially with regards to more the controversial problems associated with the ethical implications of change and how it should unfold. For instance, the interpretation of climate scenarios and the application of low carbon, climate-resilient policies across the Technology Mechanism is subject to profound misunderstandings about the social, individual and institutional drivers shaping the global response. In 2018, the SBSTA's work on Systematic Observation stressed at COP25 that the critical, pending requirements, including efforts to pursue limiting global warming to 1.5ºC, require strong political will to accelerate transitions.[53] The Systematic Observation also stressed that the Sixth Assessment Cycle of the IPCC (AR6) is expected to contain many more insights on how human activities can be attributed to transitions across social, technological and environmental domains (SBSTA, 2019). During COP25, negotiators expressed the need to clarify the transition of risk from high to very high regarding four out of five Reasons for Concern (RFC). The IPCC has clustered the risks associated with climate change into five Reasons for Concern (RFC). These are likely to increase with the increase of global warming. They are: threats to endangered species and unique systems, damage from extreme weather events ––effects that fall more severely on developing countries and poorer communities–– global aggregate impacts, and large-scale, high-impact events (IPCC, 2001; 2007). The practices and conditions of the science-policy space conveyed by the IPCC-SBSTA boundary shows that the practice of knowledge governance is conditioned by the structure of the global climate regime. Its system functions perform knowledge application which is mechanic and path-dependant. Inertia in policy making of this kind carries deeper uncertainties about the future of the global climate regime as the platform to deliver effective climate action. Coordination issues across stakeholders indicate the need for boundary work that seeks integration of messages beyond the powerful technological discourse. Other areas in this context relate to the for work on understanding the role of localised and open spaces for solutions by which to incentivise participation and bottom-up approaches. This issue suggests further attention is needed concerning questions of 'value' beyond the merely technical and economic.

A driving force of transformational narratives around climate action is contained in the technology stream of climate policy. Simultaneously, social drivers such as collective behaviour and incumbency may strongly influence the way in which technology products are designed and utilised for specific outcomes. These are not value-free, nor does their deployment necessarily help in solving persistent, complex environmental governance issues. Similarly, technology policies not accompanied by institutional and behavioural changes are frustrated when society renders them ineffective. Despite this reality, assumptions of technology-based solutions are abundant in the implementation of global policy frameworks such as the Paris Agreement. This may signify a generalised form of bias in which technological innovation and its transfer is perceived by policy makers as

[53] IPCC-SBSTA Special Communications at COP24 Event, Katowice, Poland, 2018.

inherently leading to progress, irrespective of the multiple contexts which render these practices problematic in the context of climate change.

While observing policy negotiations inside the Conference of The Parties (COP), framings of the “urgency” and “feasibility” of negative emission technologies was a commonly referenced topic in the Systematic Observation consultations convened by the SBSTA. These were referred to within the contexts of “bold” possibilities for pathways consistent with 1.5ºC and transformative climate action, as observed at SBSTA 51 consultations, under agenda item 7 (b) Research and Systematic Observation. COP25, IFEMA, Madrid, Spain, December 2019. For example, in physical terms, if mitigation targets produced under the Convention procedures are delayed, and if policy options are skewed due to time or budget constraints, and if options for Carbon Dioxide Removal (CDR) were not implemented timely, the goal of keeping CO_2 levels to 450 ppm by the end of the century would become impossible to reach (IPCC 2014). However, the scale-up of negative emission technologies is contested at best. These technology solutions point to the production of biomass energy, together with carbon capture and storage (BECCS), afforestation, ocean fertilisation and enhance weathering among others. The IPCC defines them as *“Anthropogenic activities removing* CO_2 *from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical sinks and direct air capture and storage but excludes natural* CO_2 *uptake not directly caused by human activities.”* (IPCC 2018, P. 544). Several uncertainties associated with CDR technologies, for example its future economic costs, slow implementation and need for long term political commitment towards lowering risk for research and innovation and investment are likely to be present. Nevertheless, experts communicate at the SBSTA that the use of CDR is a potentially desirable policy pathway in the future. The case of more disruptive forms of “geoengineering”, including Solar Radiation Modification (SRM) remain controversial, although not entirely removed from policy discussions. Large scale climate engineering is both risky and uncertain in its ability to limit global warming to 1.5ºC (IPCC, 2018a). Despite the resistance to these high-risk technologies, the policy window to make them salient grows due to increasing narratives of “climate crisis”. Deliberate attempts to modify climate systems are also consistent with the enduring modernist narratives of technological fixes engrained in policy discussions inside the global climate regime. However, the majority of research involving large-scale negative emission technologies have shown small contributions beyond “ecotopias” of change (Pak, 2015). For example, technology portfolios other than CDR technologies are still the main focus of global policy discussions at the SBSTA, and these aim to raise the ambition of GHG concentration goals through the implementation of Nationally Determined Contributions (NDCs) as the overarching policy instrument with which to prepare, communicate and implement mitigation action post-2020. Interestingly, geoengineering technologies are still mostly hypothetical, and their climate benefits remain unclear (Blackstock et al., 2009; Heyward, 2013; The Royal Society, 2009). The door, however, remains open for technical consultations and socio-political debates around the desirability of this technological fix (Hulme 2014), making it a candidate for future governance research. Most assessments agree that geoengineering technologies should not be considered in the climate debate, as they represent a replacement solution for already existing mitigation technologies (Royal Society, 2009). However, these technologies have opened a whole new area of scientific inquiry and have become more palatable to businesses and policy makers over time. For example, from organisations such as the Global CCS Institute, Jupiter Oxygen Corporation and the Forum for Climate Engineering Assessments (FCEA). The Global CCS Institute participated at COP 25 (2019) and formally engaged in talks with the UNFCCC Executive Secretary, where they officially launched their Global Status CCS Report which accounted for a growth of up to 37% in CCS project pipelines worldwide. Similarly, it has also been praised by researchers for linking geoengineering potential to other disruptive technologies such as Distributed Ledger Technologies (Lockley et al., 2019). This is further addressed in section 6.3.

Transition policies require that different mitigation strategies be balanced towards "net emissions reductions" (SBSTA, 2019). Almost all policy instruments consistent with this narrative include CDR technologies, but their percentage share of mitigation options differs (IPCC, 2007). For instance, different policy pathways identified in AR4 using CDR include the relative contributions of different technologies, such as BECCS and mitigation activities in Agriculture, Forestry and Other Land Use (AFOLU) (IPCC 2007). This is linked to recent developments in some countries' NDCs, as well as in the development of TNAs and TAPs. For example, Ukraine's Technology Action Plan integrates their NDCs into their TNA, committing to reduce by 60% to 1990s level of emissions using CDR targeted to the agriculture sector. It was reported at COP25 that other countries have updated their Technology Action Plans, now prioritising technological pathways such as anaerobic digesters for the production of biogas and biomass briquettes (Burundi), land field management technologies (Gambia) and bioreactors (Mozambique). While this may be positive in terms of committing to innovation while curving future emissions, they are largely based on what the global climate regime and its policy networks are framing as the way forward. Discussions at the SBSTA regarding implementation focus on which synergies can work for "economic transformations" and a "paradigm shift" through integrating Northern solutions and their innovations into policy packages.

In all these policy discussions, however, adaptation seems of secondary importance in comparison to mitigation. By continuing to postpone climate change adaptation and prioritising mitigation in its stead as the major concern of responses, there may be increased risk of those optimistic views of mitigation policy ––, appearing more cost-sound and business-friendly–– occluding costly and complex adaptation. For example, if policies do not consider each countries' exposure to different forms of risk, and focus instead mainly on economic opportunities, short gains in mitigation could generate new forms of long-term lock-ins, making adaptation more difficult and costlier on a longer timescale. In a sense, notions of 'value' may need to be renegotiated when confronting mitigation and adaptation as different parts of the same problem. Climate change is still treated by techno-economic thinking as an externality to market forces. As a result, policy networks in this interface tend to be favourable toward mitigative actions, as they see more clearly the road to internalising its costs (e.g. the carbon market), making it a business case for the short to medium term. However, since adaptation is more difficult to understand, measure, quantify and 'internalise', it tends to be diverted into a dimension separate from mitigation efforts. At present, there is still uncertainty about the potential outcomes of prioritising mitigation over adaptation policies. Another problem is the perception that mitigation strategies will need to compete against adaptation strategies for scarce investment under continuing, persistent cost-benefit frameworks (SBSTA 2019). Competition for investment sources led by economic thinking could hinder other policy goals if not integrated in a timely manner with other non-market targets and creating otherwise path-dependency towards particular forms of innovation and climate action.

Consequently, assumptions in global policy networks prioritising mitigation policy may be similarly used to tackle other policy priorities, for example those related to the Sustainable Development Goals, while influenced by overly optimistic views of the potential of climate-related innovations and technology development and transfer mechanisms. 'Idealised' implementation visions seek to provide the lowest cost for implementation while assuming that the relatively efficient functioning of global markets will align interests, without major distortions or interactions with other 'structural' failures. However, the presence of 'other-than market' —political and social— conditions render the future impacts of idealised policy approaches to climate action a matter of uncertainty. Limiting the imagination to only certain kinds of low-carbon futures could adversely affect the possibility for other future decisions that societies and organisations could make. For these reasons, techno-optimistic approaches need to find balanced practices that can effectively deal with real-world constraints beyond technical factors, including behaviour and institutional drivers, and capacities to produce coordinated responses that include the wider spectrum of actors from society. Future strategies that cannot address these issues beyond merely technocentric frameworks may carry the risk of becoming even more ineffective and entrenched in the long term. Despite these clear limitations, there is still a tendency to prioritise technoeconomic rationality as the only way by which to evaluate future climate action. The reality shows that global policy networks are still far from meeting the need to achieve effective, inclusive and anticipatory policy to address climate change in ways that deliver equitable and just transformations to sustainability practice.

6.3 Other Narratives of Transformational Change Inside the Climate Negotiations

The formal global response to climate change, composed mostly of intergovernmental organisations, policy networks and business sector organisations, has staked much the "transformational change" discourse related to climate action. During my visit to COP25 in Madrid, Spain in 2019, I met experts during official UNFCCC events and under SBSTA sessions, who signalled an increasingly popular theme in the climate negotiations: how can digital technologies support transformative climate action? This topic appeared numerous times during the Convention meetings, at informal consultations, and formal events. While it has been shown why vision of transitions and transformations are controversial topics at the SBSTA in the case of the Technology Mechanism and the Paris Agreement, the global response to transformational change narratives also needs to be considered. There are reasons to examine such discourses as part of the UNFCCC transformation narrative, as they have gained momentum and become a new, driving force in collective climate action. This section shows the negotiation, mobilisation and utilisation of the expert knowledge and digitalisation seeking to advance sustainability transformations inside the Convention process.

Many experts and participants from the global response to climate change aspire to mobilise digitalisation as a key enabler in the implementation of the Paris Agreement. In particular, the use of Distributed Ledger Technologies (DLTs) are on the rise in climate negotiations —as it is with the digital revolution in general. For instance, technologies such as DLTs have led to speculations about their potential for digitalising new forms of contractual development cooperation and speeding up the implementation of the Paris Agreement on finance and technology (Palm et al., 2020). As part of my ethnographic research, I encountered policy activities and identified global policy networks advocating a renegotiation of the social contract and acceleration of the supply and mobilisation of funds for technologies and implementation in unprecedented ways. Inside the technology stream of climate negotiations under the SBSTA, digitalisation is increasingly seen as critical to the effective mobilisation of climate action to its fullest potential. For instance, official meetings at COP25 (2019) discussed digitalisation as significant to climate contributions and solutions under the Regulatory Development Unit, together with C40, the Korea-PNG Climate Smart City Cooperation Programme, Climate Chain Coalition (CCC), Climate-KIC, and UN Global Pulse. Several meetings showed the interest of the United Nations, governmental organisations and international private sector entities to actively leverage for these technologies and support their rapid deployment as collective intelligence for climate action.[54] There is a common assumption that technologies such as blockchain are best suited to address issues of scale and other human-chain limiting factors, and these expert discussions were no exception. They highlighted the importance of the technological and non-technological aspects of advancing digitalisation as an innovative way to govern climate change. For example, there was a growing interest at the newly formed Climate Chain Coalition to focus not only on technologies such as blockchain to target digital accounting and issues of carbon trading, but to look at climate actions in the broader scope of market activities. For instance, Climate Chain Coalition aspires to be the next toolbox for adaptation and climate finance. This organisation, founded in 2017, is an expert network that focuses on the rapid growth of interest in blockchain inside the Convention and the global response concerning technologies for climate finance. The coalition expert leading the sessions shared his enthusiasm with me in an interview, which he explains as a movement:

> *"There are approximately 190 organisations that have joined the coalition from 45 countries. It is a very multi-stakeholder organisation. About 40% of our members are blockchain solution developers. The other 60% are users or researchers, on the ground NGOs, as well as institutions and initiatives such as Climate-KIC in Europe and over in the US in Yale Open Labs which we cooperate with in their networks, and in that spirit, and relating to the principles for digital development that was referred to the coalition as rapidly as it's growing is actually part of a much larger movement across the climate community where there's now a digital innovation community forming."* (Climate Chain Coalition expert, COP25, IFEMA, Madrid, Spain, December 2019).

Furthermore, recently, the launch of the International Association for the Advancement of Innovative Approaches to Global Challenges (IAAI) has been encouraging the work of the Climate Chain Coalition, which is currently expanding rapidly and calling attention to the incentive mechanisms for climate actions under the Sustainable Development Mechanisms Programme of the UNFCCC. Expectations have been high as to how rapidly the spread of networked alliances may reach out into blockchain technologies. Several experts in this network are aware that blockchain has energy consumption concerns, which would contradict mitigation efforts if significant improvements are not met. However, fast-paced digitalisation has become a strategy to support climate action, linking the global response to the global climate regime under the UNFCCC in implementation, and accelerating transparency and access to funds in for developing countries.

[54] UNFCCC official event, 5th December 2019, COP25, IFEMA, Madrid, Spain.

Another example was the Emerging Disruptive Technology Experimentation Programme at the European Institute of Technology at Climate-KIC. The organisation is dealing with the critical bottlenecks in getting digital technologies into climate action and expanding the ambition of these technologies as significant drivers of solutions as a body of the European Union, which follows the declaration of "climate emergency" under the European Parliament. For example, the new European Commission has put forward two main priorities to be delivered within the next half of 2020. These are the European Green New Deal and the digital transformation. That means that Europe is at a point in time where digital transformation is seen as both necessary and possible, for example as an 'interface for digital climate action'. Thus, several northern donors of climate funds are interested in seeing such digitalisation go ahead. The 10-year mandate to "innovate for climate action" received by the organisation is a signal that digitalisation will be pursued, for example, between industry, European universities and public-private agreements, all looking for 'systemic transformations initiatives'.

These narratives indicate the problem of innovation models in environmental governance. When referring to climate action, most innovation models lack "bold" transformational approaches, since they are structured and follow the systemic dependency of traditional financial and regulatory regimes. Thus, the argument from these narratives is to nurture possibilities through digital technologies and new policies; but assumes in most cases that it is the current global carbon economy that will learn to solve climate challenges through digitalisation and a new form of global economy. While these ideas are indeed bold and have potential, thus far they perpetuate a kind of transformation that is technocratic, based largely on economic narratives and concerned with a managerial understanding of global environmental governance.

Expert policy networks engaged in digitalisation discussions at the Convention demonstrated assumptions that solutions to climate change would become possible through their internalisation in the global market economy and through the introduction of business models which rely heavily on using digital technologies. They view the transformation as a matter of incentivised, systemic change and bold initiatives over the next decade. While these visions have saliency and potential, they are not exempt from problems, especially when it comes to governing the digital transformation, for example, with regards to issues of responsibility, ownership, inclusivity and justice. Furthermore, how far are these emergent technological revolutions changing our current economic paradigm? Global policy networks advocating for smart narratives of transformational change through digital technologies assume that diverse social paradigms will eventually align under universal claims of transformational change. For example, following the rationale that DTLs are untapped technologies with the potential to —if fully deployed, and with significant future investments secured— somehow redefine the social contract and revolutionise institutional structures of global environmental governance. Furthermore, by assuming that securing the digitalisation of services will incentivise long term behavioural change towards sustainability. However, technical, as well as legal issues concerning the governance of global intellectual property rights and cybersecurity of these systems are yet to be understood. In addition, if digitalisation will change future behaviour, in what ways? and for whom? These are matters of significant uncertainty.

Besides, technologies such as blockchain appear in this policy setting as the Prometheus of climate finance; making promises on institutional change inside the global climate regime, despite there being no evidence of their being able to deliver on such promises. Ambiguously, global policy networks advocate the accelerated introduction of DLTs as a critical element that will transform current paradigms and redefine not only trust but the future of the social contract. For example, it was framed as an articulating tool to re-define the concept of monetary value that there is a need to "rethink" the basic assumption of monetary value in climate finance, in value storage, incentives, *"what incentivises people behaviour"* and use new tools through crypto economics and DLT and blockchain to experiment and toy around with these assumptions and see what could this new paradigm look like that focus on 1.5-degree compatibility.

The discussion turned to technical issues of "interoperability", sending signals to negotiators and the audience of high systemic control, efficiency models and trust. Following this argument, in order for these technologies to be functional, technical issues of data management and understanding of data processing are critical and should be integrated in a highly interrelated way at multiple systems levels. However, these aspirations are somewhat controversial. The expert's assumptions signal a diversity of new 'black boxes'; unresolved tensions of which models suppose using them to converge all systems into a master platform that solves 'human' error, one which will supposedly resolve issues of divergent values and institutional systems to thus enable new paradigms to emerge. The big digital transformation, although very much part of our lives, assumes itself to be the best solution to realise the transformational changes as environed in the Paris Agreement.

Digitalisation storylines referred to "digital literary" and large infrastructure investments as critical components of success. However, there are significant issues of equity when it comes to digital transformations, as capacity, as well as financial capability, is experienced differently by each nation. While advancing digital literacy may be critical to the digital economy, the majority of the global population today does not understand these technologies, nor their associated risks. What role will capacity play in the digital space of collective climate action? Global policy experts inside the technology discussions under SBSTA, as observed at COP25, formulate policy narratives of transformational change to give power and agency to risky and unproven technologies to solve social and institutional problems of collective climate action and advocate for radical acceleration. According to the 'experts', the digital revolution aims to take over *"bold actions and use transformational technologies to escalate 200, 300 times the rate of change, and aim for 3000% radical change"* if we are to achieve a 1.5ºC compatible global economy in less than ten years–– As expressed by Senior Lead of Emerging Disruptive Technology Experimentation at the European Institute of Technology Climate-KIC, at Technology and Finance Conference, COP25, IFEMA, Madrid, Spain, December 2019.

This narrative suggests aspirations to Eco-modernist visions of change that tend to remove complexity of global climate governance by means of instrumental application of what are considered to be technologies of trust. This framing also implies fast and unprecedented changes to global systems and structures. The politics of transformations, official actions taken by the UNFCCC and interested parties, positively values digital technology as the way to overcome systemic rigidity. The valuation of digitalisation may also signify that new forms of agency —through AI, IoT and DLTs— are likely to play a significant role in transformations to sustainability in the next decade. As expressed by the UNFCCC Development Regulatory Unit at the Technology and Finance Conference during the COP25 negotiations. What are the implications of this? How can we learn to govern disruptive technologies, disruptive business models and disruptive policy instruments based on the increasing digitalisation of climate actions?

Further initiatives from small and medium enterprises (SMEs) value digitalisation of climate action and argue for its great potential in carbon pricing and carbon market implementation. For example, Evercity, a digital company that acts as an "ecosystem and digital platform for sustainability" in 2016 launched the project DAO IPCI for the "blockchainising" of the green economy. This project is the first of its kind, a public blockchain protocol to hold carbon credit transactions on the blockchain, becoming a reference to many policymakers, industries and other stakeholders from city networks such as C40. The strategy aims to rapidly cover the investment gap to realise the Sustainable Development Goals, needing to secure about US$2.5 trillion in future investment. These ventures attempt to solve transparency and accountability issues, impact measurements and mobilise climate finance. The DAO IPCI would drive technology solutions aiming to solve “liquidity” and “profitability” in future SDGs investments, As expressed by the Evercity expert at Technology and Finance Conference at COP25. Even further, their plan includes full integration between IoT, drones, satellites and blockchain technology to help solve these problems.

Another example shows further assumptions that this kind of technological solution will solve transparency and accountability issues, thus enabling simpler and more efficient workflows for climate finance in different developing countries, increasing liquidity and donor support for climate action. Global policy networks at this interface envisioned that a developing bank, based in New York, might invest in rural renewable energy projects in a developing country in a quicker and easier way. Development banks are overwhelmingly bureaucratic and lack the trust in institutions of developing countries. With DLTs —the company argues— bank managers would not even have to visit project sites to see what is going on there, as transparency measures will be conducted over blockchain protocols to make everything more transparent and cost-effective in implementing the Paris Agreement. Other examples include the use of drone assessments to reveal risk such as soil erosion conditions, floods and other natural disasters. These drones could send continuous data to banks and insurance companies in order to assess risk to investment and deal with donors for funds on mitigation and adaptation. The company claims that, through a drone partnership, they will be able to create a platform to predict flooding and manage its effects, arguing these drones can make predictions several days ahead of ministerial announcements by the country's emergency ministries and proclaiming it the future of disaster risk reduction and resilience.

“Smart” narratives of global climate action are at all times high on the agendas of policymakers, across the SBSTA and its technology and financial branches. Digitalisation is one of the driving themes of policy discussions on transformations to sustainability inside the technology branch of policymaking at the Convention. The possibilities of high-technology solutions appear endless only to the socio-technical imaginaries of change. For instance, with DLT and IoT technologies, expert and business partners to the UNFCCC aspire to become the global models of effective climate action, using digitalisation as the "optimal" management tool for interventions, including through the supply chain, risk mapping, funding and autonomous monitoring. They envision becoming the inner and outer layer of projects, financing, operations, and impact measurements for international development and global service providers of transformational change.

In early 2020, Evercity and Robonomics Networks launched a public blockchain for open sensor networks aiming to educate climate action NGOs on the use of digital technologies, which means they are going to build and educate on the frameworks and points of reference for digital participation of the global response, aiming to do so as part of the Convention process. In their optimistic take on digital solutions to wickedly complex problems, these private actors send signals of fast-paced futures where policy actors need to urgently accept the wide deployment of the disruptive digital technologies in their organisations. The underlying tendency, however, continues to be based on prospects of efficiency gains, of problematic business as usual, and uncertain acceleration. As a result, the UNFCCC talked of adopting a rule for digital technologies for the Paris Agreement under the Regulatory Development Unit.

The company Consensus, one of the world's largest blockchain software companies, is now the official European Union blockchain partner for the EU Observatory. This company is currently building a whole smart city infrastructure design for Dubai in partnership with IBM and has created a new partnership in December 2019 as principal technology advisors and providers to UN Climate. Their narrative argues for a global platform to engage with and educate youth and policymakers. There is a growing interest in using digitalisation to target youth movements and leverage the climate debate in light of what Greta Thunberg has done, as experts believe she has *"rescued the global energy"* on climate actions. An expert from the company Consensus advocates to *"build a platform base of blockchain technology to materialise the efforts of the young"* and bring them closer to policy makers in the topics of digital transformation and the green economy, as expressed by the Consensus expert during the Technology and Finance Conference at COP25.

However, the applicability of digital transformations goes beyond technical narratives. Visions of change thus far encountered are also political and have proposed bold transformations for the next generations of digital users that might lead to the problem of fast-paced lock-ins to global investment in such technologies through donor capital, thus securing the way in the climate market for years to come. In addition, many of these technologies are subject to deep controversies about privacy, security and energy. Policy experts engaged in these debates did not spend time reflecting on the fact that DLTs have been widely criticised for being energy intensive; especially blockchain transactions which cost in some cases more energy than the output of many countries of the global south combined, for instance with Bitcoin mining. It is unclear how the large-scale investment and deployment of digital technologies such as IoT and DLTs would deal with energy challenges if they were to scale up to entire city infrastructures around the world. Nor do these narratives explain the potential risks of lock-in and its consequences for the global institutional financial systems that would depend on digital infrastructures of this nature.

As previously mentioned, digitalising climate action means changing the playing field, for example, on transparency and traceability of actions. Under the UN Global Pulse, expert scientists leveraged for Artificial Intelligence and "responsible big data" to be included within the Sustainable Development Goals: in particular for big data in climate challenges. Specifically, the United Nations wants to modernise its functions with regards to big data in order to tackle climate change with 'solutions' such as 'climate-smart' agriculture and new tools for electricity supply and demand, for energy efficiency and secure energy access.

However, it is essential to step back and reflect on what all these practices may mean for sustainability transformations. For example, on the increasing but unreflective hype of digital technologies: the lack of understanding of their unintended consequences and lack of anticipatory regulation. These technologies rely on data; the more they receive, the better they work, but this iteration process is very energy intensive. For example, in order to make a machine recognise soil patterns, optimise transactions and evaluate interfaces, they need vast amounts of energy. The energy problem was not extensively discussed, nor was the fact that digitalisation models are also exponential models. This means that, over time, these technologies are likely to need more energy as their interfaces, applications and iterations necessary to operate grow. Today, about 3% of worldwide energy consumption comes from tech companies, and the very same estimates say that by 2040 it would be around 50% of the world total energy consumption, As expressed by the Chief Scientists UN Global Pulse, at Technology and Finance Conference, COP25. That is a significant amount of energy that needs to come from somewhere. How is this feasible with energy-related emissions reduction targets of 1.5ºC? This was an issue seldom addressed during the COP events. One of the main reasons may have been that energy concerns could hinder stakeholders' efforts to introduce their energy intensive technologies as solutions to climate change mitigation and adaptation efforts.

There are serious concerns about the feasibility and desirability of energy-intensive digital technologies moving forward as climate solutions. Other issues include the ethical problems associated with the technocentric narrative of change. Stakeholders advocating for digitalisation at the UNFCCC process need also to consider the high risks involved in relaying on technology to solve complex societal problems. Leading developed nations, such as those in Europe and among the OECD, are themselves in the processes of finding ways to govern digital technologies. Reality shows that none of them are immune to their unexpected risks. One of the keys, and perhaps most often obscured dilemmas is in this process is human agency. Climate "smart" technologies are not value-free: in order to be smart, they require human inputs, in which worldviews and values are introduced. They are thus inherently biased and prone to selection and discrimination. According to the UN Global Pulse, only about 12% of all global principles for protocols of smart technologies mention sustainability. This is a real issue and is currently outside of digitalisation discussions about transformational change inside the global climate regime. These principles and values may not necessarily be aligned with sustainable development at all, and together raise questions about the feasibility and desirability of this kind of solution to sustainability problems.

6.4 Discussions

Pursuing transformative approaches to sustainability is likely to be required to meet the critical social and environmental challenges that we face ahead. However, collaborative capability —as empirically observed in formal spaces of networked climate governance— is not found to lead to a global response that performs realistic, collective climate action. While formal global knowledge networks may be a legitimate form of technology and knowledge mobilisation, they do not show signs of solving the critical problems of coordination inside the global climate regime under the UNFCCC. Nor is formalised, networked climate governance the solution if they continue to focus their efforts on technology development and transfer. These problems point to the institutional drivers as being too entangled in their incumbency to reflect on the visions of change they promote as solutions. This calls for attention to ungoverned spaces that affect the formation and vision of global policy networks inside the UN-system and the implications for institutionalised responses to climate change.

The findings illustrate how the IPCC-SBSTA boundary efforts seek to interpret the rationale of transitions and of transformations. The interface has made significant work to integrate this knowledge into their assessments, and to communicate them in ways that are potentially useful for negotiations to mobilise policy, using them to influence change towards substantive transformative pathways. However, science diplomacy boundaries are subject to larger apparatus characterised by global policy networks which, in practice, have divergent political and economic interests. In the case of more radical "transformative" lenses, these get diluted through techno-economic discussions and highly technocratic frameworks whose existence is justified by reproducing the same technology transfer activities which seldom change or challenge business as usual. In addition, socio-political realities do not seem to have much room beyond the IPCC-SBSTA boundary, as they tend to either stay at a very high-level or become lost in overly technical discussions of technology negotiations and implementation. Furthermore, precautionary narratives of future pathways also tend to disappear when they encounter the intensive narratives and publicity of technological possibilities, such as with negative emission technologies and digitalisation, forgetting that there are also other alternatives. Global policy networks engaged in discourses of technology-based solutions to climate change exacerbate the policy momentum for their introduction using those transformational narratives which obscure the original efforts of science diplomacy through their reiteration of technocratic agendas of change.

The findings confirm that the politics and business interests using transformational narratives tend to dislike uncertainty and seek rather to implement what is perceived by the global response to be faster, smarter and more optimal technological solutions instead. The models of cooperation observed throughout this research indicate the preferred one-way strategy which persistently characterises northern claims of universal solutions to complex problems by means of technology and expertise. There is a pressing need to conclusively overcome this rationale in collective climate action across the networked spaces of the UNFCCC. Technology transfer is proven to be an ineffective way to solve problems of collective action, and its endurance shows that development cooperation models are still strongly influenced by the legacy of colonialism and the modernist paradigm of technoscience (Contreras, 2002; Crewe & Axelby, 2013; Escobar, 2004; Jasanoff & Kim, 2015). Previous chapters have given empirical accounts of how global experts and their tools are negotiated, mobilised and used as means to influence environmental governance practices at the high level of the UN-System, as well as through networked spaces reaching out to the national ministries implementing global frameworks in their countries. The use of formal global network mechanisms under the UN system needs to seriously reconsider how to continue to deliver actions to move away from technocratic rationality and empower wider, distributed networks of actors and organisations instead. The research findings strongly suggest that policy networks which are not open to uncertainty can reproduce these same uncertainties across networked spaces with potentially negative consequences. When governments have to focus their energy on global mechanisms of compliance and external frames of reference in order to access funds for support, they may generate path dependency and deviate efforts towards unrealistic outcomes. Since climate change is a global problem which requires both local and regional solutions, successful forms of climate change adaptation need to sustain deeper levels of community involvement, rather than merely global and national governance plans based on external rationalities. Similarly, in mitigation efforts, it makes no sense to promote low-carbon, resilient development while at the same time accepting the possibility of risky technologies, such as blockchain, which are carbon-intensive and require a vast amount of capital to be deployed. It does not seem reflective to promote fast, accelerated solutions seeking compatibility with 1.5º of global warming while also welcoming heavy infrastructural investments in disruptive and unproven technologies. The Technology Mechanism and Financial Mechanism should be aware that the impacts of climate change will fall unevenly and intensify underlying structural conditions, such as poverty and other equity problems, including the lack of infrastructure and access to energy, food and water systems. Hence, promoting high-technology mitigation solutions which are disconnected to the socio-ecological realities of adaptation at the local level is liable to face great frustration as climate change continues to alter our physical environments and impact human populations globally over the next decades. While this has been stated ad nausea by many, it seems not clearly enough in the eyes of formal policy networks, high-level ministries and business interests.

It was found that global policy networks do not deal with this kind of deep uncertainty in their practices. In fact, they prefer the bold narratives of transformational solutions. They tend to obscure uncertainties by proposing to scale up blueprint-type solutions which are, in reality, unfeasible. These signals stressed the need for more open forms of accountability and transparency inside the UN apparatus; forms that expose the underlying value-laden and expert-bound roles in dealing with future climate change in more useful ways. Furthermore, narratives of "smart" and "accelerated" transformations have stressed the problem of choice when it comes to creating solutions. Climate change is rooted in social practices, institutions and cultural habits. Equally, when it comes to technology and expertise, the problem of choice shows that the many assumptions of technocratic control over large-scale, complex systems and governance processes, which in fact are largely ungoverned spaces. However, instrumental rationality —whether consciously or unconsciously— seeks to reduce unknowns to measurable risk and reinforces pre-existing bounded rationalities about management and control because they are economically sound. Formal global policy networks observed in the UNFCCC illustrate a common obstacle to collective action. Situations where limited consensus is available, but expectations are high, may produce systemic effects that would tend to reinforce previous technocratic visions of change. This is indeed the case after the twenty-five years of technology transfer attempts under the global climate regime, and also in emergent transformational change narratives, which are neither cautious nor responsible. Thus, the boundary work that is produced under such formalised settings tends to be narrowed to pre-existing terms of reference and forgets the unknowns through framings of expert discussions of universal transformational agendas as near-term solutions. Global policy processes under the global climate regime tend to also neglect alternative perspectives and are deeply subject to power dynamics and the politics of change (Brown, 2014; Meadowcroft, 2011).

Global policy processes affect the way knowledge and technologies are negotiated and mobilised towards specific outcomes and the framings of expertise which are utilised in reshaping the representation of uncertainty. In this manner, the knowledge that is produced in the IPCC reports and then leveraged by the SBSTA reveals itself as a process moving from initial front-stage uncertainty communication to an obscure one characterised only by background signals which have then to be traced. This has implications for the global response to climate change, since integrated knowledge becomes sparse and transparency difficult to achieve. Through global policy networks uncertainty can also travel. The mobilisation of bias happens when global policy networks transfer their rationality and promote their visions and theories of change for the contexts in which their agency wishes to intervene.

Political decisions —such as pursuing emission reductions consistent with 1.5ºC of global warming— are desirable, although highly unfeasible under current trajectories. A positive feedback loop reinforcing the narrative of a technological fix is accelerated by narratives of urgency, which act in favour of techno-economic accounts of the future and the continued emergence of risky technologies as part solutions. The paths we choose are increasingly important as we continue to rethink our assumptions about the future we want and how are we going to get there. Equally important is to reflect upon alternative futures for collective climate action that considers wider outlooks, beyond pure technical rationality. Generating solutions that yield the structural and systemic changes required to address not just the techno-economic dimensions of transitions, but also the geophysical, ecological, socio-cultural and institutional dimensions of global environmental change; these are deeply intertwined with values, worldviews and politics.

In formalised practices of sustainability, it has been observed that global knowledge networks, institutionalised systems, and the agency of experts can greatly influence particular trajectories of change which, over time, may become authoritative parts of global environmental governance, for better or worse: this is why different forms of knowledge governance may have profound significance in steering future sustainability transformations towards desirable outcomes. Throughout this research, it has been verified that international cooperation models using technology transfer tend to focus on one-way strategies. Empirical evidence has been given to explain how technology transfer models do not deliver on their intended goals and, in fact, reinforce rationales of technology deficit in order to justify their existence. While historical responsibilities of northern countries are a key element in trying to balance the delivery of collective actives to fight climate change, there should be a critical focus towards future collective actions moving beyond technocratic rationality. As shown, more accelerated solutions do not necessarily mean wiser ones, nor desirable change in the long run nor support coordination. Furthermore, using transformational outlooks does not, in fact, mean that they will overcome business as usual. These important findings contribute to open up a wider debate about what transformations to sustainability mean in different contexts, and how to continue to support scientific, technological innovation in meeting critical social and environmental challenges towards realistic ends.

Chapter Seven

Discussions and Conclusions: The Compromise of Practical Actions

"The dilemma one recognises looms so dangerously over our future that we are desperate to believe in miracles. Technology will save us. Capitalism is good at technology. So, let us just keep the show on the road and hope for the best. This delusional strategy has reached its limits as simplistic assumptions that capitalism propensity for efficiency will stabilise the climate and solve the problem of resource scarcity are almost literally bankrupt"

(Tim Jackson, 2017)

7.1 Introduction

Chapter Seven presents the main and specific research questions (page 51), followed by theoretical discussions, contributions and conclusions of this PhD thesis. This chapter discusses the literature and research framework's findings to advance sustainability transformations research's theory and practice. This work's overall results have significant implications for sustainability transitions and sustainable development praxis seeking transformative approaches. My research informants were open and honest and showed sincere commitment to their work and their institutions and willingness to engage in this thesis' themes and discuss and share their knowledge. Efforts made by experts consulted in this research are remarkable and merit acknowledgement for their willingness to share their insights and enthusiastically discuss their roles and organisations with me. It is equally important to reflect that actors may not always give accurate descriptions of their activities, levels of influence, or how their agency affects policy outcomes.

While it takes considerable effort to practice science and technology policy at this scale, incumbent interest plays a significant part in determining comfortable positions of power that may neglect self-awareness of potential bias towards their organisations. In particular, it is a real challenge to contend with the global bureaucracies and sometimes bureaucracy's inertia that reproduces a standardised modus operandi which tends to reinforce elite cultures of expertise and obscure their outcomes. For instance, in the fact that the Technology Mechanism was never designed to solve the complex issue of climate technology policy developments across the developing world or was never meant to introduce radical transformative changes. Instead, they serve as a steering voice in the hope of catalysing private sector investors into buying on technology transfer opportunities using transition narratives. This performativity becomes problematic since it is legitimised through boundary work across a formal global knowledge network and framed as an effective body that catalyses transformational change. In addition, experts who perform their mandated tasks have themselves secured the way into very stable careers. It is the low-risk and high compliance formula that needs to be unpacked. It is, therefore, essential to discuss some of the power dynamics encountered in global environmental governance administrations and provide a critical view on the reasons as well as the mode in which the practice of technology transfer profess to accomplish transformational changes in sustainability.

Hilgartener's view on performativity suggests that the constitution of authoritative knowledge––in this case of boundary organisations in the science-policy interface, works as effective forms of cultural production through the performance of expertise. A condition that is sometimes subtle and even obscured through mandates and formalised procedures. However, the ethnographic inquiry allows to observe such performance and thus render visible the "social machinery of credibility" (Hilgartener 2000, 146). I argue that such performativity over time becomes embedded in institutions as a culture of consensual practice. In other words, the expert's figure becomes embedded in such a way that as long as it performs tasks and communicates the mandated message, it remains authoritative in the context that renders them such status. If they deviate from being critical––and subsequently having to go off the record, they may also risk contradicting their organisation's vision. Even then, I have to say, experts do take the risk and do talk about problems inside the United Nations, but the language is calculated to conform with the rules of procedure and maintain their status. Therefore, expertise in this context is also about mastering protocol and learning the specialised language required for boundary work in science-policy. Thus, the language is diplomatic and seeks to avoid making bold claims about problems to avoid having to justify what could be seen as unnecessary personal opinions on the direction of change. Therefore, a bureaucratic structure may significantly influence how agency at play frame problems and solutions and everyday institutional practices. Once learned, these routines become the safe passage to institutionalised expertise and a comfortable way to maintain the status quo.

Therefore, there is tension inherent in the compromises of practical action regarding transitions in sustainability. Environmental change may demand that people and organisations function cooperatively and apply rules and protocols to navigate environmental governance challenges in more effective ways. And the problem grows larger when highly specialised cultures of expertise command the mobilisation of resources and tools in highly bureaucratised and complex ways to access. This poses implications and the need to reflect and inform a larger audience about some of the theoretical limitations and framework challenges encountered and what may be ahead of the transitions' paradigm regarding transformative approaches. These may require more grounded foundational understandings of knowledge and governance relating to critical social and environmental challenges. Lastly, I aim to clarify that there is a necessity to rethink and open new directions to future sustainability transformations.

7.2 Findings and Contributions

This PhD addressed the main research question: ***why and how do formal global knowledge networks negotiate, mobilise and utilise technologies and expertise to steer future sustainability transformations?*** It did so by unpacking and addressing a set of sub-questions, which guided research throughout the empirical chapters. For instance, all empirical chapters covered the specific research question ***1: To what extent can the Technology Mechanism under the UNFCCC be analysed as a formal global knowledge network in the context of environmental governance?*** These findings are summarised and discussed in section 7.2.1. Specific research question **2:** ***How are technologies and expertise negotiated, mobilised and used under the Technology Mechanism?*** was addressed in chapters three, four and five. Chapter Three addressed the negotiation of technologies and expert knowledge––discussed in section 7.2.2. Chapter Four addressed specific research question ***3: How do climate technology and knowledge transfer work under the UNFCCC?*** Addressing matters concerning the mobilisation of technologies and expertise––discussed in section 7.2.3. Chapter Five explained the utilisation of technologies and expert knowledge in the context of South-East Asia––contributions discussed in 7.2.4. In addition, Chapter Five integrated specific research question **4:** ***How do networked organisations build capacity for anticipatory governance through project-based interactions?*** with overall contributions discussed in 7.2.4 as well. Specific research question **5:** ***Which framings of expert knowledge, futures and uncertainty feature Global Policy Networks' discussions of transformation and anticipation?*** was covered in Chapter Six––contributions discussed in section 7.2.5. It is important to mention that although the specific research questions were also addressed throughout different chapters. All research questions are interrelated and cover various elements of the main research question. Therefore, findings and the analysis contained in each chapter intersect with one another in a complementary fashion. Finally, 7.2.6 refers back to the main research question in light of previous findings and contributions.

7.2.1 Formal Global Knowledge Network in Environmental Governance?

To what extent can the Technology Mechanism under the UNFCCC be analysed as a formal global knowledge network in the context of environmental governance? Results from Chapter Three revealed how expert knowledge and technology negotiations are articulated under the UNFCCC as a formal expert network. The institutionalisation of climate policy by the UN system has sought to govern scientific evidence with technical socio-economic and political perspectives on climate change. Over three decades, the global climate regime has proven to be problematic and difficult to implement in practice. Today, global carbon emissions, as observed using the Keeling curve, display levels of concentrations higher than 415 ppm (UNFCCC 2019). This research found that the negotiation of technical procedures––often in spaces closed to the public—portray a regime that, as it develops, becomes more complex and more bureaucratic. The large-scale apparatus of the UNFCCC is formed by a substantial quantity of expert bodies, committees, politicians, rules, protocols and mechanisms that struggle to coordinate, integrate and implement their visions of transformation. As such, deliberative processes seek to advance the Paris Agreements' program of work, while controversy, conflicts and specific efforts among experts, country delegates, negotiators and observer institutions often fail to reach consensus during closed doors consultation contexts. Therefore, the performative "stage" (Hilgartner, 2000) of climate negotiations represents an excellent example of the global climate regime's inner tensions and international development systems where the inter-institutional competition of ideas and values is enacted using authoritative discourse. In this context, the negotiation of ideas had shown different strategies and sources of power. These activities required tracing their global connections and observing the seamless web of actors' interactions in other countries and contexts with a tie to the climate negotiations. Consequently, this research observed both rationales and processes of technology and expert-based institutional mechanisms under the UNFCCC. In particular, the Technology Mechanism of the Convention revealed that technology transfer is not just an abiding practice but is also escalating through the maturation of organisations such as the Climate Technology Centre and Network (CTCN), Technology Executive Committee (TEC), and the intention of the Financial Mechanism, under the Global Environmental Facility (GEF) and Green Climate Fund (GCF), to advance these procedures. The abundance of projects found during this research shows that technology-based solutions are represented by experts and pursued by institutions as the means to deliver impact to the Paris Agreement. Over the years, the CTCN has learned to acknowledge and is moving towards more open models of innovation in their technology assistance requests (Lee & Mwebaza, 2020). However, the empirical data collected in this research during the CTCN inception and its maturation period (2015-2020) also indicate attempts to standardise––and hence narrow, spaces for co-production of the technology-based solution in the case of modelling tools and hydro-climate technologies in South East Asia (Croxatto et al., 2020), where the transfer of technology packages was identified seeking replicability, not openness. The recent evaluation provided by Lee and Mwebaza (2020) corresponds to a new learning process for the organisation, where the technology assistance closure reports have contributed over time to re-think an innovation system design in which the CTCN could move towards–that is of open innovation and open network-based technology services. As analysed and interpreted in the case of the CTCN's theory of change, there are still significant assumptions about the design of "transformational change," which supposedly count on steady funding and expect enough human capabilities on the ground to carry out the changes envisioned in the Technology Framework.

Other assumptions involved the considerable confidence in the private sector's will to contribute to the CTCN's transfer projects and certainty that the political attitudes of certain countries would align with the global market economy and technological preferences in actions to stimulate collaborative forms of R&D connecting the Global North and the Global South in mitigation and adaptation agendas. A significant controversy around the practices of transfer is the absence of shared vision when it comes to the repository of resources, funding streams, and matters of intellectual property rights and ownership––this remains an element for the CTCN delivery model to explore when it comes to open innovation and equity-based redistribution of knowledge, technologies and resources. The creation of the CTCN as an operating network is intended to overcome these obstacles by legitimising its network and improving over time its collaboration mechanism on subjects related to technology transfer. However, it has been observed that high-level formal networked arrangements cannot usually adapt to the fast pace at which distributed networked organisations want to perform. This has led to the Technology Framework also falling into rigid and outdated guidance for complex systemic processes of innovation and obscured by the political, social, and material conditions that affect socio-technical networks of this nature.

7.2.2 Negotiating Technologies and Expertise in Formal Global Knowledge Networks.

How are technologies and expertise negotiated in such settings? The negotiation of knowledge in the formation of global environmental agreements faces an obstacle in coordinating efforts when it comes to the Paris Agreement and the 2030 Agenda on Sustainable Development. Multiple terms of reference display the difficulty of orchestrating the negotiation and integration of policies and other climate response frameworks. A fragmented system may also affect the coordination of policies at lower levels of implementation, as well as the inclusion of national and local agendas in these overarching structures. Therefore, considerable challenges await as these systems seek legitimacy to achieve those agreements. Arrangements of this type require the absorptive capacity to combine complex and distinct knowledge systems while preserving independent roles that can support and possibly change structural conditions. The problem of capacity remains significant, not merely in the practical sense, but also from an ethical perspective. These arrangements should build on more open negotiations and decision making on policies and seek more democratic and better-coordinated answers that reflect national and local needs. The Technology Mechanism, as one of the main implementing arms of the Paris Agreement, requires thoughtful extension beyond its current Technology Framework and engagement in the wider conversation and socio-political context. Furthermore, it must handle political commitments and recognise the aspirations and priorities of national and local organisations working for change—in short, becoming an enabler of knowledge sharing, funding support, and implementation of adequate capacities on the ground.

Findings strongly suggest that there is a growing demand for negotiating diverse kinds of knowledge in global environmental governance. In addition, technological advancements in ICT together with the maturation of formal global networks require that actors build on the coordination of functions in ways more inclusive than current approaches. Findings confirm that while historical responsibilities are decisive in advancing collaboration on climate change, these duties have to be reflected in the improvement of global institutional governance(Cornell et al., 2013; Gerritsen et al., 2013; Ostrom, 2010), and in ways that advance plural agendas and future-oriented collective actions. This research shows that formal governance, which pursues framings of change, the abstraction by which parts of reality are selected in order to create meaning (Cornelissen & Werner, 2014), can in fact become narrow, instrumental, and non-reflexive. Claims to historical and scientific contributions to the advancement of sustainable development then reinforce these framings (Wuelser & Pohl, 2016), while neglecting alternative perspectives, thus exposing tensions and power dynamics. The socio-political turn in sustainability research (Brown, 2014) should give more attention to power dynamics at the institutional level, reflecting on the politics of change (Meadowcroft, 2011). Otherwise, decades of policy efforts may lead to engrained practices inside specialised organisations such as the UN, with path-dependent institutional systems that tend to reinforce North-South power structures (Biermann *et al.*, 2018; Burch et al., 2018). Addressing this dilemma requires that we consider the connection between institutions and their political, material and symbolic characteristics, which are full of meaning. For example, central issues concerning ownership warrant further exploration. Trust is a social condition—a requirement for cooperation. It builds on positive expectations and intentions and the behaviours of others (Rousseau et al., 1998). Similarly, in institutions working on collective action problems, trust and ownership of processes are critical for cooperation (Ostrom, 2003). However, there cannot be trust in institutional spaces that control knowledge, technologies and resources, addressing issues of trust through the technocratic management of knowledge and expertise, which in turn becomes another powerful mechanism to leverage against ownership. Therefore, it is unlikely that technology transfer would serve the advancement of effective cooperation for solving collective action problems. From another point of view, the division of epistemic labour can also generate trust obstacles and make cooperation more difficult, as specialists need to agree on potentially divergent boundaries and policy issues would affect long-term negotiations. There is, in the practice of knowledge negotiation, a need for more pragmatic integration (Kitcher 2012). Institutions seeking to act cooperatively on climate change must trust one another in order to integrate their efforts (Anadon et al., 2016; Cash et al., 2003; Clark et al., 2011; Clark, et al., 2016). Knowledge intersections exist because they have been socially delimited and repeated over time. This historical division of epistemic activity necessitates more collaborative endeavours on integration to inform future-oriented knowledge governance. This may be achieved through plural boundary work opportunities with a focus on the combination of problem domains, expertise and disciplinary skills, rather than on closed expert systems relying on transfer. Future knowledge integration systems of global knowledge networks would benefit from deeper comprehension of how expert practitioners confront the accelerated changes imposed by highly interconnected institutional spaces and collaboratively address hierarchies and power dynamics. The use of technologies, combined with more open and reflexive practices, may in turn "steer possible futures" (Vervoort & Gupta, 2018) to positively influence institutional cooperation on climate change.

7.2.3 Mobilising Technologies and Expertise in Formal Global knowledge Networks

How are technologies and expertise mobilised? Chapter 4 examined the travel of rationalities to different cultural contexts and their implications for the mobilisation of artefacts. The chapter investigated the mobilisation of expertise and technologies from a global network articulated from Europe to Southeast Asian contexts. The chapter finds the significant distance between high-level technocratic policy agendas intended to steer national ministries to implement technology transfer in response to their national commitments. These procedures encounter national realities in other regulatory regimes and politics, which are substantially different from those of the Western world. The mobilisation of technologies and policies through networked arrangements tends to be simplified to deliver packaged solutions and standardised methods of techno-economic assessments. By using these evaluations, the system reproduces authoritative assessments to comply with high-level incumbent technocrats' expectations, demanding that the other less empowered actors comply with their mandates. Authoritative evaluations may become the boundary objects that legitimise the travelling of rationalities to different contexts and recreate, in turn, locked systemic black boxes.

Opening the black box of technology transfer on the ground reveals several dynamics. As Bruno Latour (2005) argues, "black boxing" implies social processes that are defined by the invisibility created by scientific and technical success (Latour 2005). Similarly, networked organisations legitimise the transfer of technologies through complex institutional machinery designed to increase inputs. Global technology policy creates meaning through these practices and further legitimises the model of technological deployment, which, paradoxically, exposes the opaque quality of their development. This phenomenon further sheds light on the combined material and symbolic dynamics at work in the production of tools, artefacts, infrastructures, workforces and assets in different settings, exposing embedded tensions. However, these large-scale sociotechnical fabrics are far from their technocratic claims of control-based purpose, as national context dilute these operations in divergent political and cultural realities. These findings have implications for our understanding of distributed socialisation practices that define networks and boundary work. Intersecting boundary objects, resources and artefacts perform functions, which, in the case of technology transfer, tend to be ungoverned. Consequently, the travel of technical rationalities is met with the reality that the transfer of knowledge cannot be controlled in distributed knowledge systems that follow unidirectional flows and disregard the existence of diversity, agency, and context.

Findings strongly imply that technology transfer projects, at best, belong to a rationale defined by the legacy of colonialism and the modernisation paradigm (Contreras, 2002; Escobar, 2000, 2004, 2011; Harding, 2009; Jasanoff & Kim, 2015). Modernity projects seek to rationalise and control problems by applying a vision of linear development towards a fixed, imagined future predefined to satisfy Western values of progress (Ferguson, 1999; Habermas, 1981). The methods of transfer reflect unfit solutions to difficult, wicked problems, assuming a detached, objective and universal vision that satisfies expectations of control (Crewe & Axelby, 2013; Stirling, 2010). Similarly, the social construction of technological artefacts (Bijker et al., 2012) reveals the political and value-laden nature of expertise and the reproduction of this form of agency through––as in the case of technology policies, modelling tools, and technology assessments. Technologies are both physical and social products. The development of taxonomies and technological packages further narrow this rationale––and render them more active in their deployments. However, they recreate a socio-technical fabric largely built on techno-scientific discourse. As it has been observed, this narrative also travels through formal global knowledge networks, further spreading this rationality. The activities of transfer imply the travelling of an agency, which may generate the subordination of other knowledge systems to this view by means of authoritative knowledge and the performance of analytical instrumentation. Consequently, this mechanism reproduces what Sheila Jasanoff refers to as socio-technical imaginaries (Jasanoff & Kim, 2015), and in ways difficult to change from within once they become institutionalised. The travel of technocratic rationality attempts to be apolitical in its dealings with the environment (Robbins, 2012; Eric R. Wolf, 1999), but shows the practical bearings and politics in the transmission of knowledge and its means (Habermas, 2003; Peirce, 1992). Technology and knowledge mobilisation of this nature does not recognise the role of social, cultural and political conditions that affect the process, nor does it move away from ideals of instrumental reasoning, which, deliberatively or not, attempt to reduce unknowns to measurable risk and nurture a bounded perspective on complex problems. Therefore, global knowledge networks present a dilemma when their actions serve to mobilise bias and promote changes that, as a dimension of the exercise of power (Bachrach & Baratz, 1963), advocate for particular travels of knowledge while excluding others (Mosse, 2013).

7.2.4 Anticipatory Governance, Capacity Building, and Uses of Technology and Expertise

How are technologies and expertise utilised? and *how do networked organisations build capacity for anticipatory governance through project-based interactions?* Results from Chapter 5 include more specific evidence of these themes. The capacity to deal with future climate change is relevant in environmental planning, particularly with regards to the ability of government organisations to use technical tools such as climate and hydrological modelling technologies to inform responses to risk and uncertainty in climate change adaptation. Findings from Southeast Asia confirm that although particular organisations managed to centralise the transfer of climate and hydrological technologies, the governance uses thereof is limited at the local level. Cases from the "hydroclimate cluster" exemplified these issues.

The research shows that the transfer of expert knowledge and skills is not straightforward in the context of climate and water governance. Cases from Thailand and Myanmar demonstrate the real challenges of using anticipatory governance tools and techniques across different cultural and institutional contexts. Thus, consolidated networks, which de facto may strengthen arrangements for the implementation of knowledge and technologies, prove inadequate in improving institutional capacity for environmental planning at the local level. Continuing to favour the practice of transfer undervalues the multiple social dimensions of technology and limits the adaptability of local organisations by making them dependent on external forms of expertise. In the case of adaptation governance, it is clear that socio-ecological systems require that actors concentrate on institutional dimensions, while also challenging these external rationalities. Those implementing expert tools and techniques also need to reconsider the intrinsic differences between the sites of knowledge production and the sites of knowledge use. There is distinct evidence that technology-driven solutions to difficult problems reinforce pre-existing rationalities that favour market-based capitalism when it comes to development and aid, to the detriment of alternative, localised, and sometimes previously available solutions (Leach et al., 2012; Mosse, 2013). These model-based solutions follow mostly Eurocentric rationales (Haraway, 1988; Harding, 2009; Wolf, 1982).

This chapter examined endeavours to modernise decision-making regarding technological undertakings. Technical realisations depend on local conditions; attempts to make infrastructure smarter by using modelling tools also need to be combined with understanding local needs and regulatory frameworks. This may lead to more long-term strategies befitting the local conditions, social resources and institutional capacities, most of which are already present. If this is not done, then external performative actions of expertise will continue to be valued and become authoritative—not necessarily by their merit, but rather because of the historical colonial factors from which they arise (Mosse, 2004, 2013; Tsing, 2005).

I observed how localised dynamics exemplify the problems of navigating knowledge boundaries in practice, as these are deemed to be the outcome of negotiations among epistemic communities (Cash et al., 2014; Galaz et al., 2018; Haas, 1992; C. J. Robinson & Wallington, 2012). Expert uses of knowledge usually carry assumptions about control, but uncertainty about the trustworthiness of these knowledge claims abounds. In addition, it becomes still more challenging to understand if this knowledge has been built in a fair way, clearly communicated, and that uncertainty has been acknowledged and discussed (Shackley and Wynne, 1996; Van Wyk *et al.*, 2007; Stirling, 2011). Therefore, observations of project-based interactions provide a more accurate understanding of how expert knowledge "exchange" occurs, and how boundary objects are produced and utilised. It could be said that formal global knowledge networks generating strategic centrality towards their aims deploy tools in the form of policies and technologies and seek to influence environmental governance in various parts of the world. However, the evidence has shown that these actions are not fundamentally favourable to better use of anticipatory capacity in the local context, where appropriate institutional arrangements are lacking. Consequently, they do not demonstrably improve the ability of local actors in ways that empower or support strategic planning (Fuerth & Faber, 2012; Galaz et al., 2018; Guston, 2014). Thus, robust environmental governance must think seriously about these dynamics.

There is a tension between modernist visions of change and precautionary attitudes when it comes to deep uncertainties. This tension cannot be expressed through models, and social, political and cultural accounts may need to inform otherwise biased ideas about the changes that need to happen. Global knowledge networks allow for the study of how uncertainty travels, particularly as signals that spread the mobilisation of modernist biases across different communities of practice. Global knowledge networks enable the study of uncertainty at the boundaries of science and policy at institutional levels through the empirical observation of organisational practices of technology and knowledge utilisation. Furthermore, the search for signals is a heuristic that supports the mapping and analysis of how knowledge travels and is a deliberate strategy used to deliver on particular understandings and meanings of change. The interconnectivity of global knowledge networks allows us to trace how cultures of expertise and Western rationale influence other cultural realities. While the processes of technology and knowledge transfer may be intensified by the existence of informatics, they may lack a "co-created" character, which renders them ineffective or unfair when the deployment of boundary objects and other artefacts are successful but unreflective, reproducing in turn unfit imaginaries (Jasanoff, 2004; Jasanoff & Kim, 2015; C. J. Robinson & Wallington, 2012). The boundary objects encapsulated in modelling tools and experts' technological assessments carry uncertainties with them; their mobilisation through global knowledge networks may spread these uncertainties across institutions and actors. Consequently, they become the very sign that allows the identification of such uncertainties through analysis of how these are utilised through adopting technological packages.

It is relevant to note how endeavours to operationalise global networks seek to incrementally grasp transitional momentum for change and pursue particular narratives of transformations. Moreover, it is notable that there are no strong linkages between the theory of change introduced by boundary organisations such as the CTCN and their practices leading to substantive changes towards more resilient societies, more robust institutions, or knowledge systems adequately prepared to withstand the impacts of climate change. The research has also shown how these organisations try to legitimise their systems as core components in order to channel particular kinds of agency and maintain their compliance structures. The mechanism of transfer must be so specialised that it becomes a closed space of knowledge exchange—and more authoritative on the means and tools actors use to pursue their goals. Consequently, there is still a tendency to frame solutions in North-to-South logic, which follows historical power dynamics seeking the management of ungoverned processes. However, globally connected spaces of sustainable development become opaque, requiring continuous exposure and questioning. It has been shown that practices of science-policy and boundary work across spaces of global connection can be problematic, since these become complex and large, thus challenging Western ideals of governability. These are not situations that can be solved by applying managerial lenses; they remain a governance dilemma inherent in large socio-technical systems.

The results of this research also suggest that transition approaches may become blurred when deeper contextual dimensions inform their models and managerial practices. Reality belongs to the inevitable social and political elements embedded in pursuing changes, which in the context of the need for transformations in sustainability make the imitation of such models more evident. Technocratic means, which seek to achieve substantive change, are likely to fail if their non-reflexive agency reinforces the very systemic problems they ought to manage. The contradiction points to the need to continue examining the meaning of change in different situations where different forms of agency seek to realise change by utilising tools and techniques. While formal global knowledge networks may represent a necessary effort in coordinating the implementation of global agreements, international development agencies and their systems may not be prepared to govern the fast pace of highly dynamic networked organisations at a global scale. Therefore, global knowledge networks cannot necessarily effectively govern the development of ICT and advancements in a communications infrastructure. The focus should be on the internal institutional governance of development cooperation agencies instead, so that they can respond in more desirable manners to the development of globally connected spaces where people, technologies and resources intersect. This may require the application of a shared vision and common goals in the way that expert knowledge is used. The internal "capacity" gap, which is most pressing and often understated by the organisation, highlights the need to reconsider the platforms of knowledge transmissions and re-evaluate the internal assumptions of institutionalised knowledge systems. These systems belong to more extensive socialisation processes, which are affected by the worldviews of the agents working in international development organisations. Therefore, the performance of authoritative advice––which is never value-free—would benefit from an examination of suppositions of universality and the institutionalisation of evaluation mechanisms that identify unbalanced, biased, or bounded practices occurring in implementation and project-based interactions.

7.2.5 Framings of Expertise and Transformations in Global Policy Networks

Which framings of expert knowledge, futures and uncertainty feature Global Policy Networks' discussions of transformation and anticipation? Results from Chapter 6 assess transformations in global policy networks driving the global response to climate change. Critical social and environmental challenges of the future will likely require transformative framings of sustainability policy and practice. However, collaborative capacity—as observed in formal spaces of networked climate governance—is not yet leading to a realistic performance of collective action for change. While business as usual may be changing due to unknown global effects of climate change, these changes are not yet directed by human agency in ways that are consistent with global goals and aspirations. In this sense, it is important to recognise that changes are happening, although our collective ability to steer them in the right direction remains a subject of deep uncertainty.

While formal global knowledge networks may be framed as a legitimate form of technology and knowledge mobilisation, they have yet to show clearer signs of being the solution to the problem of coordination inside the global climate regime under the UNFCCC. If they continue to focus their efforts on technology development and transfer as the strategy to achieve transformations, these will not be a solution at all. The problem points to highly formalised institutional systems being too entangled in their incumbent practices to be able to reflect and change direction in a timely manner. The case of the IPCC-SBSTA boundary efforts shows real attempts to introduce more radical "transformative approaches" into the global climate regime. However, science diplomacy and boundary work may be subject to larger apparatus, which in practice are fragmented and have divergent political and economic interests. The cases of more radical "transformative" approaches inside these spaces tend to be diluted in techno-economic discussions and frameworks that seldom change the structure in significant ways. Furthermore, almost all precautionary narratives with regards to future pathways tend to disappear when the regime encounters the aspirations of the global response, its technological possibilities and business ideas. The global response to climate change forgets there are also other alternatives to technology-based solutions such as geoengineering and blockchain to solve collective climate action, global carbon emissions, and problems of trust in climate finance. Global policy networks involved in such discourses activity seek to introduce disruptive technological solutions to climate change and increase their saliency by using transformational change narratives. They tend to obscure original good efforts in science diplomacy and reinforce opportunistic agendas instead.

These findings confirm that the politics and business interests of transformational narratives tend to dislike uncertainties and seek to implement what is perceived to be smart and fast. The models of corporation systems observed in this research showed a biased preference for these kinds of solutions, which are in fact—persistent problems that follow reductionist visions. Technology transfer is an ineffective way to solve problems of collective action and shows that development cooperation models are still strongly influenced by the legacy of western values and the modernist paradigm of technoscience (Contreras, 2002; Crewe & Axelby, 2013; Escobar, 2004; Jasanoff & Kim, 2015). The findings strongly suggest that policy networks which are not open about these uncertainties can reproduce uncertainties across networked spaces, generating path dependency and deviating efforts towards unrealistic outcomes. Since climate change is a global problem requiring local and regional solutions, collective actions necessitate deeper levels of community engagement, rather than global and national governance plans based largely on external rationalities.

The impacts of climate change fall unevenly and intensify structural conditions such as poverty and other equity problems related to lack of infrastructure and access to reliable energy, food, water security, and health. A UN system that seeks to address these structural problems must also demonstrate accountability and transparency regarding their operative environment and reform. There is a need to be reflexive about the underlying value-laden and expert-bound roles of their incumbents when dealing with future climate change problems. Transformations in sustainability are about addressing the problem of choice in designing future solutions. Climate change is rooted in social practices, institutions, and cultural habits. Similarly, narratives of control over large-scale complex systems and of governance processes regarding technologies and expert knowledge must choose between instrumental rationality and a more balanced and inclusive approach that seeks to overcome historical bounded rationalities through reflexivity and openness to uncertainty. Policy processes of this nature may enable alternative perspectives to emerge and balance power dynamics. Otherwise, the mobilisation of bias occurs through global policy networks, which transfer their framings of expertise and instrumental rationality and promote blueprint-type visions of change for the contexts where their agency wishes to intervene. Other narratives of urgency and smart solutions further accelerate these technology fix narratives, possibly acting in favour of techno-economic accounts of the future and reliance on risky technologies. These controversies should be exposed and reflected upon. Lastly, futures of collective action must engage with and criticise the techno-economic dimensions of transitions and recognise the socio-cultural and institutional dimensions of global environmental change––deeply related to values, worldviews, and politics. Research and practice should be more reflective about empowering alternative futures for collective action by recognising that particular trajectories of change may become authoritative in environmental governance over time. This is why different forms of knowledge governance may have profound effects in steering future sustainability transformations towards desirable or undesirable outcomes. Thus, there is a need for more open debates about transformations to sustainability and more context in support for science and innovation meeting social and environmental challenges towards realistic ends.

In summary, there is a need for deep restructuration of approaches and visions in sustainability research and practice. We must rethink perspectives and redefine the focus of inquiry towards alternative knowledge governance explorations. Technology should not be the main focus of collective actions related to climate change; rather, perspectives on sustainability should come back to grounded research and focus on institutions, culture, and behaviour. Fast, accelerated, and technology-based innovation narratives should cede as the paradigmatic strategies to solve collective action problems in favour of deconstruction through empirical observation and critical analysis. A substantial turn in sustainability research may benefit from continuously debunking myths about the modern horizon of industrialisation, which ought to foster fast and smart economic growth––and neoliberalism (Bracking, 2015; Ferguson, 2006; Jackson, 2017; Reno, 2011; Sawyer, 2004). Findings in this thesis support the role of agency in defining and working towards solving collective action problems in ways that can enable alternative forms of cooperation beyond the colonial powers of OECD countries, and by stressing the need to reform the UN system. Global environmental governance may benefit from a plurality of solutions to collective action problems by moving away from entrenched technocratic mechanisms and framings of control. Transformative approaches to the Paris Agreement necessitate attention to internal power dynamics and consideration of diversity and plurality inside systems, networks, and institutions. Until this has truly happened, it may not be recommendable to attribute "generative effectiveness" to science-policy boundaries at the intersection of the IPCC-SBSTA interface (Young, 2018), when in fact networked climate governance defies traditional spaces of science policy. In fact, further challenges arise with regards to how science and technology will balance against the public good in decades to come.

Global knowledge networks, and policy networks in particular, continue to be relevant efforts to address problems of coordination inside global environmental regimes. However, no evidence was found that these have the ability to significantly transform regimes from within. While this research has identified how global knowledge networks negotiate, mobilise and utilise technologies and expert knowledge to nurture sustainability transformation inside formal spaces of climate governance, it has not found substantial evidence that technology policies influence substantial transformational change, nor that they yield the necessary conditions for this endeavour. In fact, deep uncertainties appear to be present through value-laden negotiations of knowledge and the mobilisation and use of expert-bounded framings and incumbency. These findings illustrate some of the socio-political conditionings of decisions when they are based on management assumptions over large-scale ungoverned processes.

Science policy at the intersection of the IPCC-SBSTA does significant work to summarise and communicate science-based policy. However, this science diplomacy and its precautionary elements may disappear when political narratives take over the negotiation of frameworks and implementation strategies. Politics dislike uncertainties, and thus focus on optimal narrative solutions instead. Boundary work at this level may become narrowed to what is perceived as salient, conveniently forgetting what is unknown in order to pursue universal discourses of transformational change. This has implications for the way knowledge is negotiated, mobilised and utilised at different stages of the Convention process, rendering uncertainty obscure in the background, but a latent signal. With political ambitions to rapidly achieve stabilisation of emissions in the atmosphere and deploy technologies and financial resources, narratives of urgency may add to techno-economic accounts of the future and reinforce undesirable, control-based, risky technological ventures.

7.2.6 Why Global Knowledge Networks Negotiate, Mobilise and Utilise Technologies and Expertise to Steer Sustainability Transformations

This PhD thesis has demonstrated why and how formal global knowledge networks negotiate, mobilise and utilise technologies and expert knowledge in different settings. Findings show that the increasingly interconnected phenomena of knowledge networks carry numerous challenges for sustainability transformations' research and practice. Established global governance arrangements want to discover original techniques to adjust to fast-paced environments with interdependent structures and systems fuelled by global capitalism. Fragmented bureaucracies and divergent national interests may create interdependencies, which are challenging to track and govern. While fragmentation is tightly coupled with the problem of scale, a thriving multiplicity of actors at diverse levels of governance is trying to influence what in the literature is widely characterised as socio-technical-environmental systems (Patterson et al., 2017). The presence of a global climate regime, as observed by following the UN apparatus, has occupied the attention of many scientific experts and policymakers. These try to renegotiate the boundaries of its regime architecture, seeking to mobilise its functions and attempting to manage the dynamics of a large-scale system. While many have been active in this endeavour, they tend to ignore that the fragmentation of global environmental governance has had a profound effect in reinforcing 'black boxes'—with uncertainties and unknown effects (Anderson & Parker, 2013b; Edler & Kuhlmann, 2008; Latour, 2005; van Asselt, 2013).

A common feature of regimes is their resistance to substantial changes. Global policy networks seeking to introduce reforms may also fall into long-term institutional commitments, as with technology development and transfer, subject to power structures, institutional procedures, and global business's economic interests. As the dilemma of the praxis of sustainability transitions has shown, the absence of a vision beyond instrumental reason may strengthen practices that, as in the case of technology transfer, rarely address the need for model shifts that significantly transforms business as usual. Instead, the prevailing paradigm of formal cooperation systems continues to follow a one-way approach to negotiating, mobilising and utilising technologies and knowledge. In the case of mitigation and adaptation to climate change, Northern countries continue to assume to have rationalised and modelled the solutions to southern nations' problems. This PhD thesis has revealed socio-political tensions and has unpacked the reasons and processes of how particular models of change are deployed through the transfer of tools, skills, technologies and policies to other cultural contexts and are legitimised through policy discourse, assessments and the performance of expertise. While studying up, through, and by opening black boxes via empirical observations, I have shed light on the persistent rationale of linear progress and technology deficit narratives linked to transitions. Global knowledge networks are part of socio-technical systems. Such systems may still justify control-based and interventionist strategies to address complex sustainability problems. Simultaneously, global knowledge networks are mainly oblivious to the nuances: the more 'intangibles' elements bounded external rationality try to optimise, however, cannot fully comprehend or resolve other actors belonging to different socio-political and cultural contexts.

7.3 Beyond Transition Frameworks: Transformational Changes in Theory and Practice

As shown in Chapter 1, section 1.3 of the literature review, sustainability scholars do seek to advance the theory and application of sustainability transitions research. Whether by employing incremental strategies to manage niche interactions and maximise windows of opportunity or by conceptualising these transitions as socio-political momentum leading to transformations, there should be a critical turn in transitions research in general. This PhD finds that transforming regimes is also about changing frameworks and terms of reference when conducting research and informing policy. Substantial transformations depend on reconfiguring those terms of reference and the connection between structural, systemic and agency perspectives, moving away from apolitical notions of transitions. While the question of capacity to realise change remains critical to any serious research about sustainability, envisioning changes in plural directions is an inherent challenge of the transition framework. Transitions research should also seek to transform the existing paradigmatic interpretations of socio-political phenomena informed by agency and context.

First, there is a great demand for the study and practice of transitions to overcome the idea that the high-level framework of sustainability transitions delivers critical thinking by separating knowledge domains such as socio-ecological systems and socio-technical systems. This is not the case, nor is the solution a focus on techno-economic 'model' innovations without more serious consideration of the inherent politics of global capitalism. Sustainability transitions research does not engage appropriately in criticising global capitalism. As Feola (2020) recently argued, capitalism is not a “landscape” factor. Capitalism pervades socio-technical and socio-ecological systems in profound ways that require us to trace and account for trajectories and practices of change at multiple levels. This has significant implications for the fitness of the transitions paradigm in capturing this reality (Feola, 2020). Transitions research also falls short of adequately characterising other cultural contexts—particularly from the Global South, but also at high levels of power and decision making inside organisational contexts. Furthermore, this framework has a significant shortcoming in applying forward-oriented analysis that is reflexive and provides a relevant account of power based on empirically grounded research. For these reasons, this PhD finds that in order to overcome such limitations, transitions scholars should seek to deconstruct theoretical biases and reflect on the agency behind their research. In this particular case, my role as a researcher is to overcome explanatory limitations between knowledge and action and seek pathways that can pragmatically support more solid foundational understandings of knowledge governance relating to critical social and environmental problems––with many limitations. For instance, conducting ethnographic inquiry about politically contested problems require to make clear when solutions do not work. Institutions such as the United Nations face many difficulties. While it is important to unveil internal tensions and contradictions, this critique should not be taken as an attempt to demolish these efforts. To the contrary, this research aims to comprehend these phenomena in order to offer a constructive way forward. This research does not, however, change business as usual, nor does it offer straightforward answers to my research subjects' problems. It does explore tensions between incumbent actors who promote short-term visions of change utilising narratives that ought to be transformational. Moreover, it applies critique in order to encourage discussions about 'wiser' visions of change, reflecting on how organisations may pursue more genuine and transformative pathways towards sustainability.

When it comes to knowledge applications in transitions research, there is a functional difficulty regarding integration with grounded approaches. Some applications do not leave enough room for substantive empirical accounts of agency, but instead find comfort in more detached high-level theoretical abstractions of what agency means. This research reveals a general lack of experimental accounts of change processes from within the objects of study. It suggests that transitions analysis, which ought to be transformational, would to benefit from attending at how institutional systems and the power in the function in networked spaces and global interplays. This could be achieved by examining how global-reaching organisations, such as the UNFCCC, actively articulate their power structures, negotiate their rules, mobilise their knowledge and pursue their goals. These methodological contributions come from grounded ethnographic observations, which facilitate understanding of the social and power relations rooted in systems and structures and reveal tensions between multiple forms of agency as seen across connected developments and networked interactions. Therefore, transitions research requires further consideration and acknowledgement of the political dimensions as a central issue in the study of change. Earlier political ecology studies (Biersack, 1999; Kottak, 1999; Robbins, 2012; Eric R. Wolf, 1999) are seminal contributions to the study of socio-political turns in environmental studies (Brown, 2014). However, these also require interdisciplinary innovations and dialogue with research that address socio-political systemic and material conditions, as well as apply agency approaches to examining the meaning and consequences of change when it is conducted in practice. By empirically observing the performance of agency, it is possible to understand how authorities enact power through systems and shed light on their visions of development, the capacity of institutions to realise them, and the controversies embedded in pursuing their agendas.

Second, future analysis of large-scale changes from transition theory should overcome overly complicated models and concentrate on empirical reconfigurations of structures, systems and agency using more grounded approaches. Structural outlooks should consider prospects and acknowledge the influence of actors in the research and policy process. With this in mind, there is significant value in applying historical and macro-analysis of material conditions of change. The fundamental institutional changes that Polanyi discussed in his work (1944) are inspirational and instructive in thinking about how to create new economic structures and social relations. Economic reasoning that finds this approach useful may further benefit from reconsolidating structural, systemic and enabling approaches to the research and practice of change (Scoones et al., 2020)—by applying experimental interdisciplinary and grounded research. Structural approaches would benefit from contrasting theory and model-based interpretations with more observational research that challenges techno-economic assumptions. Similarly, systems thinking may continue to be a valuable strategy for the study of change, so long as it continuously utilises pragmatic research that is reflexive about uncertainty and engages in the politics of collective action problems. This would help to keep at a bay an overly technical understanding of means through a detached, depoliticised lens and avoid the sometimes overly confident managerial lenses, which can obscure social phenomena and complexity. More research is needed in the politics of systems management and incremental administrations, informed by research on social relations in systems transitions. The significant advances in structural, functional, relational and cognitive aspects of socio-technical-ecological systems (Patterson et al., 2017) may challenge new kinds of interaction and outcomes both in research and in policymaking.

More useful theoretical analysis of change––whether incremental or transformative—warrants radical perspectives informed by realistic accounts of power and explorations of the meaning of changes and how to enable them. Consequently, there is a push to move away from mid-range universalistic theories of transitions attempting to impact policy and instead engage in experimental collaborative research that provides the necessary empirics on how and why transformations happen, for whom, and in which settings. Transitions research should concentrate on overcoming comfortable assumptions, take interdisciplinary risks, and seek pragmatic pathways to knowledge and governance. This may require recognising the political nature of knowledge and making said knowledge more useful so as to enable the wider society and organisations to envision and pursue tangible transformative changes in sustainability. Finally, transition frameworks need to refresh their angle and acknowledge the problems of global capitalism, the lack of action in transitions scholarship, and the optimistic assumptions that complex phenomena can ultimately be managed by incremental adjustments that will create drive and breakthroughs. These perspectives are––as in the practice of technological transfer—ineffective and ethnocentric in their accounts of the world––as they pursue stability, order and progress. The theory is entrenched unless it discovers more grounded ways to account for the social dynamics of change and diverse meanings. Transformations are about socio-political conditions, which direct changes and have real consequences.

Third, in order to move forward in the research and practice of sustainability transformations, it may be necessary to recognise the urgent need for courageous policy-oriented research that actively debunk the paradigm of transnational *laissez faire* enterprises (Jackson 2017). There is a need for more engaging research that resolves the problem of denialism in sustainability research and renegotiates norms and visions to overcome entrenched structures and institutions subject to neoliberal governance. For example, in the case of global networks—whether policy networks, formal networks deploying technologies and expertise, scientific networks, or other novel alliances—research may benefit from addressing the idea that socialisation is made by collections of people, which together may have the power to nurture new social, economic and environmental relationships at large scales. The potential of collective efforts through networks and connectivity is immense. Collective activities enabled by technology can achieve goals that individuals cannot. However, the governance of knowledge networks in their different patterns requires redesigning and rethinking of strategies for the consolidation of social and institutional connections and the pursuit of clearer visions of changes in future sustainability. Organised networks may have structure, complexity and function, which can indeed be beneficial to the practice of changing sustainability policy and practice. These networks can produce rules and institutional systems, and they serve specific purposes. These principles must be reflexive and clearly articulated. Otherwise, they risk reproducing past conditions and potentially reinforcing them.

The capitalist economy may always clash with the state. However, market structures depend on the vision and actions of policymakers and society. There are, as Mazzucatto (2015) would argue, many tools available to reshape markets towards mission-oriented pathways. In sustainability, the problems of growth and prosperity (Jackson 2015, Moore 2015) are similarly in need of markets that deliver on inclusive and sustainable innovation. Overcoming overheated *laissez faire* is not about eliminating the global economy. It is about transforming the vision and means of governing the global economy in a manner consistent with planetary limits and following normative grounds of environmental justice and equity. These efforts also necessitate more research and practice on facing fragmented governance structures and creating effective policy instruments and networked arrangements. Innovation challenges in sustainability are not about selecting champions in competing network ecosystems, but rather working together in more pluralistic ways across society and building enabling conditions for change. In the case of the knowledge economy, there is a serious need to review techno-economic statements about the future of knowledge and work, which still heavily focus on securing the monetary value of knowledge before it can be of accessed and of use to others. These pervasive incentives are detrimental to sustainable development, as observed in the case of technological transfer and is true to knowledge institutions like universities. These practices, in reality, may block the ability of scientific knowledge to move forward in open and exploratory ways that serve the public good. A critical element is the notion of the public value of research and policy—how these are nurtured across communities of practice. More research may be needed to inform global knowledge networks about the problem of collective access and ownership and how this may be applied to knowledge and technologies to support future collective action on climate change.

Overall, in order to better understand the nature of transformations––whether environmental, technological or social and their associations—it is essential to acknowledge that changes are inherent in nature and society. Finding a common pathway to learning how to 'live with' and adapt to the gigantic, ungoverned transformation posed by climate change is a collective challenge. Consequently, nurturing 'particular' transformation pathways is a question of substantially understanding what is changing and pursuing interconnected efforts that address change. Integrating knowledge and values may be decisive in this endeavour, especially if actors seek to reconfigure and redesign plural solutions to systemic socio-technical-ecological problems. Paradigm shifts in the study of change may require a move away from large-scale managerial transition accounts. Instead, attention to useful knowledge assimilation—of what we already know—offers a constructive way to secure broad scientific, political and public participation and diversify procedures of change. These efforts may produce a more engaged scholarship that values realistic futures and yields more open, long-term visions in the practice of sustainability transformations.

7.4 Conclusions

This section reflects on the significance of this research and its overall contribution to knowledge, as well as limitations encountered and areas of inquiry for further research. First, climate change necessitates cooperation, creativity and innovation in the integration of existing knowledge in order to make policies, resources, tools and other forms of expertise more useful. This PhD study empirically observed that institutionalised knowledge applications of sustainable development and transition management are political, complex, intertwined, globally-connected, and yet particular approaches––even though they tend to claim universality. The understanding of how formal cooperation networks negotiate, mobilise and utilise technologies and expert knowledge in practice has provided a more precise assessment of their aspirations, constraints and future challenges in pursuing transformations to sustainability. By innovatively combining methodologies, this research applied multi-sited ethnography, social network analysis and policy analysis in a practical way to trace dynamic contexts of global connection. This PhD project examined practices of science and technology policy through technology-driven networks in multiple locations in Europe and Southeast Asia. To that end, it analysed processes and conditions by which modelling technologies, climate negotiations, technology transfer activities, risk management technological ventures and ways of dealing with uncertainty are implemented in a formal global knowledge network articulated under the UN system. Mobile contexts involving project-based interactions, negotiations, expert meetings, advisory boards, technological assessments, technology transfer programmes and other materials grounded the research and allowed me to observe and participate within networked organisation settings. The thesis examined how the transfer of artefacts interact through the Technology Mechanism and its network and used case studies of climate and hydrological modelling deployments in Thailand and Myanmar, with reference to comparative cases in Southeast Asia. Furthermore, the research mapped and analysed the global response of networked organisations with particular attention to power dynamics and the development of a global climate regime, which is still dominated by North-South structures despite claims of transformational change and inclusive agendas. The empirical material collected and analysis developed in this work allowed for a critical evaluation of transformational change narratives inside institutionalised networks and science-policy spaces. In sum, this PhD thesis has contributed to a better foundational understanding of knowledge governance with grounded research that informs critical social and environmental challenges. The work contributes to efforts to rethink futures of collective climate action, and it advances sustainability transformations theory and practice.

Second, in global environmental governance, the negotiation, mobilisation and utilisation of knowledge and technologies are three critical elements that shed light on the performance of formal collective climate action frameworks. In this process, the figure of the State continues to be of crucial importance in addressing global as well as national environmental governance. Expert groups and country representatives mostly conduct the international climate negotiations process under the UN system, and they play a crucial role in advancing coordination on addressing climate change. Their work is, indeed, critical. However, it is also necessary to recognise that it has become more difficult for governments and intergovernmental institutions to govern the entangled participation of multiple actors at transnational levels. The fragmentation of global bureaucracies and business ventures is immense. Hence, it is likely that State bureaucracies, as well as intergovernmental "formal" cooperation networks, will need to find more efficient, inclusive, cohesive and collaborative ways to work with other forms of agency and other organisations––ensuring that hybrid forms of governance are represented and nurtured. The study of formal global knowledge networks allows for the empirical representation of power and the meaning of power in transnational governance arrangements. In much of the existing policy-oriented transitions research, and especially the research on environmental governance issues, power relations are often neglected due to assumptions about the universal common good, the joint action of common interests, and other similar discourses. This fact suggests that the relevance of power and power relations should be at the centre of the study of institutions governing environmental transformations. In networks, power tends to be diffuse. More distributed, it cannot always be easily identified, nor used to coordinate actions; these activities are not bounded by State rules, and their power of legal enforcement is limited. The case of global policy networks has shown that the relationship between framings of expert knowledge and the practices of expertise provide direct evidence for the attribution of the exercise of power and agency across networked spaces. However, as long as policy networks remain policy elites, their participation in climate negotiations and discussions of transformational change policies might not be desirable on the ground––beyond closed negotiation doors—nor in the best interest of national and subnational stakeholders. In turn, policy bureaucracies themselves can become the drivers of ruling ideas, which tends to influence the intellectual work of the climate change global agenda. These are policy elites that control the flows of knowledge, technologies and resources in sustainable development. Moreover, routines and institutional rules obscure the accountability of their actions, to the detriment of more open spaces in which different forms of knowledge governance for sustainability are co-created.

Third, climate governance of this nature offers clumsy solutions that address mixtures of policy styles and normative principles in ways highly influenced by economic-centric and technology-centric approaches and elite cultures of expertise and specialisation. As a result, global policy bureaucracies working to address climate change in formal settings tend to represent silo thinking and dominant narratives, which are reproduced through environmental regimes. Global climate governance of this nature relies on political authority (often disguised as scientific authority), yet continues to foster narratives of change. As the case of technology transfer has proved, these narratives are problematic, based almost exclusively on technical rationality and market approaches. These phenomena represent tensions and contradictions embedded in efforts to achieve substantial transformations in sustainability policy and practice. Observations of how the "chain of meaning" (Collins & Evans, 2007) is articulated across networked governance experts can serve to ethnographically unveil these frictions. "Black boxes" tend to reinforce the diffusion of unfit settings of vertical interlinkages in goal-based environmental governance; in turn, they can blur issues of accountability, transparency and legitimacy in the eyes of the public and the broader global response to climate change. There are, however, different forms of legitimation beyond technical rationality, institutional control, and traditional mechanisms applied as universals in different socio-political contexts. Further research is needed to continuously capture emergent alternative networks actively negotiating, mobilising and utilising knowledge to transform practices in sustainability.

Finally, given the continuous rise of networked forms of social organisation, traditional mechanisms using rationalistic-institutionalist programmes focusing exclusively on state actors and interests may lose legitimacy over time as the solvers of complex global environmental issues. Most financial capacity to nurture sustainability transformations is still anchored in funds, public and private, coming from the Global North––and with Westernised visions of change. Continuous research should inform the politics that influence the evolution of this structural reality. The fragmentation of global environmental governance also suggests that the global environmental regime under the UN system may require considerable institutional reform over the next decades.

In summary, an essential step toward greater coordination could begin with the acknowledgment of the myriad participants in climate action, improving their integration by institutionalising their complementarity with global knowledge networks and other mechanisms. Further research is needed on the institutional dynamics of change at different scales of governance, as well as the development of future frameworks that could support a better understanding of their integration. Design and experiment with future governance systems based on substantial legitimacy, transparency and accountability may be a point of departure. Finally, it is critical to recognise the unprecedented widespread, fast, and ongoing transformations which the earth system and our societies—in the plural—are experiencing. This requires that we deeply question our assumptions and become creative in finding new methodologies and approaches to integrate and catalyse the incredible capacity and available knowledge generated by humanity towards realistic political, economic, social and environmental sustainability pathways. This may require humility in recognising that global governance mechanisms of this nature are an unresolved challenge to collective action problems—and that multiple alternatives should be pursued, collectively and independently, to change the current and future reality of human habits and choices.

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Glossary

1.5°C pathway

A pathway of emissions of greenhouse gases and other climate forcers that gives an approximately one-in-two to two-in-three possibility, given contemporary knowledge of the climate response, of global warming, either remaining below 1.5°C or returning to 1.5°C by around 2100 following an overshoot. **(From IPCC, 1.5º Report).**[55]

2030 Agenda for Sustainable Development

A UN resolution in September 2015 adopting a plan of action for people, planet and prosperity in a new global development framework anchored in 17 Sustainable Development Goals (UN, 2015). https://sustainabledevelopment.un.org/post2015/transformingourworld

Abrupt change/abrupt climate change

Abrupt change refers to a change that is considerably faster than the speed of change in the recent history of the affected elements of a system. Abrupt climate change points to a large-scale transformation in the climate system that takes place over a few decades or less and persists for at least a few decades and causes substantial impacts in human and natural systems. {WGI, II, III} (IPCC, AR5, 2014)

Acceptability of policy or system change.

The extent to which a policy is evaluated unfavourably or favourably, or rejected or supported, by members of the general public (public acceptability) or politicians or governments (political acceptability). (From IPCC, 1.5º Report).

Adaptation

The process of adjustment to actual or expected climate and its effects. In human systems, adaptation attempts to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects. {WGII, III} (IPCC, AR5, 2014)

Adaptation pathways

A series of adaptation choices involving trade-offs between short-term and long-term goals and values. These are processes of deliberation to identify solutions that are meaningful to people in the context of their daily lives and to avoid potential maladaptation. {WGII, III} (IPCC, AR5, 2014).

Adaptive capacity

The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences. This glossary entry builds from definitions used in previous IPCC reports and the Millennium Ecosystem Assessment (MEA, 2005). (From IPCC, 1.5º Report).

Anthropogenic removals

[55] For this PhD thesis, various definitions contained in this glossary were taken from the IPCC's Glossary, since they represent comprehensive definitions on matters relating to climate change.

Anthropogenic removals refer to the withdrawal of GHGs from the atmosphere as a result of deliberate human activities. These include enhancing natural sinks of CO2 and using chemical engineering to achieve long-term removal and storage. Carbon capture and storage (CCS) from industrial and energy-related sources, which alone does not remove CO2 in the atmosphere, can reduce atmospheric CO2 if it is combined with bioenergy production (BECCS). (IPCC, 1.5º C Report)

Anticipatory governance

A broad-based capacity extended through a society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible'. It motivates activities designed to build capacities in foresight, engagement, and integration – as well as through their production ensemble. These capacities encourage and support the reflection of scientists, engineers, policymakers, and other publics on their roles in new technologies. (David Guston 2014).

––Related to Anticipatory Governance: Foresight. A methodologically pluralist approach to plausible futures with an emphasis on such methods as scenario development that provide a more diverse and normative vision compared with other methods that seek to identify a single, most likely future. (Barben et al. 2008).

––Related to Anticipatory Governance: This concept of governance attends broader STS concerns that have emphasized the contextual nature of knowledge, democracy, the interactive nature of policymaking, and, perhaps most importantly, the centrality of 'uncertainty, doubt and indeterminacy' to such processes. That is, this approach recognizes that governance does not consist simply of government or the activities of public sector organizations, but instead also includes governing activities that are more broadly distributed across numerous actors. (David Guston 2014).

Average Degree (SNA).

From Tasleem A (2015) The mathematics of Social Network Analysis, *International Journal of Computer Applications Technology and Research*, 4(12), 889-893. Also see https://docs.kumu.io/guides/metrics.html

The number of vertices adjacent to a vertex v is called as the degree of v or deg (v). This measurement can get maximum, minimum and average degree. The average degree of a graph is a network level measure and it is calculated from the value of degree or all the nodes in the network. For a graph G with V vertices and E edges the average degree of G can be expressed in the equation:

$$D_A(G) = \frac{2 \text{ x } |E|}{|V|}$$

Betweenness centrality (SNA).

From Tasleem A (2015) The mathematics of Social Network Analysis, *International Journal of Computer Applications Technology and Research*, 4(12), 889-893. Also see https://docs.kumu.io/guides/metrics.html

In order to identify the leaders in a network, the quantity of interest in social network analysis is the betweenness centrality of an actor i. It measures the fraction of the shortest paths through a given node. It quantifies the number of times a node act as a bridge along the shortest path between two other nodes. High degree centrality represents crucial role in the information flow and cohesiveness of the network, thus are considered central to the network due to their role in the flow of information. Consequently, nodes with high betweenness are the gate keepers. The betweenness centrality of vertex v can be expressed using the equation:

$$C_E(v) = \sum_{s \neq v \neq t \in V} \frac{\sigma_{st}(v)}{\sigma_{st}}$$

where σ_{st} is the total number of shortest paths from node s to t and $\sigma_{st}(v)$ is the number of paths that pass through v.

Centrality (SNA).

Centrality is a measure of the information about the relative importance of nodes and edges in a graph. Centrality measures like Degree Centrality, Closeness Centrality, Betweenness Centrality, Eigenvector Centrality, Katz Centrality and Alpha Centrality play an important role in graph theory and network analysis to measure the importance or prestige of actors or nodes in a network. https://docs.kumu.io/guides/metrics.html

Climate change

Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, climate change as: *'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.'* The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes. (From IPCC, 1.5º Report).

Climate governance

Purposeful mechanisms and measures aimed at steering social systems towards preventing, mitigating, or adapting to the risks posed by climate change (Jagers and Stripple, 2003). (IPCC, 1.5ºC Report, 2018)

Climate justice

Justice that links development and human rights to achieve a human- centred approach to addressing climate change, safeguarding the rights of the most vulnerable people and sharing the burdens of climate change and its impacts equitably and fairly. This definition builds upon the one used by the Mary Robinson Foundation – Climate Justice (MRFCJ, 2018). (From IPCC, 1.5º Report).

Climate model

A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes, and accounting for some of its known properties. The climate system can be represented by models of varying complexity; that is, for any one component or combination of components a spectrum or hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical or biological processes are explicitly represented, or the level at which empirical parametrizations are involved. There is an evolution towards more complex models with interactive chemistry and biology. Climate models are applied as a research tool to study and simulate the climate and for operational purposes, including monthly, seasonal and interannual climate predictions. (From IPCC, 1.5º Report).

Climate projection

A climate projection is the simulated response of the climate system to a scenario of future emission or concentration of greenhouse gases (GHGs) and aerosols, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative forcing scenario used, which is in turn based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realized. (From IPCC, 1.5º Report).

Climate-resilient development pathways

(CRDPs) Trajectories that strengthen sustainable development and efforts to eradicate poverty and reduce inequalities while promoting fair and cross-scalar adaptation to and resilience in a changing climate. They raise the ethics, equity and feasibility aspects of the deep societal transformation needed to drastically reduce emissions to limit global warming (e.g., to 1.5°C) and achieve desirable and liveable futures and well-being for all. (From IPCC, 1.5º Report).

Closeness centrality (SNA).

From Tasleem A (2015) The mathematics of Social Network Analysis, *International Journal of Computer Applications Technology and Research*, 4(12), 889-893. Also see https://docs.kumu.io/guides/metrics.html

Is the degree of direct or indirect nearness between any node and the rest of the nodes in the network is represented by closeness centrality. It is the inverse sum of the shortest (geodesic) distance between a node and the rest of all other nodes in the network. For a graph G with n nodes the closeness centrality of a node v can be expressed using the equation:

$$C_C(V) = \frac{n-1}{\sum_{k=i,}^{n} d(u_i, v)}$$

where $d(u_i, v)$ denotes the geodesic distance between u_i and v.

Clustering coefficient (SNA).

From Tasleem A (2015) The mathematics of Social Network Analysis, *International Journal of Computer Applications Technology and Research*, 4(12), 889-893. Also see https://docs.kumu.io/guides/metrics.html

It represents how well a node's neighbourhood is connected. It measures the ability of a node's neighbour to form a complete graph or clique. The value of the coefficient is directly proportional to the degree of connectedness of the neighbours, the higher the clustering coefficient. It represents Stanley Milgram's theory of six degrees of separation using the average path length metric. A representation is considered small world if the average clustering coefficient is significantly higher than a random graph constructed from the same set of vertices. It can be expressed in the following equation:

$$\bar{C} = \frac{1}{n}\sum_{i=1}^{n} C_i$$

where $C_i = \frac{\lambda_c(v)}{\tau_c(v)}$, $\lambda_G(v)$ is the number of subgrapghs of G having 3 edges and 3 vertices including the vertex v. $\tau_G(v)$ is the number of subgraphs of G having 2 edges and 3 vertices including v such that v is incident on both edges.

Confidence

The robustness of an ending based on the type, amount, quality and consistency of evidence (e.g., mechanistic understanding, theory, data, models, expert judgment) and on the degree of agreement across multiple lines of evidence. In this report, confidence is expressed qualitatively (Mastrandrea et al., 2010).

Degree Centrality (SNA).

From Tasleem A (2015) The mathematics of Social Network Analysis, *International Journal of Computer Applications Technology and Research*, 4(12), 889-893. Also see https://docs.kumu.io/guides/metrics.html

It is the simplest of all the centrality measures and its value for a given node in the network is the number of links incident on it and is used to identify nodes that have highest number of connections in the network. However, it does not consider the centrality or prestige of the incident nodes. For a graph $G = (V, E)$, the degree of a node or vertex v, $(v \in V)$ can be expressed using the equation $C_D(v) = deg(v)$, where deg(v) is the number of edges incident on the vertex v. For entire graph G the degree centrality can be expressed using equation:

$$C_D(G) = \sum_{i=1}^{|V|} \frac{[C_D(v*) - C_D(v_i)]}{H}$$

Where $v*$ is the node in G with highest degree centrality and $H = \sum_{j=1}^{|Y|} C_D(y*) - C_D(y_j)$, where $y*$ be the node with the highest degree centrality in a graph X of G with Y nodes. The value of H when a graph has a star like structure.

Eigenvector Centrality

Is a more sophisticated version of degree centrality. It not only depends on the number of incident links but also the quality of those links. Meaning that having connections with high prestige nodes contributes to the centrality value of the node in question:

Let $A = (a_{v,u})$ be the adjacency matric of a graph G with V vertices and E edges. Then A can be defined as

$$A_{v,u} = \begin{cases} a_{v,u} = 1, \text{if vertex v is linked to vertex u} \\ a_{v,u} = 0, \text{otherwise} \end{cases}$$

The eigenvector centrality of a vertex v can be defined using equation

$$C_E(v) = \frac{1}{\lambda}\sum_{u \in N(v)} x_u = \frac{1}{\lambda}\sum_{u \in G} a_{v,u}\, x_u$$

When N(v) represents the set of neighbours of the vertex v and λ is constant.

Deliberative governance

Deliberative governance involves decision-making through inclusive public conversation, which allows opportunity for developing policy options through public discussion rather than collating individual preferences through voting or referenda (although the latter governance mechanisms can also be proceeded and legitimated by public deliberation processes). (From IPCC, 1.5º Report).

Development pathways

Development pathways are trajectories based on an array of social, economic, cultural, technological, institutional and biophysical features that characterise the interactions between human and natural systems and outline visions for the future, at a particular scale. (From IPCC, 1.5º Report).

Downscaling

Downscaling is a method that derives local- to regional-scale (up to 100 km) information from larger-scale models or data analyses. Two main methods exist: dynamical downscaling and empirical/statistical downscaling. The dynamical method uses the output of regional climate models, global models with variable spatial resolution, or high-resolution global models. The empirical/statistical methods are based on observations and develop statistical relationships that link the large-scale atmospheric variables with local/regional climate variables. In all cases, the quality of the driving model remains an important limitation on quality of the downscaled information. The two methods can be combined, e.g., applying empirical/statistical downscaling to the output of a regional climate model, consisting of a dynamical downscaling of a global climate model. (From IPCC, 1.5º Report).

Early warning systems

(EWS) The set of technical, financial and institutional capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss. Dependent upon context, EWS may draw upon scientific and/or Indigenous knowledge. EWS are also considered for ecological applications e.g., conservation, where the organization itself is not threatened by hazard but the ecosystem under conservation is (an example is coral bleaching alerts), in agriculture (for example, warnings of ground frost, hailstorms) and in fisheries (storm and tsunami warnings). This glossary entry builds from the definitions used in UNISDR (2009) and IPCC (2012). (From IPCC, 1.5º Report).

Geoengineering

In this report, separate consideration is given to the two main approaches considered as 'geoengineering' in some of the literature: solar radiation modification (SRM) and carbon dioxide removal (CDR). (From IPCC, 1.5º Report).

Global warming

The estimated increase in global mean surface temperature (GMST) averaged over a 30-year period, or the 30-year period centred on a particular year or decade, expressed relative to pre-industrial levels unless otherwise specified. For 30-year periods that span past and future years, the current multi-decadal warming trend is assumed to continue. (From IPCC, 1.5º Report).

Governance capacity

The ability of governance institutions, leaders, and non-state and civil society to plan, co-ordinate, fund, implement, evaluate and adjust policies and measures over the short, medium and long term, adjusting for uncertainty, rapid change and wide-ranging impacts and multiple actors and demands. (IPCC, 1.5ºC Report, 2018)

Impacts

(consequences, outcomes) The consequences of realized risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather and climate events), exposure, and vulnerability. Impacts generally refer to effects on lives; livelihoods; health and well-being; ecosystems and species; economic, social and cultural assets; services (including ecosystem services); and infrastructure. Impacts may be referred to as consequences or outcomes, and can be adverse or beneficial. See also Adaptation, Exposure, Hazard, Loss and Damage, and losses and damages, and Vulnerability. (From IPCC, 1.5º Report).

Incremental adaptation

Adaptation that maintains the essence and integrity of a system or process at a given scale. In some cases, incremental adaptation can accrue to result in transformational adaptation (Termeer et al., 2017; Tàbara et al., 2018).

Industrial revolution

A period of rapid industrial growth with far- reaching social and economic consequences, beginning in Britain during the second half of the 18th century and spreading to Europe and later to other countries, including the United States. The invention of the steam engine was an important trigger of this development. The industrial revolution marks the beginning of a strong increase in the use of fossil fuels, initially coal, and hence emission of carbon dioxide (CO_2). (From IPCC AR4, 2014).

Industrialized/developed/developing countries

There is a diversity of approaches for categorizing countries on the basis of their level of development, and for denying terms such as industrialized, developed, or developing. Several categorizations are used in this report. (1) In the United Nations system, there is no established convention for designation of developed and developing countries or areas. (2) The United Nations Statistics Division divides developed and developing regions based on common practice. In addition, specific countries are designated as Least Developed Countries (LDC), landlocked developing countries, small island developing states, and transition economies. Many countries appear in more than one of these categories. (3) The World Bank uses income as the main criterion for classifying countries as low, lower middle, upper middle and high income. (4) The UNDP aggregates indicators for life expectancy, educational attainment, and income into a single composite Human Development Index (HDI) to classify countries as low, medium, high or very high human development. (From IPCC AR4, 2014).

Institution

Institutions are rules and norms held in common by social actors that guide, constrain and shape human interaction. Institutions can be formal, such as laws and policies, or informal, such as norms and conventions. Organizations – such as parliaments, regulatory agencies, private and community bodies – develop and act in response to institutional frameworks and the incentives they frame. Institutions can guide, constrain and shape human interaction through direct control, through incentives, and through processes of socialization. See also Institutional capacity. (From IPCC AR4, 2014).

Institutional capacity

Institutional capacity comprises building and strengthening individual organizations and providing technical and management training to support integrated planning and decision- making processes between organizations and people, as well as empowerment, social capital, and an enabling environment, including the culture, values and power relations (Willems and Baumert, 2003).

Integrated assessment

A method of analysis that combines results and models from the physical, biological, economic and social sciences and the interactions among these components in a consistent framework to evaluate the status and the consequences of environmental change and the policy responses to it. See also Integrated assessment model (IAM).

Kyoto Protocol

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty adopted in December 1997 in Kyoto, Japan, at the Third Session of the Conference of the Parties (COP3) to the UNFCCC. It contains legally binding commitments, in addition to those included in the UNFCCC. Countries included in Annex B of the Protocol (mostly OECD countries and countries with economies in transition) agreed to reduce their anthropogenic greenhouse gas (GHG) emissions (carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6)) by at least 5% below 1990 levels in the first commitment period (2008–2012). The Kyoto Protocol entered into force on 16 February 2005 and as of May 2018 had 192 Parties (191 States and the European Union). A second commitment period was agreed in December 2012 at COP18, known as the Doha Amendment to the Kyoto Protocol, in which a new set of Parties committed to reduce GHG emissions by at least 18% below 1990 levels in the period from 2013 to 2020. However, as of May 2018, the Doha Amendment had not received sufficient ratifications to enter into force. See also United Nations Framework Convention on Climate Change (UNFCCC) and Paris Agreement. (From IPCC, 1.5º Report).

Multilevel governance

Multilevel governance refers to negotiated, non-hierarchical exchanges between institutions at the transnational, national, regional and local levels. Multilevel governance identifies relationships among governance processes at these different levels. Multilevel governance does include negotiated relationships among institutions at different institutional levels and also a vertical 'layering' of governance processes at different levels. Institutional relationships take place directly between transnational, regional and local levels, thus bypassing the state level (Peters and Pierre, 2001)

Nationally Determined Contributions

(NDCs) A term used under the United Nations Framework Convention on Climate Change (UNFCCC) whereby a country that has joined the Paris Agreement outlines its plans for reducing its emissions. Some countries' NDCs also address how they will adapt to climate change impacts, and what support they need from, or will provide to, other countries to adopt low-carbon pathways and to build climate resilience. According to Article 4 paragraph 2 of the Paris Agreement, each Party shall prepare, communicate and maintain successive NDCs that it intends to achieve. In the lead up to 21st Conference of the Parties in Paris in 2015, countries submitted Intended Nationally Determined Contributions (INDCs). As countries join the Paris Agreement, unless they decide otherwise, this INDC becomes their first Nationally Determined Contribution (NDC). (From IPCC AR4, 2014).

Paris Agreement

The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) was adopted on December 2015 in Paris, France, at the 21st session of the Conference of the Parties (COP) to the UNFCCC. The agreement, adopted by 196 Parties to the UNFCCC, entered into force on 4 November 2016 and as of May 2018 had 195 Signatories and was ratified by 177 Parties. One of the goals of the Paris Agreement is 'Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels', recognising that this would significantly reduce the risks and impacts of climate change. Additionally, the Agreement aims to strengthen the ability of countries to deal with the impacts AI of climate change. The Paris Agreement is intended to become fully effective in 2020. See also United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol and Nationally Determined Contributions (NDCs). https://cop23.unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

Participatory governance

A governance system that enables direct public engagement in decision- making using a variety of techniques for example, referenda, community deliberation, citizen juries or participatory budgeting. The approach can be applied in formal and informal institutional contexts from national to local but is usually associated with devolved decision-making. This definition builds from Fung and Wright (2003) and Sarmiento and Tilly (2018). (IPCC, 1.5ºC Report, 2018)

Pathways

The temporal evolution of natural and/or human systems towards a future state. Pathway concepts range from sets of quantitative and qualitative scenarios or narratives of potential futures to solution- oriented decision-making processes to achieve desirable societal goals. Pathway approaches typically focus on biophysical, techno-economic, and/or socio-behavioural trajectories and involve various dynamics, goals and actors across different scales. (From IPCC AR4, 2014).

Risk

The potential for adverse consequences where something of value is at stake and where the occurrence and degree of an outcome is uncertain. In the context of the assessment of climate impacts, the term risk is often used to refer to the potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Risk results from the interaction of vulnerability (of the affected system), its exposure over time (to the hazard), as well as the (climate-related) hazard and the likelihood of its occurrence. (From IPCC AR4, 2014).

Scenario

A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of technological change, prices) and relationships. Note that scenarios are neither predictions nor forecasts, but are used to provide a view of the implications of developments and actions. See also Baseline scenario, Emission scenario, Mitigation scenario and Pathways. Scenario storyline A narrative description of a scenario (or family of scenarios), highlighting the main scenario characteristics, relationships between key driving forces and the dynamics of their evolution. Also referred to as 'narratives' in the scenario literature. See also Narratives. (From IPCC AR4, 2014).

Small island developing states (SIDS)

Small island developing states (SIDS), as recognised by the United Nations OHRLLS (Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States), are a distinct group of developing countries facing specific social, economic and environmental vulnerabilities (UN-OHRLLS, 2011). They were recognized as a special case both for their environment and development at the Rio Earth Summit in Brazil in 1992. Fifty-eight countries and territories are presently classified as SIDS by the UN OHRLLS, with 38 being UN member states and 20 being Non-UN Members or Associate Members of the Regional Commissions (UN-OHRLLS, 2018).

Social Network Analysis (SNA).

The focus of Social Network Analysis (SNA) is relationships, their patterns, implications, etc. Using it, one can study these patterns in a structural manner SNA can be used to identify important social actors, central nodes, highly or sparsely connected communities and interactions among actors and communities in the underlying network. The study of social networks for behaviour analysis of actors involves two aspects: (a) the use of formal theory organized on the basis of mathematical conventions and (b) the empirical analysis of network data as quantified by various social network analysis metrics. There are five different levels of social network analysis, each of them characterised by the structure of the underlying network. It may be at actor level, dyadic level, triadic level, subset level, or network level. Chelmis and Prasanna [10] proposed several social network analysis measures (metrics) that can be used to identify influential nodes in a social network https://docs.kumu.io/guides/metrics.html / https://en.wikipedia.org/wiki/Social_network_analysis

Social-ecological systems

An integrated system that includes human societies and ecosystems, in which humans are part of nature. The functions of such a system arise from the interactions and interdependence of the social and ecological subsystems. The system's structure is characterized by reciprocal feedbacks, emphasising that humans must be seen as a part of, not apart from, nature. Berkes and Folke (1998).

Solar radiation modification

(SRM) Solar radiation modification refers to the intentional modification of the Earth's shortwave radiative budget with the aim of reducing warming. Artificial injection of stratospheric aerosols, marine cloud brightening and land surface albedo modification are examples of proposed SRM methods. SRM does not fall within the definitions of mitigation and adaptation (IPCC, 2012, p. 2). (From IPCC AR4, 2014).

Sustainable development

(SD) Development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987) and balances social, economic and environmental concerns. See also Sustainable Development Goals (SDGs) and Development pathways (under Pathways). (From IPCC, 1.5º Report).

Transformation pathways

Trajectories describing consistent sets of possible futures of greenhouse gas (GHG) emissions, atmospheric concentrations, or global mean surface temperatures implied from mitigation and adaptation actions associated with a set of broad and irreversible economic, technological, societal and behavioural changes. This can encompass changes in the way energy and infrastructure are used and produced, natural resources are managed and institutions are set up and, in the pace, and direction of technological change. (From IPCC, 1.5º Report).

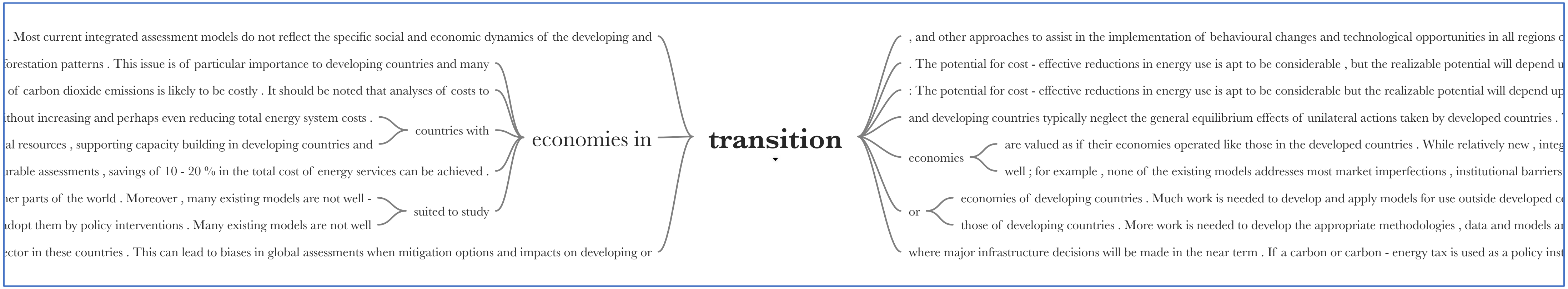
United Nations Framework Convention on Climate Change (UNFCCC)

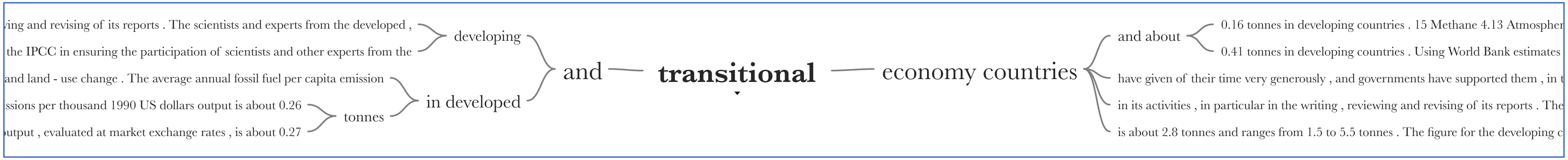
The UNFCCC was adopted in May 1992 and opened for signature at the 1992 Earth Summit in Rio de Janeiro. It entered into force in March 1994 and as of May 2018 had 197 Parties (196 States and the European Union). The Convention's ultimate objective is the 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.' The provisions of the Convention are pursued and implemented by two treaties: the Kyoto Protocol and the Paris Agreement. See also Kyoto Protocol and Paris Agreement. https://unfccc.int/process-and-meetings/the-convention/what-is-the-united-nations-framework-convention-on-climate-change

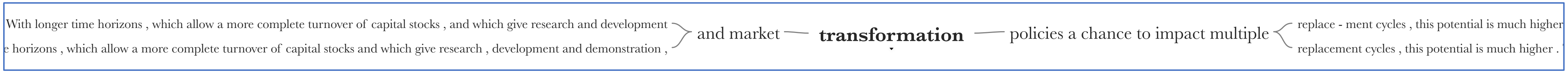
Annexes

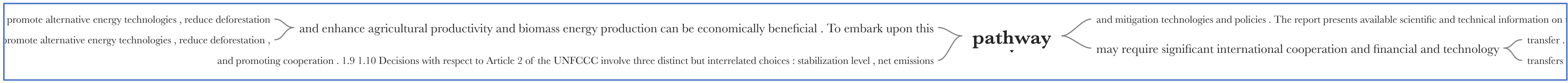
The following section contains material concerning Coded Data and Word Tree Analysis of IPCC reports in NVivo.

AR2 - NVivo 2020









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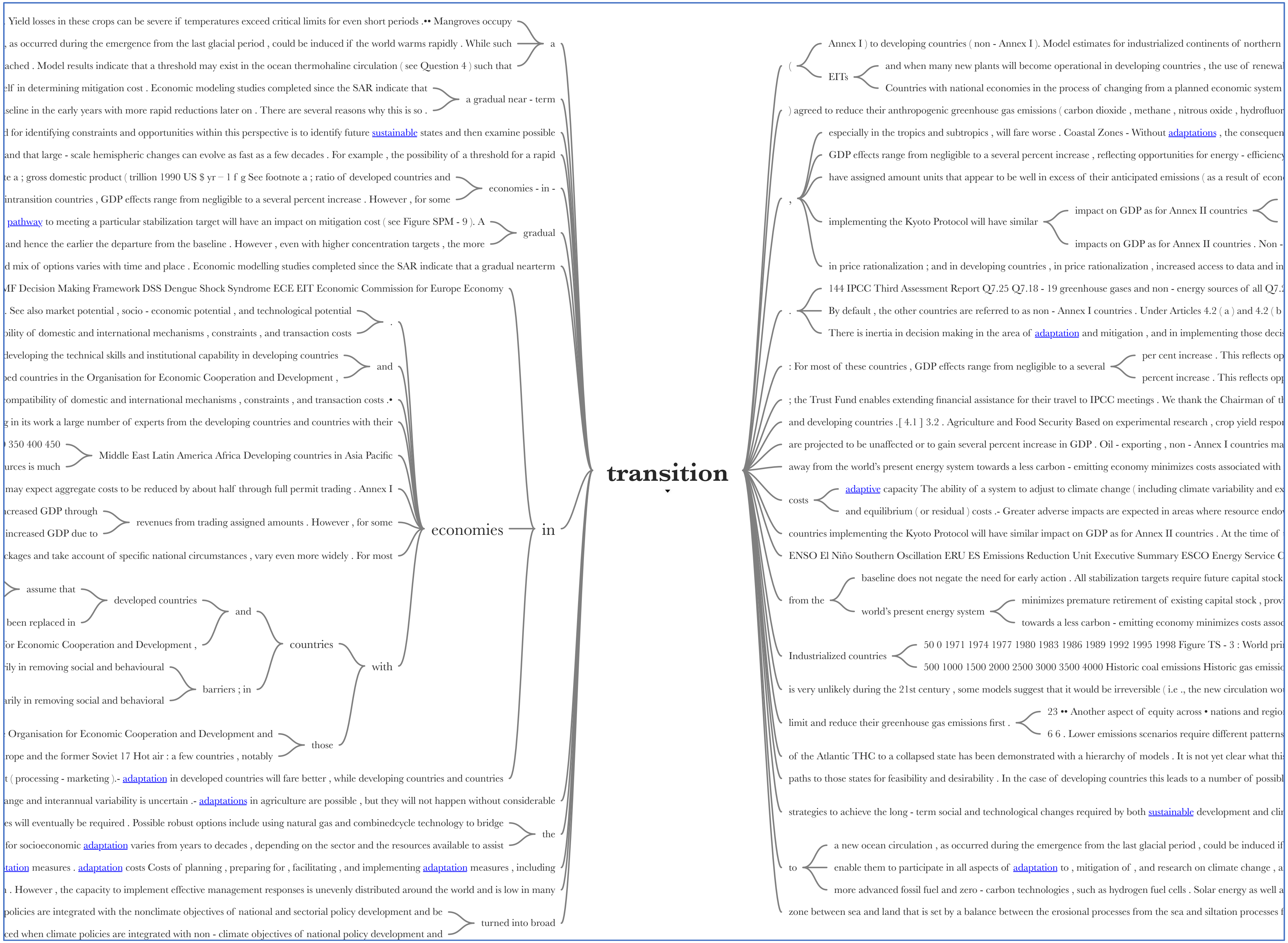
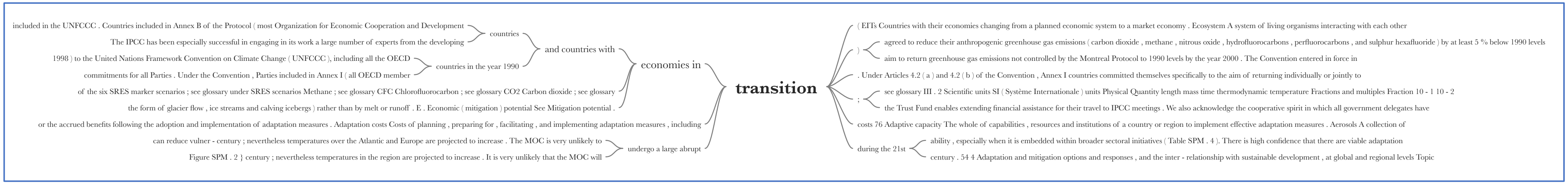
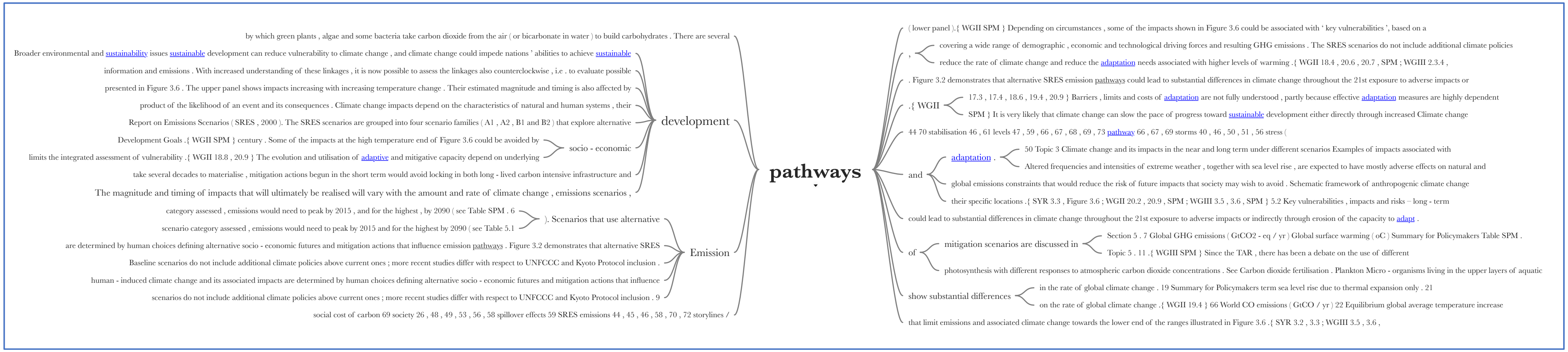


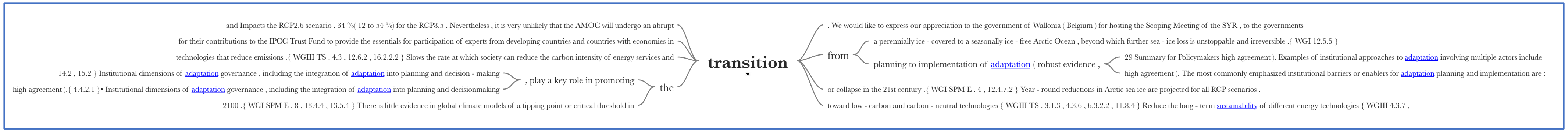
AR3 - NVivo 2020

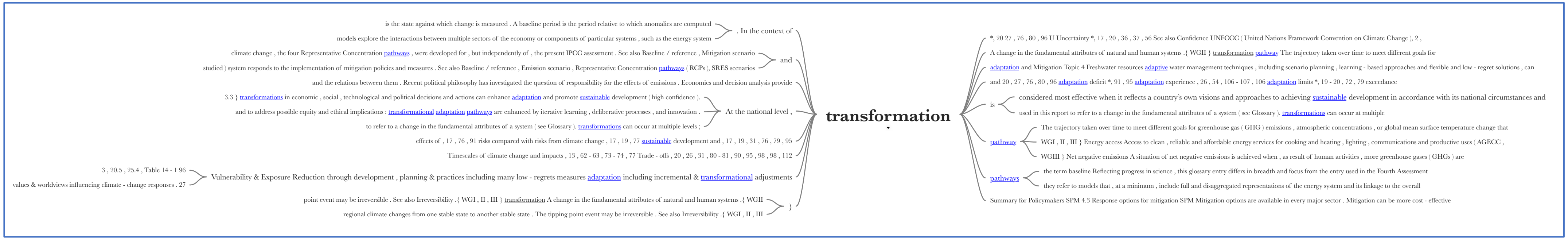
AR4 - NVivo 2020

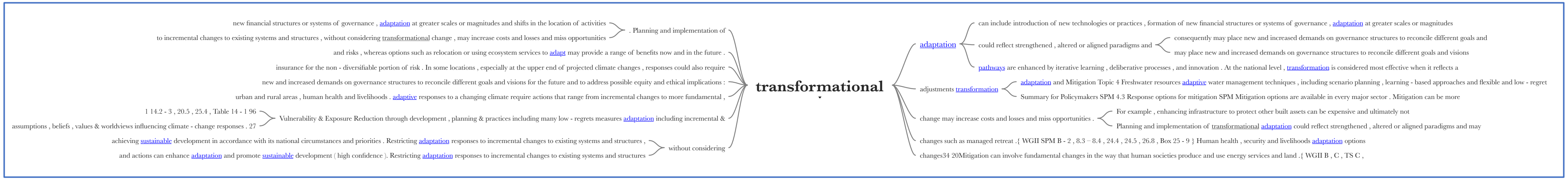




AR5 - NVivo 2020

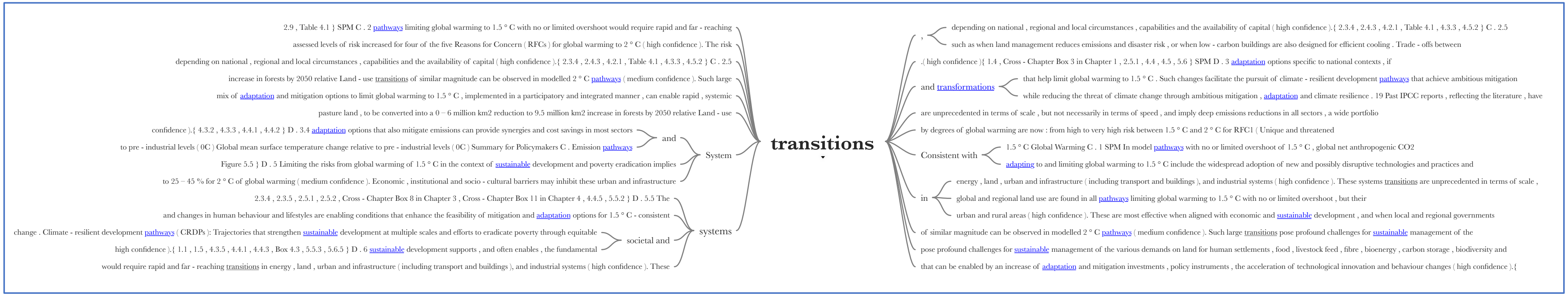


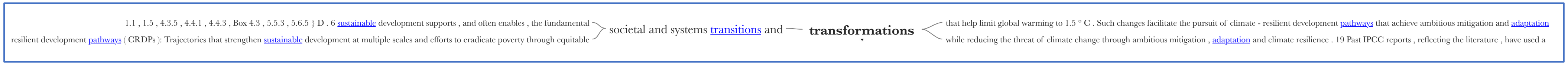




R5 - NVivo 2020

SR15 (1.5ºC) - NVivo 2020





R5 - NVivo 2020