An Exploratory Research on the Impact of IoT and 5G Technology in the Climate Policymaking Process

Raúl Emilio Fretes Diaz Romero

Master's in International Studies.

Supervisor:
Professor Eng. Pedro Joaquim Amaro Sebastião, Assistant Professor
ISCTE-Instituto Universitário de Lisboa

November 2020

SOCIOLOGIA
E POLÍTICAS PÚBLICAS

An Exploratory Research on the Impact of IoT and 5G Technology in the Climate Policymaking Process

Raúl Emilio Fretes Diaz Romero

Master's in International Studies.

Supervisor:
Professor Eng. Pedro Joaquim Amaro Sebastião, Assistant Professor
ISCTE-Instituto Universitário de Lisboa

November 2020

Acknowledgments

I would like to express my recognition and gratitude to all the people who contributed and helped me with the following work. First and foremost, I would like to thank my supervisor, Pedro Sebastião, for his assistance, involvement, support, and encouragement to develop this dissertation.

I would also like to show my appreciation to all the professors I had the chance to study in my academic journey, shedding light on the world's problems.

Furthermore, working on this thesis on climate change was more than just an academic work but a *wake-up call* for action, transmitted from the manifestation of unrest of the youth and climate advocates worldwide that highlighted and projected this wicked problem. I thank you for being a source of inspiration for this sustainable transformation challenge.

Finally, and most importantly, I would like to thank my family for the tremendous support they have shown me, as they never stopped encouraging me. My gratitude and love to my mother and father, who I deeply miss, and my brother for their endless support and love.

Abstract: *For decades, climate change and climate-related issues have exponentially increased, causing a global multi-sectoral and multi-stakeholder negative impact. In response to this global issue, policymakers and decision-makers have begun to scheme climate policies and responses to avoid further harm. However, the policy process and its currents policy infrastructure, instruments, and tools seem to not be up to the task to tackle a complex and irreversible systemic problem engulfed in uncertainties that expands on a broad temporal and spatial scale. The climate policy cycle is a challenging task requiring enormous data, planning, Evaluation, and monitoring. However, these procedures are often ignored due to their complexity, the lack of climate information, and climate portfolios available to the different stakeholders. In this exploratory research, we delve and explore the challenges and difficulties of the climate policymaking process and how can the research and development of Information and Communication Technologies (ICTs) that enable the collection of real-time climate data, specifically the Internet of Things (IoT) and 5th Generation of Mobile Communication Systems (5G), can become a potential climate policymaking instrument and tool.*

Keywords: Climate Change, Policymaking Cycle, Internet of Things, 5G Network, Climate Monitoring Systems; Innovation

JEL Codes: O21, O31, O38, O39, Y4, Z18.

Resumo: *Durante décadas, as mudanças climáticas e as questões relacionadas ao clima aumentaram exponencialmente, causando um impacto negativo global multissetorial e de múltiplas partes interessadas. Em resposta a esta questão global, os formuladores de políticas e tomadores de decisão começaram a traçar políticas e respostas climáticas para evitar mais danos. No entanto, o processo político e sua atual infraestrutura, instrumentos e ferramentas parecem não estar à altura da tarefa de lidar com um problema sistêmico complexo e irreversível envolto em incertezas que se expande em uma ampla escala temporal e espacial. O ciclo da política climática é uma tarefa desafiadora que exige enormes dados, planejamento, avaliação e monitoramento. No entanto, esses procedimentos são muitas vezes ignorados devido à sua complexidade, à falta de informações sobre o clima e aos portfólios climáticos disponíveis para as diferentes partes interessadas. Nesta pesquisa exploratória, nós aprofundamos e exploramos os desafios e dificuldades do processo de formulação de políticas climáticas e como a pesquisa e o desenvolvimento de Tecnologias de Informação e Comunicação (TICs) que permitem a coleta de dados climáticos em tempo real, especificamente a Internet das Coisas (IoT) e 5ª Geração de Sistemas de Comunicação Móvel (5G), pode se tornar um instrumento e ferramenta potencial de formulação de políticas climáticas.*

Palavras-chave: Alterações Climáticas; Ciclo de Políticas Publicas; Internet das Coisas, Sistemas de Comunicações Móveis de 5G; Sistema de Monitorização Climática; Inovação

Classificação JEL: O21, O31, O38, O39, Y4, Z18

INDEX

TABLE INDEX

Chapter 1. Introduction

Estimations indicate that climate change will have a direct socio-economic impact on our society, that will not only afflict agriculture and food productions, our health[1]but also cause the displacement of individuals around the globe due to the increase and intensification of weather and climate disasters (WMO, 2019) with long-lasting consequences (e.g., coral bleaching; acidification of the oceans; glacial retreat; melting of the arctic ice sheets; rise of sea levels; flood and wildfire) that will continue throughout centuries (OECD, 2007; USGCRP, 2017; WMO, 2019). These estimates result from more than a century of accumulative scientific knowledge[2] that manages to perceive the possible effects that climate change might represent to our world (History, 2017). However, the subject only gained international recognition ever since the foundation of the Intergovernmental Panel on Climate Change (IPCC) by the World Meteorological Organization (WMO) and the United Nations Environmental Program (UNEP) in 1988[3] as a result of a series of international agreements that have flourished with the sole objective to tackle, manage and prevent different forage of global climate change (History, 2017). Despite the real concerns and numerous climate agreements, international organisms and policymakers/decision-makers continue to struggle to develop climate policies that appropriately tackle climate change. If left unchecked, scientist predicts that we will surpass a point of no return, destroying Earth's current ecosystem and dooming our future generations in the process.

With a short window to act, we can, sadly, state a transition from the territory of climate change to one of the global climate crises. For no government nor international organism has managed to develop a reliable climate agreement nor climate policies based upon scientific pieces of evidence that scientists had provided over the decades. At the same time, climate change is still regarded as a "relatively invisible" nor absolute for the typical individual[4] due to their short-term perspectives (Levin, K. Cashore, B. Berstein, S. & Auld, G. 2012).

---

[1] For more information read Joy Shumake-Guillemot, Virgina Murray and Sari Kovat's "*Impacts of Heat on Health"*.

[2] Scientist like Joseph Fourier and John Tyndale already propose relative theories regarding the atmospheric and climate concerns that dates to 1827 and 1859, respectively, in France and Britain (History, 2017). However, in 1896 Swedish scientist Svante Arrhenius will be the first to estimate a possible correlation of warming from the widespread coal burning. Sixty years later in 1956 in an article from the New York Times. Dr. Gilbert Pass conveyed how accumulated greenhouse gas emissions from fossil fuel would lead to long-lasting environmental changes (Revkin, A.C 2010, January 4).

[3] In the same year, NASA scientist James Hanses, for the first time in history, testifies to the U.S. Senate that "*Global Warming Has Begun"*.

[4] *"(…) this phenomenon means individuals are less short-sighted about future trade-offs (…)"* (Levin K. Cashore, B. Berstein, S. & Auld, G. 2012, p.128). Which has frustrated so many climate policies advocated into develop climate change policy (Levin, K. Cashore, B. Berstein, S. & Auld, G. 2012).

The development of technologies has continuously proven itself the leading cause of human civilization to thrive and survive. Even now, the progress of technological innovation is perceived as a way to fully address climate change (OECD 2011; Earth Institute at Columbia University, 2017; UN, 2018) and even lowering the cost of achieving said objectives (Hascic, I. et.la. 2010). Where Information and Communication Technologies (ICTs) on climate change reports filling the informational needs of policymakers/decisionmakers to unfold "*key feature*" for the development of policies could address these (Sala, S. 2009; Earth Institute at Columbia University, 2017; UN, 2018). Regardless, few studies that specifically tackle technological innovation and climate policy development exist. Thus, we argue that it remains a challenge for policymakers/decisionmakers to effectively gather and analyze desirable information on the matter to initiate properly, conduct, and conclude the policy process *(*Dessai, S. & Sluijs, J. 2007; Levin, K. Cashore, B. Berstein, S. & Auld, G. 2012; Studinka, J. & Guenduez, A.A. 2018; Doukas, H. & Nikas, A. 2019). We argue that the current climate policymaking process is lacking due to the reasoning that climate issues possess the characteristics of a "*Super Wicked Problem*[5]*" (*Levin, K. Cashore, B. Berstein, S. & Auld, G. 2012) and, simultaneously, a "short-term ticking time bomb" that must be primarily properly addressed to achieve the desire climate goals (Studinka, J. & Guenduez, A.A. 2018). As a result, we are in desperate need of technological tools that can manage to uncover, inform and report, in the foreseeable future, crucial features and information for policymakers/decision-makers to monitor, evaluate, haste, and improve the climate policymaking process (Scheraga, J.D. Elbi, K.L. Furlow, J. & Moreno, A.R. 1996; Sala, S. 2009; World Resource Institute, 2010: Levin, K. Cashore, B. Berstein, S. & Auld, G. 2012) that can translate to our current climate needs (World Resource Institute, 2010; Makarau, A. 2010-2011; Govender, S. 2010-2011; Zambrano-Barragan, C. 2010-2011).

1.1.Research Objectives

Addressing the under-study subject of climate policymaking and policy instruments with the potential of a platform powered by an Internet of Things (IoT) system enhanced with the upcoming 5th Generation of Wireless Communication System (5G) could hypothetically fill this gap, formulating the following research question: *"How can the development of an IoT-5G Climate Monitoring Intelligent System impact the climate policymaking process?*

The research question is addressed through exploratory research compressed of a literature review of various scientific articles on the potential technological advances of IoT, the upcoming 5th Generation

[5] Kevit etl.la. utilize Rittel and Webber's concept of wicked problems as "p*roblems that lack simplistic or stringboard planning responses*" for this theory (Levin, K. Cashore, B. Berstein, S. & Auld, G. 2012).

Wireless Communication System, articles regarding the subject of the policy process and climate policymaking process, and the application of a survey research method via questionnaires that will be applied to decisionmakers/policymakers, and IoT & 5G technicians, engineers and or specialist followed by a semi-structured interview to meet the following research objectives:

- Identify the difficulties and characteristics of the climate policy process;
- Identify the key features of IoT;
- Identify the key features of 5G Wireless Communication system for IoT;
- Identify the utility and impacts of a 5G Enhanced IoT system services as a climate policy instrument.

1.2. Main Contributions

During this study's assessment and development, opportunities to test this idea's viability have risen in forms of interaction with high-level governmental institutions, grant proposals, essay and research contests, and start-up idea proposal competitions. Thus far, this proposal has managed to achieve the following:

- Awarded as the National Portuguese winner of the CAF Contest: Ideas para el Futuro 2020;
- Participating in the Inter-Regional Level of the CAF Contest: Ideas para el Futuro 2020;
- Awarded a research internship grant with the FCT – "Curso de Verao com Ciencia" program: "From Science to Market";
- Participating in UNFCC TEP-A: Adaptation Youth Policy Case Competition on Climate Change;
- Participating in the Altice International Innovation Award 2020;

Chapter 2. Literature Review

2.1. Climate Change

Throughout Earth's history, climate changes have occurred naturally (e.g., variability in Earth's orbit, variability in the solar output, tectonic activity, volcanic activity, natural greenhouse emission, and feedback) unnaturally[6]. Climate changes have and can still be disruptive to Earth's ecosystem, which, ultimately, has "(…) *led to the extinction of many species, population migrations, and pronounced changes in the land surface and ocean circulation* (…)" (The Royal Society, 2020 p.9). However, our current climate situation is unlike any past climate event since both the Earth's natural cycle and our society cannot adapt. Uniquely due to the pace at which it is developing. Therefore, climate change can be easily distinguished

[6] According to scientist, first animals breathed up the oxygen in the water and poison their own environment with carbon dioxide causing climate alternations which caused mass extinctions (Schuster, R. 2018)

as the most illustrious problem and the topic of our time (NASA, n.d; UNFFC, 1992; Le Treut, H., R. Somerville, U. Cubasch, Y. Ding, C. Mauritzen, A. Mokssit, T. Peterson and M. Prather, 2007; Jackson S.T. 2018; The Royal Society, 2020).

According to Muhammad Ishaq-Ur Rahman, climate change discourse began almost solely within the scientific community out of curiosity. Through its discoveries, it initiated the social studies and impact studies of climate change in the 1970s[7]. Spiraling towards an eco-centric paradigm that, ultimately, has gone beyond that towards an anthropocentric paradigm (see Figure A1.1) that requires assessment (Rahman, M.I. 2012). Within the climate discourse, the most useful definition comes from the international agreement of countries of the United Nations Framework Convention on Climate Change (UNFCC) in 1992, which defines climate change as the "*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 periods*" (UNFCC, 1992, p.7). The Intergovernmental Panel on Climate Change (IPCC), an intergovernmental body of the United Nations (UN), classify climate change as a threat that has been mostly influenced by human activity (IPCC, 2014; IPCC, 2019). Stating that climate change is the alteration of the atmospheric composition due to the combination of natural variability and human activity since the UNFCC definition "*makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes*" (IPCC 2019, p.120). NASA provides a more general definition scientific-oriented definitions on climate change as the long-term change in the average weather patterns that come to define Earth's local, regional and global it further states that the current climate change has started "*since 20th century,(...) primarily driven by human activities, particularly fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere (...)"* (NASA, n.d.). Lastly, it is essential to highlight authors like Mike Hulme, who perceives climate change differently and realizes historical, cultural, and scientific research and analysis on past, present, and future of climate studies (traced back to Greek civilization[8], the scientific discoveries of climate change, and the future of climate change) and has determined that it is a historical emergent phenomenon of the evolution of the physical transformation of the climate system into a cultural symbol that can be expressed through curricular, personal identity, religious practice, education, politics, and arts. Therefore, he sees climate change as a "*new condition through human life now takes shape*" (Hulme, M. 2017. p.6).

[7] In 1979, the first World Climate Conference (WCC) was held were it was proposed to "keep an eye to the climate", where the first definition on human induced climate change was introduced (The New York Times, 1979).

[8] "*For example, in the third century BCE, Aristotle's student Theophrastus observed and documented local changes in climate induced by human agency: the clearing of forests around Philippi in Greece warmed the climate, while the draining of marshes cooled the climate around Thessaly*" (Hume, M. 2017. p.1).

Despite no clear contemporary definition among scholars and institutions, there is an explicit homogenous agreement on the reality and dangers of anthropogenic climate change produced by the accumulation of human-induced Greenhouse gases (e.g., Carbon Dioxide, Methane). Therefore, this dissertation's development must *differentiate the natural climate cycle from climate change reality.*

We can define climate change as the changes of climatic patterns attributed to the accumulations of internal (natural) and external (organisms) influences that transform the global atmosphere composition, which ultimately has long-term repercussions on Earth's natural climate ecosystem cycles. Meanwhile, the current climate change scenario or "anthropogenic climate change" can be defined as changes in climatic patterns attributed to the accumulation of natural and anthropogenic activities that transform the global atmospheric composition, which ultimately has both a long-term repercussion on Earth's natural climate and ecosystem as well as in the foreseeable development of our socio-economic and cultural system.

As the deadline to adequately act upon climate change lingers ever so close, it has undoubtedly become the most complex challenge for humankind, as the consequences of failing to address it are irreversible and almost everlasting (OECD, 2007; USGCRP, 2017; WMO, 2019; Ripple, J.W. et.la 2019**)**. Reaching to a degree of urgency that, for the first time in The World Economic Forum history, climate-related issues has been ranked as the most prominent global risk (Global Risk Report, 2020), proving unequivocally that our society and planet are facing a global crisis of the unparalleled magnitude that we can argue that humanity has entered a new era:

> "*Many observers have said that is an unprecedented era in the world history: "Earth has entered a new epoch, one that is likely to continue in unpredictable and dangerous ways" (Angus. 2016, p.29) because human activities have become so large and pervasive as to become a kind of natural force. Indeed, "the Earth system as a whole [is] being qualitatively transformed by human actions (Angus, p.33). Thus, for decades (…), the level of human impact on the ecosystem has now become so great that civilization has entered a new world era, the Anthropocene*" (Barkdull, J. 2017, p.6).

It is imperative to develop multi-sectoral climate policies that involve governments, institutions, businesses, and individuals. However, the development of such is hard to denote due to the nature of climate change. Therefore "*policymakers and the public now urgently need access to a set of indicators that convey the effects of human activities on* [e.g.] *GHG emissions and the consequent impacts of climate, our environment and society*" (Ripple, J.W. et.la 2019 p. 1), "*(…) the adoption of new policy analysis techniques (…)"* (Levin, K. Cashore, B. Berstein, S. & Auld, G. 2012, p.129), and the technology, tools, instruments, and infrastructure to do so (Govender, S. 2010-2011; Zambrano-Barragan, C. 2010-2011).

2.2. Policymaking Process

Addressing multiple societal challenges (e.g., poverty, health economy, climate change, taxation), decision-makers require the best available information, tools, methods, and techniques to form appropriate responses. Thus, the policymaking process appears as a premeditated principle of guidelines to rationally address these issues (Wellstead, A. & Stedman, R. 2015). Involving a series of policy processes or stages that form an "*infinite cycle of decision and policies,"* where policies and decisions are not independent of previous or future ones. This is the policy cycle **(**Kann, W. & Wegrich, K. 2006).

The policy cycle goes through several stages, from the inception of the societal problem to the policy agenda to the conclusion of the method of implementation, where the impacts are then measured and evaluated based on result and reactions of the impact and outcomes, as well as the unintended consequences that create a feedback loop, hence the endless cycle, allowing for the chronological systematization and comparison of diverse debates, approaches, and methodologies of each individual approach's contribution. This cycle has been simplified into a model that encompasses the Agenda Setting, Policy Formulation, Policy Adoption, Policy Implementation, and Policy Evaluation phases (Knill, C. & Tosun, J. 2006; Kann, W. & Wegrich, K. 2006).

2.2.1. Agenda Setting

Agenda setting allows for decision-makers to recognize and identify policy problems, which require intervention. Once the societal issues are recognizing, it is then put onto the public agenda where political attention is given to all feasible, relevant options.

However, there are many societal challenges, and thus only a few are chosen to be addressed (Knill, C. & Tosun, J.2006), allowing for external and internal actors to influence or shape the agenda (Kann, W. & Wegrich, K. 2006) such as public officers, bursary processes, mass media and groups of interests (Knill, C. & Tosun, J. 2006; Kann, W. & Wegrich, K. 2006).

Kann, W. & Wegrich, K (2006) further recognizes and emphasizes that merely objective problems (e.g., air pollution, water contamination) do not lead to problem recognition, but instead giving it a "*plausible definitions (…) and* [the] *development of a policy image allows to attach a solution to the problem* (…)" (Kann, W. & Wegrich, K. 2006, p.46) making scientific and expertise roles less influential since they are based around the socially constructed needs of reality (Barkembus, J. 1998).

2.2.2. Policy Formulation

After the policy problems, proposals and demands are defined, they are transformed into programs through the definition, discussion of their objectives and their likely scenarios, and their acceptance or rejection of its course (Knill, C. & Tosun, J. 2006; Kann, W. & Wegrich, K. 2006).

The process is constraint by the nature of the problem and the difficulty of adapting it (Knill, C. & Tosun, J. 2006) that can be mitigated with techniques and tools that allow, in pair with intelligent and systematic reasoning, for the identification of efficient and effective solution (Barkembus, J. 1998; Kann, W. & Wegrich, K. 2006). This has been achievable by introducing budgetary defined goals and targets and cost-benefits analysis (Kann, W. & Wegrich, K. 2006).

2.2.3. Policy Adoption

The approval of a policy program is then determined by its feasibility (economic and political resources), the allocation of competences and obligations between actors and sectors, by the relevance of the public and political party's opinion, values, and interests, and by either technocratic, decisionist or pragmatic (scientific) policy approach, been the later the most applied (Knill, C. & Tosun, J. 2006; Kann, W. & Wegrich, K. 2006).

2.2.4. Implementation

A crucial stage of the cycle that specifies the nature of the decides on the policy program's specific course of action through resource allocation and the conversion of new laws, programs, and response. However, it is adoption does not guarantee success in the policy maker's aims and goals since it is not controllable nor predictable and thus, are often changed, distorted, delay, or even blocked (Knill, C. & Tosun, J. 2006; Kann, W. & Wegrich, K. 2006), making it a neglected part of the policy process due to its difficulty (Barkembus, J. 1998).

2.2.5. Evaluation

The end goal of a policy is contributing to problem-solving or its reduction. Consequently, the policy becomes a subject of appraisal carried out by experts with knowledge on the subject that are evaluated via scientific analysis and reports, governmental reports, public debate, and even opposition activities. These elements allow for the Evaluation of the policy's outcome, and it is unintended results against its intended goals that allow decisionmakers to draw a lesson that ultimately leads to either termination or its re-design of the policy (Knill, C. & Tosun, J. 2006; Kann, W. & Wegrich, K. 2006).

Nevertheless, a full evaluation of policies is rare due to the exposure and influence of political interests that hinder its outcome. Either be by biased conclusion according to the position of interest and values of actors (e.g., opposition interpretation of policy evaluation) as well as the strong incentive of governments to avoid the precise definition of goals to avoid the risk policy failures culpability (Kann, W. & Wegrich, K. 2006) and hence establishing a preference to give "(…) *more attention to creating new laws and programs than to evaluate the performance of existing ones*" (Barkembus, J. 1998, p. 8).

2.3. Climate Policymaking Process

The subject of climate change in the field of science has been relatively well developed in both theory and analytical methodology, making it possible to assert what we do know and what we do not know about the potential consequences of its effects (Levin, K. Cashore, B. Berstein, S. & Auld, G. 2012). In the area of social research, the subject of climate change is far less articulate (National Research Council. 2010; Levin, K. Cashore, B. Berstein, S. & Auld, G. 2012; Koteyko, N. Nerlich, B. & Hellsten, I. 2015).

According to Sybillevan den Hove (2000), there are four major characteristics to climate change: i) Complexity, where the function of the ecosphere obeys a non-linear dynamic that is intrinsically complex that are inter-connected among even more complex environmental phenomenon's; ii) The uncertainty of it, that is divided into two types, ii.a.) Uncertainty rooted in imperfect scientific knowledge that could be partially reduced through the development research and, ii.b) Intrinsic uncertainty, irreducible complexity that will always exist, and that requires data enable adaptation; iii) The Large Temporal and Spatial Scales that boards; and iv) It is Irreversible nature, where the ecosystem and some life-supporting functions may not be able to be restored once critical levels are reached (Hove, S. 2000).

Suraje Dessai and Jeroen van der Sluijs (2007) divides the field of climate policymaking into three schools of thought on how to approach these characteristics through a: i) Prediction oriented school, where uncertainty requires to be characterized, reduce, managed, and communicate to improve and develop modeling tools and techniques that could describe the climate and its impacts; ii) Resilience oriented school, where certain uncertainties are deemed irreducible. Therefore, it is oriented to increase the learning capability to obtain stability and be prepared for the unexpected; iii) Mixed-oriented school (Dessai, S. & Sluijs, J. 2007).

Despite having these climate policy models, policymaking decisions seemed to be following a predictable pattern, opting to analyze the cost-benefit examinations and explain these sets of objectives through policy feedback instead of a more comprehensive contextual approach (Barkdull, J. 2017). This process, due to its high level of uncertainty, complicates climate-related assessment and future policymaking process (Scheraga, J.D. Elbi, K.L. Furlow, J. & Moreno, A.R. 1996; OECD, 2007 Hascic, I, et al. 2010; Studinka, J. & Guenduez, A.A. 2018**;** Roelich K. & Giesekam, J. 2019).

Haris Doukas & Alexadros Nikas' report (2019) highlights this issue, explaining that climate policy strategies bases on the Evaluation of climate-economic models are not sufficient to adequately address this matters since it mostly based on an indirectly representation and calculation of the economic impacts, thus failing to incorporate the climate complexity of its uncertainties and risk, that consequently leads to relying on the nature of assumption and exclusion of stakeholders from the policymaking process (Doukas, H. & Nikas, A. 2019). Another challenge for policymakers/decisionmakers, according to Carolina Zambrano-Barragan (2010-2011), lays on the policies, considering that the impact of climate change and the potential outcomes the strategies to adapt to them are under uncertainty while having the prerequisites of been short-term pressing needs while retaining the necessity of preparing for "*tomorrow's climate impact*" (Zambrano-Barragan, C. 2010-2011). These prerequisites will eventually lead to the necessity of introducing new decision-type instruments and issues into the policymaking cycle due to climate change unique spatial and temporal impact, its high-level of uncertainties and risks, the inexperience of policy and decision-makers to deal with an issue with the conditions above since actions and interventions can result in unintended consequences (Scheraga, J.D. Elbi, K.L. Furlow, J. & Moreno, A.R. 1996; OECD, 2007 Hascic, I, et al. 2010; Studinka, J. & Guenduez, A.A. 2018**;** Roelich K. & Giesekam, J. 2019). These unexpected results could prove irreversible since there will be few opportunities and time to attempt a solution (World Resource Institute, 2010). Charlesworth and Okereke (2010)[9] further support the statement indicate the evolution of climate-related policies:

> "*(...)* [The] *current policy responses do not adequately address the possibility of rapid climatic changes, because they make unwarranted assumptions regarding the predictability of climate change, including tipping points, and are based on utilitarian ethical assumptions (optimization, using, e.g., cost-benefit analysis and similar approaches) that are likely not shared unanimously*" (Charlesworh & Okereke, 2010, *apud* Wardekker, A. 2011 p.18).

Additionally, the analytical framework on climate change to inform policymakers/decision-makers is still insufficient due to the scarce literature on climate change policies (Dessai, S. & Sluijs, J. 2007). It is within our best interest to reinforce our climate policies process to address the climate impacts (Steves, F. 2013). Nevertheless, it is still possible for recurring qualities to be spotted, either be the challenge(s) that is to provide essential, timely, and useful information regarding climate change, the impossibility of generating probabilistic estimative of actions due to irreducible uncertainties[10] (Roelich K. & Giesekam, J. 2019) and the large temporal and spatial scale that hinders policymakers/decisionmakers to develop adequate climate policy portfolio and actions (Scheraga, J.D. Elbi, K.L. Furlow, J. & Moreno, A.R. 1996; OECD, 2007; Dessai, S. & Sluijs, J. 2007; Hascic, I et al. 2010; Zambrano-Barragan, C. 2010-2011; World Resource

[9] Charlesworth, M., C. Okereke (2010). Policy responses to rapid climate change: An epistemological critique of dominant approaches. *Global Environmental Change*, 20 (1), 121-129.

[10] According to Roelich & Giesekam, irreducible uncertainties are those that are not possible to generate probabilistic estimates of outcomes that ultimately limits the ability to generate decision (Roelich K. & Giesekam, J. 2019).

Institute, 2010; Studinka, J. & Guenduez, A.A. 2018; Doukas, H. & Nikas, A. 2019). Butler, Demski, Parkhill, Pidgeon, & Spence[11] (2015) further state:

"(…) [The process of] *decision making in climate change mitigation* [policies] *is fraught with uncertainty. This includes endemic uncertainty arising from insufficiency of models, necessities to set boundaries [...], inaccuracy of measurements, and other issues that systemically generate ignorance as a function of constructing knowledge"* (Butler, Demski, Parkhill, Pidgeon, & Spence, 2015, *apud* Roelich K. & Giesekam, J. 2019 p.176).

Climate-oriented policy and decision-making must be designed responsively and flexibly to the unforeseeable to adapt to the ever-changing circumstances (World Resource Institute, 2010). As is proving to be a thorny issue for both climate researcher to provide information and for policymakers/decisionmakers to address the issues since the critical challenge for evaluating climate change is to be able to evaluate the uncertainties and risk and produce policies that yield the positive desire to lock-in, and short and long-term results (Scheraga, J.D. Elbi, K.L. Furlow, J. & Moreno, A.R. 1996; Sala, S. 2009; World Resource Institute, 2010: Levin, K. Cashore, B. Berstein, S. & Auld, G. 2012). Furthermore, the United States National Research Council (2010) recognizes these complexities and issues, acknowledging that climate policies are less well developed than others and asserts that "*understanding and addressing climate change is* [a] *formidable challenge*" (National Research Council, 2010. p. 151). Although assessment of the uncertainty risk is part of scientific (and social) research, exploratory research will never be able to eliminate the uncertainties and risk of climate change since the quantification is not always possible (National Research Council, 2010; Roelich K. & Giesekam, J. 2019; Doukas, H. & Nikas, A. 2019). Nonetheless, research input is still required to improve the understanding and inform and support the policymaking procedure (see Figure A1.2). "*Consequently, a better understanding of climate policies is paramount to inform public-and-private sector decisions regarding climate change"* (National Research Council, 2010, p.401).

Kevin Levin et. la (2012) further comment on the matter, describing climate change as a "*Super Wicked Problem"* due to its distinctive grisly features that highlights it as a real menace to society: those who cause the problem (governments, institutions, and companies) are also the ones that seek to provide a solution to it (e.g., how Shell promotes the investment in Carbon Capture and Storage facilities); the policies responses are taken to solve the climate issue are mid to long term base on new information, thus discounting the future irrationally; the lack of any central authority that directly addresses on the matter; and they are ill-equipped to identify solutions (Levin, K. Cashore, B. Berstein, S. & Auld, G. 2012). Addressing this entails

[11] Butler, C., Demski, C., Parkhill, K., Pidgeon, N., & Spence, A. (2015). Public values for energy futures: Framing, indeterminacy and policy making. Energy Policy,87, 665–672.

the development and implementation of new approaches that, ironically, "*require*[s] *the adoption of new policy analysis techniques that are consistent with, rather than ignore, the key features of this class of* [climate] *problems"* (Levin, K. Cashore, B. Berstein, S. & Auld, G. 2012, p.129) since it is integral and essential to unfold data concerning these "*key features"* as well as the means to fully evaluate the uncertainty properties of climate change as to invigorate the climate policymaking course (Scheraga, J.D. Elbi, K.L. Furlow, J. & Moreno, A.R. 1996; Sala, S. 2009). The importance of collecting climate data has and will continue to become an increasingly urgent necessity to implement policies and continuously update them to achieve determinate climate goals (World Resource Institute, 2010).

Therefore, avoiding climate catastrophe can only be achieved through robust, efficient policies that enable lock-in sustainable transition development that considers the various risks and uncertainties that climate change possesses (Köhler, J et al. 2019). Still, the lack of climate change policy frameworks and consistent knowledge and definitions of risk and uncertainties cripples this progress. Thus, developing and implementing climate policies have political, socio-economic challenges (EBRD, 2011) that require the ability to capacitate and improve all stakeholder capability to generate and obtain relevant data projections of the climate and Earth's changing system. As information for prior, during, and after the policymaking process applies a "*forward reasoning*"[12] to achieve good climate policy results that achieve short and long-term goals and sticking into long-term objectives. Where climate-related policies require constant, adequate, and accurate information and case examples to develop choices (World Resource Institute, 2010, Makarau, 2010-2011; Street, R. 2010-2011). Development of new infrastructure, technologies, management techniques, and tools, etc. for policy and decision-making plays a considerable role (Zambrano-Barragan, C. 2010-2011) in the establishment of a system of climate data collection and dissemination, and policy feedback that grants the development of a climate policy portfolio (see Figure A1.3).

2.4. Climate Policymaking and Technology

Technological development and deployment have proven to be a great ally in the fight against climate change (e.g., renewable energies; environmental monitoring sensors, etc.) and for the development of climate-related policies and actions (Mois, G. Folea, S. & Sanislav, T. 2017; Saha1, H.M. et. la. 2017; Singh, C. et. la. 2018; Pearl, M. Alexander 2019) that allowed us to understand further climate uncertainties and risks as well as providing us with new climate knowledge that could potentially be implemented into

[12] An approach where policymakers must identify ways in which interventions might create policy pathways that move towards ideal outcomes and that focus in which it may trigger and nurture path-dependent processes (Levin, K. Cashore, B. Berstein, S. & Auld, G. 2012).

the climate policymaking process (Mois, G. Folea, S. & Sanislav, T. 2017) allowing us to meet current and future climate goals (Zambrano-Barragan, C. 2010-2011). However, the trend of fully utilizing climate data and information, exact long-term climate information, in the policy and decision-making process is unusual due to the "*(…) lack of successful examples that* [managed to*] integrate long-term information into* [the] *decision-making* [process, especially in underdeveloped countries[13]] *(…)"* (Singh, C. et. la. 2018 p.397).

The nature of climate changes has proven to be a difficult task for policymakers/decisionmakers to formulate, manage and develop uncertainties responses, either be mitigation or adaptation (Roelich, K. & Giesekam, J. 2019) to the point where the *"long-term nature of consistent* [climate] *policy treatment (…) exceeds the typical terms of most political regions.* [where] *Elected officials and by default, bureaucrats are notorious for their short-term horizons*(…), *thereby limiting the potential for implementing* [appropriate climate policies] *(…)*" (Lee 1993 as in Arvai, J., Bridge, G., Dolsak, N. *et al*. 2006, p.221) since these uncertainties have effects also afflict the socio-economic and environmental spheres (Roelich, K. & Giesekam, J. 2019). Understanding the complex interaction of all dimensions affected by climate change (e.g., economy, climate, energy, human activities, impacts of potential policy strategies) is essential.

Carolina Zambrano-Barragan (2010-2011) argues that active management throughout the development of climate-related strategic decisions is crucial since they require continuous incur adaptation with the emergence of new climate data and trends. Additionally, she establishes recommendations that to develop a consistent strategic decision, they required a framework that is socio-institutional flexible, as climate-related issues are multi-layered to act upon (e.g., impacts dispersed through space and time) and institution have no previous experience; the development and management of information, knowledge, tools, and strategies are crucial, as they are crucial elements in any decision and policymaking process, especially under uncertainty and risks (e.g., most climate data is concentrated on lower latitudes. Thus, reliable tropical climate data is low); the development of a climate portfolio; and the definition of climate indicators and the application of periodical monitorization and evaluation of outcomes and changes to evaluate climate policies (Zambrano-Barragan, C. 2010-2011). Policymakers/decisionmakers require the right, adequate and accurate information, and knowledge so they may be able to develop actions and responses to the various climate-related situations (World Resource Institute, 2010). Moreover, Amus Makarau (2010-2011) and Sives Govener (2010-2011). The "*World Resources Report 2010-2011: Experts Perspectives*" categorizes these climate policies issues and needs into categories: ~~i)~~ climate surprise risks (extreme climate events), that necessitates quick responsive policies and efforts base on the identification of geographical hotspots

[13] According to Singh, C. et.la. underdeveloped countries lack the ability to properly develop climate policies due to their limited to obtain small climate and weather data and information (Singh, C. et.la. 2019).

and the tools for rapid data collection, analysis, modelling and planning to facilitate early warning systems, risk responses and mitigation strategies[14]; ~~ii)~~ long-time climate risks (e.g. changes in weather patterns, increase of extreme events, sea-level rise), that involves medium-long term plans, policies and contingencies base on scientific-based climate, hydrological, geographical, and socio-economical projection and dynamics information (trends, vulnerabilities and risks); and ~~iii)~~ highly uncertain risks (droughts, floods, cyclones, extreme weathers), that requires policies with great reach base on the identification of uncertainties trends that will require inter-agency coordination, archives of climate policies and actions example for policymakers/decisionmakers, and research and technology development on assessments tools to obtain realistic climate future scenarios[15] (Makarau, A. 2010-2011; Govender, S. 2010-2011). Ergo, to manage to apply these recommendations into the policymaking process, the policies themselves require to be adaptable to the constant input of data and trends. Climate policies must be able to be flexible so they can manage to meet, some if not all, new social, technical, climatic, or environmental circumstances; durable, so they can be able to address the long-term effects of climate change; proactive, so they may meet all the objectives and avoid negatives outcomes; and robust, so they may have reached to all sectors as well as a global reach to deal with the systemic reach of climate change (World Resource Institute, 2010; Makarau, A. 2010-2011; Govender, S. 2010-2011; Zambrano-Barragan, C. 2010-2011). It is essential to acknowledge and be aware of the flow of data, knowledge, and climate change trends to facilitate effective climatic responses and actions, seeing that they own supervene and short-term dynamic characteristics. Thus, it not a matter of "if," but a matter of "when" these transformations will occur (Liverman, D. 2010-2011).

Roger Street (2010-2011) and the National Research Council (2010) argue that perfect information will not solve these concerns (Street, R. 2010-2011; National Research Council, 2010), requiring "*a series of activities in different sectors and over decades.* [where] *The response to particular actions cannot reasonably be predicted. So, decision support approaches should be reflexive and allow for flexibility to adjust future actions based on the outcomes of previous actions (Leach et al.[16],2010; Lindblom[17],1959).*

[14] In Southern Africa the Wide Area Monitoring Information System (WAMIS) is used to collect satellite-based information services that provides near real-time monitoring and mapping of capacities of the natural events that are happening and allowing for disaster risk management (Makarau, A. 2010-2011).

[15] According to Amus Makarau, it is impossible to be fully prepare for these climate uncertainties since they cannot be fully analysed and relate them to certain climate trends. However, it is possible to model and plan climate scenarios to assess their potential impacts in each sector by using the worst-cases scenarios (Makarau, A. 2010-2011).

[16] Leach, M., Scoones, I., & Stirling, A. (2010), "*Governing epidemics in an age of complexity: Narratives, politics and pathways to sustain-ability*". Global Environmental Change,20, 369–377.

[17] Lindblom, C. E. (1959). "*The science of 'muddling through'*", Public Administration Review,19,79–88.

However, the future implications of short-term decisions must be considered to keep desirable future options open [*Haasnoot et al*[18]*.,2013; Stirling*[19]*,2010]*" **(**Roelich, K. & Giesekam, J. 2019). Nevertheless, information still proves to be essential for this development. The challenge is to find available and relevant information and identify and set parameters or goals that are key in understanding its nature before, during, and after the policymaking cycle (Street, R. 2010-2011; Roelich, K. & Giesekam, J. 2019). Therefore "*monitoring is an essential part of these approaches, to detect change in assumptions or uncertainties, and signal when corrective or contingency actions are required*" (Roelich, K & Giesekam, J. 2019, p.177).

Scheraga Hence, et.la (1996) highlights the importance and potential of climate systems of information and knowledge, and the development and implementation of decision and policy making-support tools that could aid in the gathering, organization, analysis, and allocation of methods of data into the policymaking process while, simultaneously, tracking the effectiveness of policies, potentially aiding in the organization and visualization of the information, analysis, and classification of risks and potential trade-offs based on a rapid and comprehensive communication network, accurate, reliable laboratory-based diagnosis, as the process is limited to the available resources and mechanism (Scheraga Hence, et.la 1996).

The United Nations has stated that these forms of technological advancements, such as Information and Communications Technologies (ICTs), have the potential to help in the painstaking process of decision and policymaking and even hold promises for further advancements and acceleration to achieve the UN's Sustainable Development Goals (SDG) (UN, 2018). Besides, the *Earth Institute at Columbia University's ICT & SGD Final Report* indicates that ICTs can help achieve the SDGs through technologies and services. Where ICT's infrastructure will boost the speed and scale of technology and information (self-)diffusion that could lead to a rapid upgrade rate, reduction of costs of deployment, and low-cost digital training that, ultimately, will aid in the growth of public awareness and action of the SDG[20] across many sectors (Earth Institute at Columbia University, 2017). Hence, it is safe to assume that ICTs will play a fundamental role in achieving the SDG'S goals, and ultimately, climate change. Moreover, Simone Sala (2009), in his paper "*Information and Communication Technologies for climate change adaptation, with a focus on the agricultural sector,"* situates the potential of information systems and tools for climate change into three categories to address climate change's policy uncertainties. (Sala, S. 2009, p.2):

[18] Haasnoot, M., Kwakkel, J. H., Walker, W. E., & ter Maat, J. (2013). "*Dynamic adaptive policy pathways: A method for crafting robustdecisions for a deeply uncertain world*", Global Environmental Change,23, 485–498.
[19] Stirling, A. (2010). "*Keep it complex*", Nature,468, 1029–1031.
[20] For more information Earth Institute at Columbia University (2017), "*How Information and Communications Technology can Accelerate Action on the Sustainable Development Goals. ICT & SDGs Final Report*", Ericsson, the International Telecommunications Union (ITU) and the GSMA.

1) *Comprehensive systems and methodologies for institutions* able to identify and qualify climate change impacts as well as assess points of vulnerability;
2) *Downscaling tools*, able to produce climate data to develop appropriate scale impact modeling and development realistic climate scenarios for actions;
3) *Systems and tools for specific sectors (e.g., agriculture, forestry, air quality, healthcare, sea, etc.)*. Information tools can produce accurate data through which it could be possible to investigate, target, and analyze issues within specific sectors.

In this context, Shadi Al-Sarawi & et.la (2017) states that the deployment of IoT is set to revolutionize ICT's information and data transferring process thanks to its capability to connect and transfer information and data (Al-Sarawi S. Et.la. 2017). Likewise, Patel K. K. & Patel M. S. (2016) states that IoT's ability to continuous (or regularly) collect and analyze data would, potentially, enrich the planning, managing, and decision-making process (Patel, K.K. & Patel, M.S. 2016) were measured to develop technologies and share information could, theoretically, streamline solutions on these pressing global matter.

2.5. Internet of Things

According to Magnus Akerman et. al. (2018), there is a growing trend of how decisions, plans, and actions are developed and implemented by the evolution and improvement of data processing and storage technologies. Empowering decision and aiding policymakers/decisionmakers to rely more on data than intuition, allowing for (some) prediction and prevention of action failures and unwanted results (Lundgren, C. Åkerman, M. Bärring, M. et al. 2018). The Internet and the World Wide Web (WWW) is one of these technologies that have steered these changes in the decision-making process and how people communicate with each other. From these changes, "*the Internet of Things is born with the idea to reproduce this idea of human interconnection but for the machine*[s] *(…)* [that] *goes beyond the human-to-human communication allowing the devices to communicate together without human interaction*" (Hardion, V. et. la 2013, p.974).

The definition of IoT is still on the working and, according to Pradyumna Gokhale, Onket Bhat & Sagar Bhat (2018), it has been "*generally define as dynamic global network infrastructure* [e.g., devices, instruments, vehicles, buildings] [embedded] *with self-configuring capabilities* [e.g., electronics, software, circuits, sensors] *based on standards and communication protocols*" (Gokhale, P. Bhat, O. & Bhat, S. 2018, p.41) that have the potential to improve the efficiency and accuracy of interaction but requires an infrastructure that is adaptable, extensive, scalable, decentralized and heterogeneous (*idem*). Pallavi Sethi and Smruti R. Sarangi (2017) further support the lack of a well-define definition of IoT, describing it as a "*new kind of world where almost all the devices and appliances that we use are connected to a network* *and where we can use them collaboratively to achieve complex task that require a high degree of intelligence (...)* [and that IoT is] *not a single technology, but an agglomeration of various technologies that work together in tandem*" (Sethi, P. & Sarangim, S.R. 2017, p.2). Keyur K. Patel & Sunil M. Patel (2016) offer a more detail-oriented definition and described it as a *"(...) network of physical objects (...) a network of devices of all types and sizes, vehicles, smart phones, home appliances, toys, cameras, medical instruments and industrial systems, animals, people, building, all connected all communicating and sharing information based on stipulated protocol in order to achieve smart reorganizations positioning, tracing, safe and control and even personal real-time online monitoring, online upgrade process control and administration*" (Patel, K.K. & Patel, M.S. 2016, p.6122) that is characterized by its interconnectivity, its heterogeneity, it's enormous scale, and connectivity (*idem*). Lastly, Shadi Al-Sarawi et. la. (2017) provides a shorter definition, describing it as the agglomeration of massive smart devices that can communicate with each other that enables to collect and exchange of information and data from human-to-human, human-to-devices, and device-to-devices that can connect to anything, anywhere at any time (Al-Sarawi, S. et. la. 2017).

Although it is definition varies from author to author, IoT's functions, characteristics, and applications remain similar: **1)** "Things" (devices) are embedded with sensors that enable its interaction with the physical environment through the collection and storage; **2)** Communication infrastructures, that enable the communication, transmission, and transference of information, **3)** Processors, that processes the collected and store data, and **4)** Actuators, which enables to put in effect alteration in the environment based on the processed data (Sethi, P. & Sarangim, S.R. 2017). Therefore, we can simply describe IoT as a mixture of diverse hardware (sensors, processors unities, actuators, and communication infrastructures) and software (e.g., communication protocols and intelligent algorithms) that provides a solution based on the information technologies that enable the storage, retrieves and processing of data and communication. Permitting for the convergence of the physical and the virtual world capable of enriching the planning, managing, and decision & policymaking since "*objects make themselves recognizable, and they obtain intelligence by making or enabling context related to decisions thanks to the fact they can communicate information about themselves*" (Patel, K.P. & Patel, M.S. 2016, p.6122). Which can accumulate, archive, and ultimately be accessed by other devices or individuals (Sethi, P. & Sarangim, S.R. 2017; Al-Sarawi S. et. la. 2017; Gokhale, P. Bhat, O. & Bhat, S. 2018; Patel, K.P. & Patel, M.S. 2018) and interact with their environment.

2.5.1. Sensors

Sensors are small size, low cost, ease-to deploy devices (Sethi, S. & Sarangi, R..S. 2017) that enable the detection of changes in the physical world throughout the transformation of physical stimulus into a signal that can be recorded or measured (Sureshkumar & Rajesh, R. 2018). Allowing real-time data to be collected, processed, and archive (Patel, K.P. & Patel, M.S. 2018). This is a vital part of any IoT framework towards data collection from the environment to indicate responses or action (Mois, G. Folea, S. & Sanislav, T. 2017; Sureshkumar & Rajesh, R. 2018) as "*the process of effecting a change in the physical world's often dependent on its state at that point of time. This is called context awareness*" (Sethi, P. & Sarangim, S.R. 2017, p.2).

Currently, there is a large quantity and variety of sensors available for usage. These devices can be divided depending on the utility of sensors according to the external stimuli' nature. Pallavi Sethi & Smruti R. Sarangi (2017) and Sureshkumar and R. Rajesh (2018) provide an overview of these:

i) *Physical Sensors,* in which the sensor responds to physical changes (e.g., length, temperature, pressure, weight, electricity, etc.) measuring it. For example, environmental sensors can be utilized to sense, measure, and respond to a set of environmental parameters (humidity, temperature, air pollution, water pollution);

ii) *Chemical Sensors,* in which the sensors respond to a chemical reaction. For example, chemical sensors can be used for the detection of chemical substances in the water supply;

iii) *Biosensor,* in which either a physical or a chemical sensor operates and responds to biological samples.

2.5.2. Actuators

Actuators are devices in the IoT framework that enable the interaction in the environment (Hardion, V. et. la 2013) through the conversion of energy into motion (Sethi, P. & Sarangim, S.R. 2017) based on gathered processed data of sensors (Mois, G. Folea, S. & Sanislav, T. 2017; Sureshkumar & Rajesh, R. 2018). According to Pallavi Sethi and Smruti R. Sarangi (2017), actuators are used for mechanical actions that can be classified into hydraulic actuators, which utilizes hydraulic power; pneumatic actuators, which utilizes compressed air; and electric actuators, which utilizes electricity (Sethi, P. & Sarangim, S.R. 2017).

2.5.3. Communication Infrastructures

IoT is restricted by the vast number of smart devices that need to monitor and control requiring support for identification, transmission, and management of massive amounts of data, the mobility, the processing capability storage volume, power life, radio range of the devices, security, etc. constrain IoT environment and function (Al-Sarawi, S. et. la. 2017; Mois, G. Folea, S. & Sanislav, T. 2017; Sethi, P. & Sarangim, S.R. 2017; Rao, K. S. & Prasad, P. 2018). "*Therefore, the IoT implementation requires a communication protocol that can efficiently manage these conditions*" (Al-Sarawi, S. et. la. 2017, p.685) where "*these networks (…) are built to support the communication requirements for latency, bandwidth or security*" (Patel, K.K. & Patel, M.S. 2016, p. 6125).

Al-Sarawi et. la. (2017) and Pallavi Sethi & Smuti R. Sarangi (2018) overview the most used IoT communication Infrastructures **(see Figure A1.4):**

- **SigFox**, A low bit-rate power, and low power wireless communication technology utilizes very long waves to transmit small data packets at low data transference speeds (10-1000 bits) to distances up to 50 km. However, the communication range can be increased up to 1000 km at the trade-off limiting the message size (12 bytes) and limited messages (140 SMS/day). Designed preferably for portable devices with limited battery power;

- **Cellular (2.5G/3G/3.5G/4G/4G LTE)**, High power and high consuming technology that allows for reliable high-speed connectivity over distances and device's mobility;

- **Near Field Communication (NFC),** a Very short-range secure wireless communication technology designed for portable mobile devices with limited battery power. NFC enables data transmission (106-216 - 424 kbps) among devices via touch/binding (few cm), transferring all data types between NFC devices. NFC has two modes of operation: Active mode, where both devices generate a magnetic field to communicate date; and passive mode, where one device generates the magnetic field;

- **Bluetooth Low Energy (BLE**), Short-range (15-30m), low bandwidth, low-latency, low energy wireless communication technology developed by the Bluetooth Special Interest Group for portable devices with limited power for quick small data package transference (125 kbps – 2 Mbps). Although BLE is like classic Bluetooth, they are not compatible with each other since BLE is not able to support data streaming;

- **Zigbee**, A communication protocol-based technology used for Personal Area Network. Designed by the Zigbee Alliance for reliable low power and low-cost wireless communication technology for low data rate (< 250 kbps), long battery, and secure networking devices at short range (10-100 meters);

- **Radio Frequency Identification (RFID)**, Identification technology in which small radio frequency transponder (RF Tag) where the data is store and read by a reader device (reader). There are two types of RFID tags: Actives tags that have a power source (battery, and thus limited) and are programmed with unique information; and Passive tags draw power from the readers. However, RFDI have a range limited of 100 meters and cannot be used to measure or diagnose data;

- **lPv6 Low Power Wireless Personal Area Network (6loWPAN),** developed by the Internet Engineering Taskforce by utilizing Internet Protocol 6 (IPv6), allows device scalability and stability over IEEE 802.15.4 protocol. It is the most used standard in IoT since it allows for devices to communicate with all other IP-based devices on the internet at short-range (10-100m), low-cost, low bandwidth, and power consumption a data rate <= 250 kbps.

2.5.4. Requirements and Challenges

Rob von Kraunenburg & Alexi Bassi (2012) declare that Global Cooperation, where different global approaches from different nations (e.g., China, US, and EU) are different from one another; Business Model of IoT; Ethics, Control, Surveillance and Consent of Data, where the development of an interconnected society raises privacy issues that will lead to the development of future ethics designed and the introduction of new rights and regulations (e.g. "right to be forgotten, right to oblivion); IoT planning between a top-down or bottom-down innovation plan; and Diverse Technological challenges are issues that challenged the development and implementation of a reliable IoT system (Kraunenburg, R. & Bassi, A. 2012).

IoT's vast number of smart devices that are to be interconnected, monitor, and control implies a technological challenged that requires efficient coordination and energy consumption (Kraunenburg, R. & Bassi, A. 2012; Rao K.S. & Prasad, R 2018) and a communication infrastructure that can provide support for mobility and scalability due to the requirements of ultra-low latency, very high reliability, very high bandwidth and data rate (Mois, G. 2017; Rao K.S. & Prasad, R 2018; Gokhale, P. Bhat, O & Bhat, S. 2018).

Cybersecurity is another challenge that demands an IoT architecture to be able to preserve, protect and respect private information and privacy (Kraunenburg, R. & Bassi, A. 2012; Mois, G. 2017; Rao K.S. & Prasad, R 2018; Gokhale, P. Bhat, O & Bhat, S. 2018;). Security measures must be enforced from the smart devices to the application (Patel, K.K. & Patel, M.S. 2016). Furthermore, it is essential to highlight an interconnected society's impact on our current rights and regulations (Kraunenburg, R. & Bassi, A. 2012), making it a subject of great interest and importance for future research and opportunity for social and technological development.

Lastly, The Next Generation Mobile Networks Alliance (NGMN) developed an IoT vision revolving around massive numbers of mobile and static devices that can interact and communicate in real-time. Enabling automated traffic control tasks in smart cities, E-health, early warning systems, control networks, etc. will require an efficient network and energy consumption and an ultra-reliable communication network. These conditions can be met by obtaining high throughput mobility, ultra-low end-to-end latency, critical reliability, and a high data rate. (NGMN, 2015). Where "*5G promises to bring reliability, latency, scalability architecture, services, edgeless computing and ubiquitous mobility that is needed* [ed] *for IoT (…)*" (Rao K.S. & Prasad, R 2018, p.150) comes into play.

2.6. 5G Technology

Over the decades, cellular communication technology has grown and advanced significantly. Now, the upcoming fifth generation of mobile, cellular technologies, networks, and solutions (5G) set to move beyond its standard mobile device network (Eze, K. Sadiku, M. & Musa, S. 2018) expected to enable a fully mobile and connected society that could empower a socio-economic transformation in terms of productivity and sustainability (NGMN, 2015).

To understand this impact, we must comprehend the evolution and changes of the different cellular communication technology standards. Cellular communication technology can be traced back to the 1970s with the 1st Generation (1G) analog-cellular systems that enabled voice communications possible. However, due to its low quality of service, poor battery consumption, and oversize devices, it was limited. The 2nd Generations (2G) surges around the 1990s with GSM and digital transmissions that pioneered SMS text messaging and low-rate data. Still, these services were limited and of low quality. The 3rd Generation (3G) came in the 2000s, with the introduction of high-speed IP data networking and the possibility for data transmissions and internet access, which enable applications such as video conferences, location-based services, etc. The 4th Generation (4G) came around the 2010s, with the growth of mobile broadband, which empowered 10x the speed of current 3G—working as an extension of 3G that has allowed for higher band-with and network services. The 4G Long Term Evolution (4G LTE) introduction enables high-speed data transfer for up to 100 Mbits/s. it was thus enabling true mobile broadband on a unified standard. However, unresolved challenges such as high energy consumption and spectrum crisis remained unresolved (Grigorik, I. 2013; Mohammad Meraj ud in Mir et al. 2015; Eze, K. Sadiku, M. & Musa, S. 2018).

5G is the evolution of our current LTE 4G mobile communications set to, potentially, revolutionize how our society connects enabling. 5G network, as all cellular networks, consists of cells divided into sectors that feature an outstanding (up to) 20 Gb/s data rate and ultra-low latency end-to-end trip (< 1mS), low and efficient energy consumption, and improvement of mobility support that facilitates ultra-high definition videos, virtual reality, real-time applications (e.g., sensors, data analysis, data gathering), and the ability to support billions of devices to support massive Machine to Machine (M2M) communications such as IoT devices (Warren, D. & Dewar, C. 2014; NGMN, 2015; West, D. 2016; Peterson, E.R. 2018; Sadiku, M. & Musa, S. 2018; O'Donnel, B. 2020) as seen in Figure A1.5.

Chapter 3. Use Cases

As we have previously stated, the effect and impact of climate change will afflict and disrupt all aspects of daily life and the natural cycle of the earth's ecosystem and the biosystem. We argue that technological advances can give us an upper hand in overcoming these issues by developing decision and policy making support infrastructure, tools, and instruments through the implementation of IoT-5G climate monitoring intelligent systems.

Although this dissertation is mere exploratory research, applying examples of case studies to offer more in-depth insights on the matter could help develop further progress of this thesis' subject since they are optimal and useful at offering a foundation for the development of more structured research topics. Furthermore, case studies are "*particularly well suited to new research areas or research areas for which existing theory seems inadequate. This type of work is highly complementary to incremental theory building from normal science research. The former is useful in early stages of research on a topic or when a fresh perspective is needed. At the same time, the latter is useful in later stages of knowledge"* (Eisenhardt 1989, pp.548-549 in Rowley, J. 2002, p.16).

However, there are little to no use cases from the date this dissertation has been making. Therefore, we will showcase a few examples of how IoT systems could improve policymaking in policymaking related to climate issues. Nevertheless, this approach is especially beneficial in a situation where there is little or no information nor control on the research subject (Rowley, J. 2002)

3.1. Smart City Use Case

As the climate effects and impact are predicted to grow, it will most certainly have an impact on cities, exposing the population and its infrastructure to uncontrollable climate-related issues and problems such as extreme climate and weather patterns, especially those that are located in islands and coastal regions (IPCC, 2019). Environmental monitoring has become of capital importance, especially in the cities, where climate impacts and effects are reaching levels that jeopardize infrastructure and citizens' well-being. As a result, cities around the world, especially island nations, such as Taiwan, have been applying IoT system as a potential solution to mitigate these consequences as showcased in the following Case Study (Yang, T. et.la. 2018):

- <u>Taiwan's' Dayusws' Early Warning System</u>

The case of the island nation of Taiwan is predicted to be afflicted by floods. Thus, there is a necessity to develop efficient strategies and measures to mitigate and prevent flood hazards. Yang, T. et.la (2018) highlight and recommend the technological potential of developing real-time early warning systems based on flood forecast information and real-time observation.

For this issue, a smart water system to prevent flood hazards (Dayusws) was developed to produce a flood forecast system with lead time predictions in the Huawei Science Park to realize a flood simulation. The site was pre-analyzed to define a set of parameters deemed crucial for the system, e.g., maximum flood quantity of the area, rainfall intensity per second, and water storage capacity to ensure that the collected data is suitable.

The system consists of a series of sensors and monitoring networks observation in real-time that gathers and transfer data to a big data platform where it is processed and integrated into a compilation of high-

resolution data from over 20 satellite data and a decision support system for the development of modeling simulation to trigger an appropriate active disaster mitigation measure.
The outcome is the reproduction of a flood modeling simulation forecast with an exponential time lead of 6 hours.

3.2. Ocean Monitoring

Climate change effects are set to impact the oceans through acidification (increase C02 levels in the water), causing massive environmental damage to their ecosystem. These issues would require policies that enable control and monitoring to avoid potential adverse outcomes from climate change impacts and potential policy and climate responses**.** Therefore, to mitigate these am IoT system targeted to these issues could represent a possible resolution to these paradigms as seen here (Alkandari A., Alabduljader Y., Moein S.M. 2012):

- Case Study of Kuwait Beaches

Harmful algae and bacterial outbreaks in Kuwait Bay have led to the killing of fishes due to the transmission of bacteria from great fishes from the Arabian Gulf, the incubation and propagation of Shellfish Poisoning Syndrome fishes and clams. These conditions were affected by the unusual warm condition of more than 35cº and the inorganic and organic nutrients from sewage outfalls in the waters. Besides, oil pollution (drilling rigs leaks and cooking oils and grease), dumping of industrial waste and sewage, air pollution, and agriculture runoff of pesticides and fertilizers have affected water quality. To measure the characteristics and quality of the waters of Kuwait, a Wireless Sensor Network (WSN) to monitor the pollution rate and climate effects of the water environment have been envisioned as a low-cost, low power, high effective solution thanks to its ability to compare real-time data and the monitoring system that could allow for the suggestion of improvement of infrastructure—for this, pre-determined water monitoring parameters, depending on the area of deployments (near petroleum, refineries, and sanitation stations), such as temperature, PH levels, dissolved oxygen levels, nitrate, and ammonia were utilized.

The WSN framework consists of a sensory system that is divided into the main control center at the public authority of agriculture and fish resource, and measured distributed sensory devices that are divided into Sensor Nodes (SN), that are submerged to the bottom of the water, e.g., sounds sensors, water quality sensors, temperature sensors, water depths sensors. That is responsible for transmitting data, and Cluster Head (CH), such as data buoys, that capture data from SN regarding the physical properties and state of the water (e.g., salinity, temperature, depth, etc.) that transmit the data to reception centers to stationary RFDI reader that are located nearby roads that will send data to the correct control center. These are divided into clusters based on the communication strength signal, where Zigbee utilizes SN (short-range communication). CH utilizes a long-distance Ethernet Radio satellite communication protocol to transmit the data due to the large area that they have to cover. To promptly deal with pollution, they develop a guidance system centered on data readings based on pre-determinate elements like NH3, Carbon Dioxide, Chlorine where Green = Equilibrium and Safe; Yellow = Beginning of Pollution; Red = Complete Contamination. The system has only been simulated and tested in pools to analyze the water temperature. The system has showcased advantages regarding the procedure's cost-efficiency in terms of human resources, time consumption, and budget, proving a potential maritime monitoring tool.

3.3. Smart Farming

Agricultural activities are not only one of the sectors at most risks from the effects of climate change since most of its activities depend on natural resources, such as water and soil quality, and the diverse climate variables. It is also considered one of the mains contributors to GHG. Thus, having to tackle multiple simultaneous issues, IoT can offer a potential solution to these issues while also been economically friendly, as seen in the following case study (Chieochan, O. Saokaew, A. & Boonchieng, E. 2017):

- Case Study of Lingzhi Mushroom Farming

The government of Thailand sought to promote the development and implementation of new agriculture technologies into Thai agriculture. Thus, the Maejo University Chiangmai developed research on an economical prototype of a smart Lingzhi mushroom farm using current information technology to control the Lingzhi mushroom's environment, intending to promote new modern agriculture options to the farmers. To develop this system, they measure and define parameters of mushroom development and production: light exposure, an average seasonal temperature of 20-25 c^o, airflow, humidity levels between 90-95%, and cultivation period of 90 to 120 days. All these parameters were taken into consideration. However, according to Maejo university's research, humidity levels have been the most crucial growth factors of spores and mushroom leaves. By identifying and defining parameters of sustainable growth of mushrooms, Maejo university can define the IoT framework. The prototype system for farming consisted of sensors to monitor and measure the farm's humidity level over the mushroom growth period (4 months). Whenever the 90-95% humidity threshold was not met, actuators would control the humidity level via automatic sprinklers and fog systems. The IoT system was always verified by traditional humidity measures such as wet bulb and dry bulb thermometers to validate the system measurements. The collected humidity levels data was sent to a cloud computing system (processor) and displayed to both computers and phones and the watering and fog status.

This study has highlighted the potential of smart farming systems due to the cheap cost of development and implementation of the system in comparison to traditional human resources labors as well as the measurement results of the prototype that have shown that the IoT humidity system has surpassed the traditional manual measurement system since the results of were more detail-oriented.

Chapter 4. Methodology

The policy cycle is a time consuming, tedious and complicated process that requires a vast amount of information on the agenda's subject(s) to unfold the possible takes and decision (Knill, C. & Tosun, J. 2006; Kann, W. & Wegrich, K. 2006; Wellstead, A. & Stedman, R. 2015). However, on the matter of climate change, policies seem to present additional distinctive traits and characteristics that conditionate these and inhibiting the climate policy cycle (Scheraga, J.D. Elbi, K.L. Furlow, J. & Moreno, A.R. 1996; OECD, 2007; Dessai, S. & Sluijs, J. 2007; Hascic, I et al. 2010; Zambrano-Barragan, C. 2010-2011; World Resource Institute, 2010; Kevin Levin et.la 2012; Studinka, J. & Guenduez, A.A. 2018; Doukas, H. & Nikas, A. 2019). We required to explore the dimensions of climate policymaking and its characteristics to address this issue since (climate) policies are to consider the de facto principle, rule, and guideline that are formulated for or adopted by countries, organizations, and institutions to prevent further anthropogenic interference to the Earth's climate system (IPCC 2014; UNFCC 2016; IPCC, 2019). To manage to develop these climate policies capable of obtaining the desired results, we require, paradoxically, additional tools, techniques, and instruments that can manage to identify, obtain, evaluate and communicate critical features and progress prior, during, and after the climate policy cycle. As a result, we can assume that the potential of ICT, such as IoT and the 5th Generation Wireless Technology (5G), have the potential to become a technological innovation tool that could manage to impact the climate policy cycle (West, D. 2016; Peterson, E.R. 2018).

The purpose of this study is to explore the IoT-5G impact in the climate policy cycle. We have not been able to find much information regarding the study of climate policymaking tools and the use of IoT-5G instruments and considering the lack of technical knowledge regarding the aforementioned technology, exploratory research permitted for research flexibility and adaptability, seeing that the topic in question relatively new and with little to non-previous knowledge, nor specific theory nor model(s) to situate (Goundar, S. 2013; Swedberg, R. 2018). Although exploratory research may not be as rigorous as other types of research (Goundar, S. 2013), it can be used whenever there is a general lack of knowledge about some topic. Moreover, there is always a need for new and exciting research hypotheses, which fosters this (Merton 1975, as in Swedberg, R. 2018).

Richard Swedberg (2018) positions the exploratory study as a valuable research tool for the study development either for student's dissertations or for the development of the new promising idea(s) for future research(s) that could lead to potential *Transformative Research* (Swedberg, R. 2018). It is plausible, considering that an exploratory approach can effectively lay the ground for future research, allowing for research flexibility and adaptability, and it has the potential to save time and costs (Goundar, S. 2013; Swedberg, R. 2018). After all:

> "*The objective of the exploratory research defines the problems accurate, clarify concept, collect details, and discarded informal and unnecessary ideas, and after the framing of the hypothesis of the study. Literature research, survey, focus group, and case studies are usually used to conduct exploratory research. Exploratory research may develop hypotheses, but it does not seek to test them*" (Darabi, 2007 in Shodhganga 2015. p. 78).

Nevertheless, "*Skeptics (…) have questioned the usefulness and necessity of exploratory research* (…)" (Goundar, S. 2013, p.28) because exploratory research also derives disadvantages and limitations that could potentially harm the veracity and validity of our outcome (Shodhganga 2015; Goundar, S. 2013; Swedberg, R. 2018):

I) This type of research generates qualitative information, and interpretation of such is subject to bias and possessing a small sample size (Goundar, S. 2013). Although true, experimental study results can help identify tendencies and range of causes and alternative options of specific problems, consequently enabling further research (Goundar, S. 2013; Swedberg, R. 2018).

II) The finding(s) of exploratory research cannot be generalized. However, the thesis's goal is not to generalize but to effectively lay the basis or ground for future related studies that could generate further opportunities and transformative research (Shodhganga 2015; Swedberg, R. 2018) in the area of ICT (IoT-5G) and climate policy. However, results should not be used exclusively as a method but as theorizing, a mechanism to generate new ideas, high-risk test ideas, etc. to not repeat what is already known (Swedberg, R. 2018).

III) Lastly, exploratory research results usually are not useful for decision-making at a practical level. Though this is also true, exploratory research results can still provide significant insight (Shodhganga, 2015) that could sparkle a conversation and further debate and research regarding this issue that could be later translated into action (Goundar, S. 2013; Swedberg, R. 2018).

Exploratory research was considered a fundamental approach since it is considered to be "*(…) the soul of good research*. [in which,] *without the ambition to say something new, research would come to a standstill*" (Swedberg, R. 2018. p.2). Thus, obtaining and providing more data on IoT-5G networks and climate policymaking could potentially contribute to the issue, enabling the development and fruition of new research topics and debate for a more sustainable, timely, flexible, and adequate climate response(s).

4.1 Research Design

There are three methods of data analysis – Qualitative, Quantitative, and Mixed. We use a quantitative approach to test pre-determined hypotheses and produce generalizable results by observing the relationship among variables (Creswell, J.W. 2014; O'Leary, 2017). As the qualitative approach uses "*(...) to develop theories when partial or inadequate theories exist for certain populations, samples or existing theories do not adequately capture the complexity of the problem we are examining. We also use qualitative research because quantitative measures and the statistical analyses simply do not fit the problem*" (Creswell, J.W. 2013. p. 48) while a mixed approach involves "*(...) both quantitative and qualitative data, integrating the two forms of data, and using distinct designs that may involve philosophical assumptions and theoretical frameworks*" (Creswell, J.W. 2014. p33).

Hence, to gain a better insight and understanding on the matter of the potential of IoT-5G in the climate policy cycle, a qualitative exploratory approach was used[21]. As it allows to conduct flexible, in-depth explorations, in small samples, of a particular phenomenon or subject to answer about experiences, meanings, and perspectives to further investigate concepts (ACAPS, 2012; Creswell, J.W. 2013; O'Leary, 2017) while still providing rich and detail information about the subject despite the resource's limits (ACAPS, 2012). Data quality was also ensured by analyzing the gathered data and crystallizing its content through the source data triangulation (see Table 4.1). Furthermore, persistent and prolonged engagement with the content related (O'Leary, 2017) until August of 2020, through coding and closely examining of data to identify broad themes and patterns and the eventual categorizing and discussing of its content that enabled the recognition of tendencies within the authors' main ideas and concepts regarding the subject of interest.

[21] Throughout our exploratory research, some quantitative elements where identify as we operationalize the varibales. However, no actions regarding quantitative data gathering and analysis were performed throughtout this reserach.

Table 4.1. Example of Summary of Gather Secondary Data

Author	Main Idea/Point	Tendency in Themes
Sala, S. (2009)	CC is plagued with uncertainties, especially for the agricultural sector. ICT systems have the potential to address part of these uncertainties and issues.	• Climate Change Complexity • Climate Change Policy • ICT potential for DM
Scheraga J.D. (2009)	Climate change is plagued with uncertainties that hinder policy responses. Recommends ways to assess it to expose tendencies in critical areas through the investment of monitorization and surveillance system as a decision-making tool	• Climate Change Complexity • Recommendation to address • Technological Innovation and potential for DM
National Research Council (2010)	Overall social science and policymaking on climate change are lackluster due to its complexity. Making climate policy less develop. Recommends better methods of assessing and understanding it to inform policymakers/decisionmakers	• Climate Change Complexity • Policymaking Issues • Recommendations
Dessai, S. & Sivjs, J. (2007)	Exposes lack of literature regarding CC policy and insufficient analysis for policymakers/decisionmakers Vital for tackling CC, due to their characteristics	• Climate Change Complexity • Policymaking Issues • Recommendations
Arvai, J., Bridge, G., Dolsak, N. *et al*. (2006)	Climate change is a riddle with uncertainty and complexity. The policy tends to be short-term and ill-inform. Lack of data regarding is compensated through assumptions or educated guesses Recommends an int. body that monitors climate policy	• Climate Change Complexity • Policymaking Issues • Recommendations • Technological Innovation
Singh, C. et.la. (2018)	Weather and climate data are a crucial ingredient for sound policymaking. Lack of successful examples (portfolio) that integrated this information, especially underdeveloped Regions, Inhibits further policy development. Tech. Dev to obtain info is crucial to understand it.	• CC complexity • Policymaking Dependency on Data • Technological Innovation
Lundgren, C. Åkerman, M. Bärring, M. et al. (2018)	the decision, plans, and actions are developed and implemented by the evolution and improvement of data processing and storage technologies that have led decision and Tech policymakers/decisionmakers to rely more on data than intuition	• Policymaking • Technological Innovation
Wellstead, A. & Stedman, R. (2015)	There is a necessity for a guide for climate decision-makers regarding policy-relevant-data, research, and advice.	• Policymaking • Climate Policymaking issue

Table 4.1: An example of the examination, coding, and categorization process performed on the gathered secondary data.

For the data collection, the application of a combination of primary data consisting of exploratory questionnaires on crucial informants and secondary data involves analyzing a series of case studies, scientific articles, white papers, internet articles, exploratory researchers, and books.

Narrowing the pre-selection of topics and content was made through operationalizing the variables (see Table 4.2). Facilitating and displaying an assortment of tendencies within the literature. Regarding the nature of the secondary data, the majority originates from an academic background (e.g., scientific background, engineering, political science) that are contemporary (2010-2020). Few exceptions were performed on some content that either date back in time and blog post that cut due to their importance and relevance for the research development.

Table 4.2. Operationalization of Variables

Dependent Variable	Dimension	Indicators
Climate Policy	Decision Makers & Influencers	• Politicians • CEOs • Experts • International Organizations • Citizens
	Criteria for Development	• Knowledge • Evaluation Process • Time • Resources • Areas of Critical Interests • Complexity of the problem • Innovation • Tools, Methods, and Instruments
	Development/Implementation Issues	• Time Consuming • Complexity • Deadline to act • Conflict of Interests • Unpredictable Outcomes • Systemic Impact • Transboundary Impact

Independent Variable	Dimension	Indicators
IoT-5G	Utility Potential	• Data Gatherings • Reliability of Data • Quality of Data • Efficiency • Applications
	Operating Requirements	• Infrastructure • Specialize Researchers • Indicators/Themes of application
	Investments Requirements	• Private • Public • External (e.g., International Funds)

Table 4.2: Operationalization process of the independent and dependent variables and their correspondent dimension and indicators for the pre-selection of primary and secondary data.

The application of mixed questionnaires (see Annex D) was administered to two samples composed of those considered and judged to be experts on climate policy, climate-related areas and issues, ICTs, IoT, 5G, and telecommunication systems and infrastructures. Most participants were obtained through snowballing sampling, where existing study subjects recommend acquaintances and colleagues as potential future subjects.

The questionnaires for climate policymakers/decision-makers were designed to gain in-depth information regarding climate policies' characteristics, issues, and trends. The questionnaires for IoT and 5G experts were designed to understand further and expand the knowledge of its potential. These were composed of open questions centered around the research's critical concepts, and multiple-choice questions focus on the dimension and indicators developed previously in our operationalization (see Annex D). Allowing for the reproduction of specific data that might be otherwise unavailable with other methodologies, as the collection of data by this method might generate quantifiable empirical information that enables comparison between the outcomes of both questionnaires (ACAPS, 2012; Creswell, J.W. 2013; O'Leary, 2017) were qualitative methods have been used to gain an understanding of underlying reasons, opinions, and motivations by uncovering trends in thoughts and opinions, and providing insights into problems that could lead to the development of hypotheses for new research

Furthermore, questionnaires were selected as data gathering methods for being one of the most cost-effective and time-effective options, specifically online questionnaires. Since it allowed us to reach a vast number of potential respondents in an inexpensive and resourceful manner, making it possible to fit into our timetable, furthermore, these types of questionnaires pose no pressure to the respondents, allowing for more reflection to correctly answer, potentially providing more accuracy to their response. However, one of the problems we have faced during data gathering is that respondents tended to provide a lethargic answer or simply not bother answering or ignoring it. Predominantly from highly technical and complex areas, e.g., IoT-5G technical experts, Telecommunication Researchers, Minister of Environments, City Mayors, Policy Analyst, Climate Researchers see Annex F). Nevertheless, these questionnaires were conducted on pre-selected individuals who were predominantly accepted to partake in this research (P. Gill, K. Stewart, E. Treasure & B. Chadwick, 2008).

4.2. Limitation of Research

Throughout the research, we spotted a tendency within the gathered secondary data. They were showcasing a significant decentralization of information and the process regarding climate policymaking, the absence of a climate policy portfolio for potential comparison of concepts, and the scarcity of an IoT and 5G development, as well as suitable examples and case studies to evaluate and showcase the potential of these technologies in the area of policymaking. The latter potentially explain by the technological 5G race between nations like China and the USA that either does not intend to share their findings or attempt to sabotage each other's development and implementation. Furthermore, we must be aware of the possible bias regarding the outcomes and uses performances of IoT and 5G systems, as most of the gathered data has been provided by cellular communication and mobile alliances and companies. Consequently, the outcomes of this research must be taken with a critical eye.

Chapter 5. Findings

5.1. Questionnaire Results and Analysis

The results of our climate policymakers/decisionmakers' questionnaire have shown that climate change possesses all the policy mentioned above characteristics (see Figure B1.1). It is complexity (57,1%), conflict of interests (50%), deadline to act (50%), and dynamic changes (42,8%) are among the most highlighted concerns for policymakers/decisionmakers. Furthermore, the main concerns tended to focus on the overall lack of knowledge in climate and environmental finance, investments, information, and its lack of case studies, public information, and projects to share (climate portfolio). Most of this knowledge seemed to be focused on technical international and university studies. They highlight the importance of developing and implementing policies that enable stakeholders (e.g., policymakers/decision-makers, enterprises, and individuals) to shift their attitudes and expectations (85,7%). The second main concern was the direction and stance of climate change as a political and financial restrainer due to their financial and time-consuming, long-term investment requirements (minimum of 4 years) that limit its design and implementation (71,4%). According to a minority, this is caused by a prevailing socio-economic fossil fuel model dependency (21,4%) that stimulates cognitive climate dissonance (14,2%). Lastly, a disparity in access to scientific information between countries. Where developing countries face severe limitations to access this type of information, limiting their design and implementation potential of policies.

Regarding climate data (see Figure B1.2), half of the respondents believe that the currently available data is relevant enough to develop climate policies. However, they highlight that acquiring further data from all policy and decision-making (global, regional, national, state/provincial, local, household) and different socio-economic sectors is necessary to tackle climate change effects and impacts adequately. In counterpart, 29% of the respondents state that it was not enough, representing a challenge for local governments and the Nation States, like Paraguay, requiring further studies on the climate state and climate scenarios by sector and municipalities. Lastly, 21% did not answer, stating that it is within their comprehension that international organization and institutions, like the IPCC, provide critical information and sufficient for formulating mitigation and adaptation policies, but not sufficient for the formulating of responses, as responses need solutions that do not depend on climate data (but other things, like availability of alternative energy sources).

The majority of the respondents agreed that data has an essential role in telling the story of climate change, helping refine choices, and informing stakeholders about the likely impacts of the options available (see Figure B1.3). It is facilitating the examination of the evidence of climate change that enables the identification of target(s) of key(s) parameter(s) of where we want to get (or what we want to avoid). However, the judgment on data availability seems divided (see Figure B1.4). The data's overall accuracy and reliability rating average of 7.4 out of 10 (see Figure B1.5). Still, the outcome of climate policies and responses seem unclear, where 36% assessed them as unsuccessful, 35% as either Neutral (7%), unknown (14%), or N/A (14%), while only 29% deemed them as successful (see Figure B1.6). The same is the potential for real-time climate data, where 41% see real-time climate data as an essential input for the measure of risks, losses, and impact for the development and implementation of the policymaking process. Stating that the evidence that can substantiate and justify long-term and in-depth investments and re-orientation of direction is beneficial for the population's defense and safeguard policies, 30% see no advantages, and 29% N/A. (see Figure B1.7).

Concerning policymaking/decision-making infrastructure, instrument(s), and tools to gather data, 57% of our respondents have access/ownership of such, 22% do not, and 21% N/A. (see Figure B1.8). Appraising it, from a scale of 0 to 10 (0=Never and 10= Always), on how often these are used, and the reliability, changes, and termination of the policies and responses, scoring a low average of 3.85 out of 10 (see Figure B1.9). Recommendations on expanding and developing further policy infrastructure, instrument(s), and tools were highlighted.

Regarding the climate policy paradigm (see Figure B1.10), 81% agree that these are expected to be flexible, durable, proactive, and robust as diverse sectors and activities have different impacts on the climate and the policy cycle. The same is true for regional and organizational differences. For this reason, it is highlighted that climate policies should be adaptable to each circumstance to be effective. One of the respondent's further stresses that these policies must enforce penalization and encouragement. Thus, it is necessary to track these policies' progress regarding their objectives and the current climate data to understand if the policy has the impact it was supposed to have. As monitoring, assessing, learning, and adapting are all essential to successfully dealing with uncertainty. The minority (19%) has "partially" denied this thought. Agreeing for flexibility and policy revision while disagreeing with the need for "rapid" changes. By the end of the questionnaire, we expose our respondents with the scenario of a project proposal of an IoT-5G Climate Monitoring Intelligent System (IoT-5G CMIS) as a potential policymaking/decision making infrastructure and instrument investment opportunity (see Annex C). The vast majority has displayed great interest and seen the advantages of the proposal. Advocating and recommending the testing of the IoT-5G CMIS on a small scale, in different settings and with different target audiences, to fully understand its policy capabilities.

Nevertheless, one of the respondents did not see the relevance of the technology mentioned above to the sufficiently known issue and understood it even before the Internet. Still, he has seen the positive side of the system. It may make some marginal contributions to addressing some of the issues (e.g., better climate modeling and instant observational data availability).

On the side of IoT-5G experts, the participants were asked to answer questions on the potential of IoT and 5G infrastructure as climate policymaking/decision-making instruments, and if an IoT-5G based system was the right approach to deploy an IoT system direct towards large rural, rural-urban, and urban areas (50 to 100 km), able to handle moving devices, provide quick, reliable, and constant data flow and end-to-end response for the gathering of climate data, and the monitorization and evaluation of climate-related activities, and policy impacts. From their perspective, all had agreed[22] that 5G network coverage,

[22] The actual result state that 80% of our respondents see 5G as the best infrastructure to deploy a climate change IoT system. Despite one of the respondents answering WiFi HaLoW as another suitor for the system, it still restated that 5G network is best suit for industrial or business use in larger scale.

availability, bandwidth, latency, among other feature, can pave the way to an IoT Climate Monitoring Intelligent System which requires extensive range, mobility, real-time response, etc. that might provide real-time data able to help policymakers/decision-makers to understand the effects and impacts of policies, allowing them to experiment on changes with immediate results that shall help them decide whether policies need further improvement or if they currently respond to the target need (see Figure B2.1 & B.2.2)**.** Additionally, it is easy to access. Exposure to many users and coverage areas improves its potentiality while also being economically viable by repurposing pre-existing 3G-4G infrastructure for the fast deployment of 5G networks.

The majority agree that the introduction of a 5G network will impulse the development of new technologies (e.g., remote control measuring sensors that collect real-time air quality data in any urban area) that could establish new policymaking infrastructure, instruments, tools, techniques, and services, potentially empowering the process. At the same time, a minority sees little to no impact (see Figure B2.3). Considering the ever-change climate paradigm conditions, all agree that climate policies must be flexible, robust, etc. (see Figure B2.4). They are asserting that these types of issues require tools that facilitate the implementation of fast adaptation. The power of real-time data would allow for the continuous monitoring and evaluation of the policy and decision process, potentially leading to improvement. Lastly, we presented the same project proposal of an IoT-5G Climate Monitoring Intelligent System (IoT-5G CMIS) as a potential policymaking/decision making infrastructure and instrument investment opportunity (see Annex C). Like their counterparts, the majority has displayed curiosity, interest, and the proposition's investment potential. They are stating that this type of solution is increasingly essential for society's survival and the planet. With better and more accurate insights from the surrounding environment, we can make better and more efficient decisions. More intelligent and suitable policies can be applied to be better understood and accepted by different stakeholders and decision-makers. In that case, investment decisions in those types of solutions would be easier to take.

Analyzing and comparing the results of the questionnaires, we can observe that both policymaking/decision making experts and IoT/5G experts mostly agree on the core subject matters of our exploratory research Expressing that the collection, analysis, and display of data plays a significant role in the decision making process among all stakeholders, foreseeing excellent investment and utility opportunities in emerging policy infrastructure, tools and instruments like the IoT-5G CMIS proposal.

5.2. Opportunities & Recommendations

By the end of 2025, it is expected for 5G oriented products and services to have over 2,6 billion subscriptions covering up to 65% of the world's population. Simultaneously, the number of cellular IoT connections expected to reach 5 billion worldwide. With an estimated value between $3.9 trillion to $11.1 trillion a year by 2025, only private and public entities cooperate. Thus, it is an excellent opportunity to adopt new technologies, innovation, and business concepts (Tamsons, A. 2020).

Furthermore, Ericsson (2018) has identified nine clusters of opportunity with over 200 individual use cases that can enable shared investments and resource allocation across a larger revenue pool that allows incrementing scalability across different industries and sectors (Ericsson, 2018). However, it is within the ambitions and deployment actions that will ultimately determine whether these cluster value opportunities are harnessed (see Figures E1) due to their "*(...) technical and operational deployment difficulty, as well as how challenging they are from a go-to-market perspective, compared to the current typical operator capabilities in these areas*" (Ericsson, 2018, p.5).

A niche market opportunity seems wide-open within data monetization from the primary and secondary data gathered and little market research. As we well know, data has become a precious product within our society, and, within this scenario, "*real-time data can be used to offer analysis and maintenance services in addition to the core business*" (Vodafone, 2020 p.7). Most emerging IoT business model data is not only used for internal optimization purposes but also sold to third parties for quality control improvement, predictive maintenance, production planning, market analyses, developing new manufacturing solutions, etc. (Vodafone, 2020).

While climate change and sustainability efforts are increasingly becoming one of our generation's most prominent concerns within all social aspects, including business priority, as seen in our literature review, suggesting that these efforts have become the biggest concert of our generation withing all social-economic aspects. In fact:

> "*Nowadays, a winning business is, to a large extent, defined by its capabilities to minimize its carbon footprint. (...)* [were], *technology innovations play an important role: adopting a smarter, more connected business model often brings energy efficiency as a side effect. Digital technologies such as 5G and IoT are predicted to reduce global emissions by up to 15% by 2030, which will be critical in combatting climate change*." (Tamsons, Å, 2020, paragraph 10).

The IoT and 5G base business concepts have been demonstrated to revolve, mostly, in the areas of automatization, monitorization, and tracking and enhancing services and products (see Figure E2). However, within this, the concept of a product-service oriented to individuals, private and public sectors empowers the engagement with the climate-related activities based on the monetization of climate data and data sharing (Vodafone, 2020). This business concept could potentially enable, promotes, reinforce, and supports the development, implementation, monitorization, evaluation, and comparison of climate-related policies and actions, poses an excellent niche venture opportunity for both private and public institutions, both financially and against the fight with climate change. Where the identification and prevention of foreseeable climate events and climate policies malfunctions by pattern recognition, asset performance management (e.g., risk minimization, process improvement, product improvement, increasing customer satisfaction), optimization of operations and actions, and the enablement of innovative, proactive business models and concepts revolving around climate data, sustainability adaptation, among other SDG's.

Concentrating ICT investment, development, and implementation, such as IoT and 5G systems, to combat climate change in rural, suburban, and rural areas could not only collectively promote sustainable, efficient, and equitable economic development in rural and rural-urban, and urban areas and activities but also have appealing prospective commercial usage as well as boosting the achievement of many of the SDG's (See Figure E3). Where both private telecommunication and technology enterprises and public entities form a partnership for the implementation of IoT-5G system cells and sensors within the areas mentioned above to track and monitor essential environmental and climate-related activities, information, and patterns through the gathering of environmental data (e.g., C02 levels, Water Quality, Soil Quality, etc.), Climate-related activities and situations (e.g., Agrobusiness and farming techniques, water consumptions, energy consumptions, environmental tracking, etc.) and improving citizens/consumer interaction. These could prove essential for developing sustainable businesses and efficient climate policies while simultaneously expanding the cellular communication reception in avoided areas, optimizing agricultural activities, gathering climate-data and climate-policy data results, and citizen/consumer within the policymaking process, and improving private-public relation and interactions.

A potential prospective are displayed in the enhancement of Private-Public partnerships, the acknowledgment, and profitability of climate data collection to fight climate change, the development of new business models based on climate and cybersecurity (e.g., climate consultancy, climate auditing, cybersecurity, etc.), development of climate policy portfolio, and even development of an interactive application for different types of users (consumer/citizen, private entity, public entity) offering climate-related information (e.g., c02 tracking, energy tracking, money-saving, etc.) and services regarding current products (e.g., e-bikes, e-scooters, car-sharing availability, and cost) and enhancement of policy and product development interaction (see Annex C).

Chapter 6. Conclusion

6.1. Main Conclusions

Like IoT and 5G systems, technological innovations have the potential to become a powerful instrument for policymakers/decision-makers on climate change. The policymaking process, particularly climate-related ones, seem to not be in pair with the impacts and effects of climate change. Research suggests that policymakers/decisionmakers' capabilities to handle the issue are obstructed, not only by their socio-economic and cultural biases and interest but also by the systemic reach and unique convoluted characteristics that englobe the climate paradigm (e.g., deadline to act, extensive temporal and spatial reach, irreversibility, dynamic changes). These policies seem to require further thought-process in their formulation to deal with the issues as mentioned above, requiring them to be *flexible*, so policymakers can manage to meet, some if not all, new social, technical, climatic, and environmental circumstances; *durable* so that they can address the long-term effects of climate change; *proactive*, so they may meet all the objectives and avoid negatives and neutral outcomes; and *robust*, so they may reach all sectors and stakeholders, as well as a global reach to deal with the systemic reach of climate change. However, these conditions are tough to meet due to the lack of policymaking infrastructure, instruments, tools, and techniques regarding climate-related data collection, curation, and storage, alongside the negligence in the policy cycle, specifically the monitorization, and evaluation of the policies, has, to some degree, inhibited the accomplishment of sound and effective climate policies. Where the potential of continuous monitoring and evaluation of these policies could aid to rapidly detect change(s) in assumption(s), variable(s), or/and uncertainties(s) to adapt or correct desire policy outcomes.

This exploratory research has exposed a potential niche opportunity for both the private and public sectors. As the focus and manner of how we handle climate change and climate-related activities and events are already being considered, the future of our socio-economic progress to propel a green/sustainable society. Inevitably, this will heavily rely on the provision of accurate, precise, and reliable climate-related data and trends, propelling to the development of climate policies, actions, responses, services, and products, as well as new business opportunities and concepts.

Lastly, this research aims to contribute to the design of the technical architecture for policymakers. The assessment of climate change and climate-related activities in real-time may enable the correlation of various data obtained by sensors, display the evolution of climate trends, and automatically produce corrective actions, measures, and recommendations to reverse undesirable trends and impacts cross-regional and cross-sectoral level.

6.2. Future Work

It is recommended, based on this exploratory study, for a multi-disciplinary examination of the real potential of IoT-5G technologies directed, not only towards policymakers/decisionmakers, but to all stakeholders, on climate policies, but also on to other policies, as they seem not to hold adequate infrastructure, instrument(s), tool(s), and techniques that can assist the policy cycle. Other studies on the potential socio-economic and environmental impact through research, development, and testing of potential prototype systems (as proposed in the recommendation section) to fully identify and comprehend the potential of these in the climate policy cycle could lead to the execution of useful and, perhaps, vital instruments for the coming decades.

Therefore, experimental research and development on these applications are deemed critical for stakeholders, as it is highly recommended. Future research could lead to potential performance breakthroughs in this area while also expanding to other areas of interest. It contributes to identifying key trends and patterns for innovating, refreshing, and successful sustainable strategies, products and services, and business opportunities for all sectors and disciplines.

Chapter 7. Bibliography

ACAPS (2012), “*Qualitative and Quantitative Research Techniques for Humanitarian Needs Assessment: An Introductory Brief*”, Access on 05/07/2020. https://www.acaps.org/sites/acaps/files/resources/files/qualitative_and_quantitative_research_techniques_for_humanitarian_needs_assessment-an_introductory_brief_may_2012.pdf

Arvai, J., Bridge, G., Dolsak, N. *et al.* (2006). “*Adaptive Management of the Global Climate Problem: Bridging the Gap Between Climate Research and Climate Policy*”, *Climatic Change* 78, 217–225. https://doi.org/10.1007/s10584-006-9094-6.

Alkandari A., Alabduljader Y., Moein S.M. (2012), “*Water Monitoring System Using Wireless Sensor Network (WSN): Case study of Kuwait Beaches*”, Proceedings of the 2012 Second International Conference on Digital Information Processing and Communications (ICDIPC); Klaipeda City, Lithuania. 10–12 July 2012; pp. 10–15.

Al-Sarawi, S. et.la. (2017), “*Internet of Things (IoT) Communication Protocols: Review*,” 8th International Conference on Information Technology, Universiti Sains Malaysia, Penang, Malaysia.

Barkdull, J. (2017), “*Environmental Policy and Foreign Policy*,” Cameron *Environmental Policy and Foreign Policy* Thies(ed.).Oxford Research Encyclopaedia of Foreign Policy Analysis, Oxford University Press, Access in 04/04/2020 http://politics.oxfordre.com/view/10.1093/acrefore/9780190228637.001.0001/acrefore-9780190228637-e-365.

Barkenbus, J. (1998), “*Expertise and Policy Cycle*,” Energy, Environmental, and Resource Center, The University of Tennessee.

Chieochan, O. Saokaew, A. & Boonchieng, E. (2017), “*IOT for Smart Farm: A case study of the Lingzhi Mushroom Farm at Maejo University*”, 1*4th International Joint Conference on Computer Science and Software Engineering (JCSSE)*, Nakhon Si Thammarat, 2017, pp. 1-6, DOI: 10.1109/JCSSE.2017.8025904.

Creswell, J.W. (2013), “*Qualitative Inquiry & Research Design: Choosing Among Five Approaches*,” Third Ed. SAGE, London.

Creswell, J.W. (2014), “*Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*,” Fourth Ed. SAGE, London

Dessai, S. & Sluijs, J. (2007), “*Uncertainty and Climate Change Adaptation – a Scoping Study,”* Copernicus Institute, University of Utrecht, Netherlands.

Doukas, H. & Nikas, A. (2019), “*Decision Support Models in Climate Policy,”* Elvesier European Journal of Operational Research 280. P. 1-24.

EBRD (2011), "*The Low Carbon Transition*," Special Report on Climate Change, Grantham Research Institute on Climate Change and the Environment. Pp. 38-70.

Earth Institute at Columbia University (2017) "*How Information and Communications Technology can Accelerate Action on the Sustainable Development Goals. ICT & SDGs Final Report*", Ericsson, the International Telecommunications Union (ITU), and the GSMA.

Ericsson (2018), "*The Guide to Capturing the 5G Industry Digitalization Business Potential"*, Access on 14/08/2020. https://www.ericsson.com/assets/local/networks/documents/report-bnew 18001324.pdf?_ga=2.197593576.696602222.1603646188-1041799427.1603646188.

Eze, K. Sadiku, M. & Musa, S. (2018), "*5G Wireless Technology: A Primer*", International Journal of Scientific Engineering and Technology Vol No.7, Issue Np. 7, pp.62-64.

Govender, S. (2010-2011), "*What Type of Information are Needed for Climate Change Adaptation Decision-Making in Africa*", World Resource Report 2010-2011: Expert Perspectives (Word Resource Institute eds.) Accessed on 06/02/2020. https://www.wri.org/our-work/project/world-resources-report/what-types-information-are-needed-climate-change-adaptation

Goundar, S. (2012), "*Chapter 3 - Research Methodology and Research Method*" Accessed on 06/07/2020. https://www.researchgate.net/publication/333015026_Chapter_3_-_Research_Methodology_and_Research_Method

Gokhale, P. Bhat, O. & Bhat, S. (2018), "*Introduction to IOT*," International Advanced Research Journal in Science, Engineering and Technology, Vol. 5, Issue 1.

Grigorik, I. (2013), "High Performance Browser Networking," O'Reilly Media,

Hardion, V. et.la (2013), "*The Internet of Things and Control System*," Software Technology Evolution Proceedings of ICALEPCS, San Francisco, California, USA.

Hascic, I, et al. (2010), "*Climate Policy and Technological Innovation and Transfer: An Overview of Trends and Recent Empirical Results*" OECD Environment Working Papers Nº30, https:/dx.doi.org/10.1787/5km33bnggcd0-en.

History, (2017), "*Climate Change History*," A&E Television. https://www.history.com/topics/natural-disasters-and-environment/history-of-climate-change. Access in: 20/04/2020

Hove, S. (2000), "*Participatory Approaches to Environmental Policy-Making: The European Commission Climate Policy Process as a Case Study*", Ecological Economics, Vol. 3, Issue 3. Pp.457-472.

Hulme, M. (2017), "*Climate Change, concept of"* The International Encyclopaedia of Geography. John Wiley & Sons, Ltd. DOI: 10.1002/9781118786352.wbieg0343.

IPCC (2014), "*Climate Change 2014 Synthesis Report Summary for Policymakers*". Accessed in 10/02/2020 https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_SPM.pdf

IPCC, (2018) "*Annex I: Glossary*" [Matthews, J.B.R. (ed.)]. In: Global Warming of 1.5°C. An IPCC Special

Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. In Press

Jackson, S.T. (2018), "*Climate Change*," Encyclopaedia Britannica Inc. Access Date: 28/01/2020. https://www.britannica.com/science/climate-change.

Jann, W. &Wegrich K. (2007), "*Theories of Policy Cycle*," In Handbook of public policy analysis: Theory, Politics and Methods, Chapter 4, pp. 43-62.

Koteyko, N. Nerlich, B. & Hellsten, I. (2015), "*Climate Change Communication and the Internet: Challenges and Opportunities for Research*", Environmental Communication, 9:2, 149-152, DOI: 10.1080/17524032.2015.1029297.

Köhler, J et al. (2019), "*Environmental Innovation and Societal Transitions*," Vol. 32, pp.1-32. https://doi.org/10.1016/j.eist.2019.01.004.

Kraunenburg, R. & Bassi, A. (2012), "*IoT Challenges*", Communications in Mobile Computing, *mUX J Mob User Exp* Vol.1, nº9. https://doi.org/10.1186/2192-1121-1-9

Knill C. & Tosun J. (2008), "*Policy Making*," Daniele Caramani (ed.), Comparative Politics. Oxford: Oxford University Press, pp. 495-519.

Le Treut, H., R. Somerville, U. Cubasch, Y. Ding, C. Mauritzen, A. Mokssit, T. Peterson, & M. Prather, (2007) "*Historical Overview of Climate Change*" In Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA

Levin, K. Cashore, B. Berstein, S. & Auld, G. (2012), "*Overcoming the Tragedy of Super Wicked Problems: Constraining our Future Selves to Ameliorate Global Climate Change*", Policy Science. Nº45 pp.123-152 https://doi.org/10.1007/s11077-012-9151-0

Lundgren, C., Åkerman, M., Bärring, M. et al. (2018), "*Challenges Building a Data Value Chain to Enable Data Driven Decisions: A Predictive Maintenance Case in 5G-Enabled Manufacturing*", Procedia Manufacturing, 17:411-418http://dx.doi.org/10.1016/j.promfg.2018.10.064

Liverman, D. (2010-2011), "*Informing Adapting,*" in World Resource Report 2010-2011: Expert Perspectives (Word Resource Institute eds.) Accessed on 03/02/2020. https://www.wri.org/our-work/project/world-resources-report/informing- adaptation

Makarau, A. (2010-2011), "*Decision Making in a Changing Environment*," as in World Resource Report 2010-2011: Expert Perspectives (Word Resource Institute eds.). Accessed on 04/02/2020. https://www.wri.org/node/40274

Mohammad Meraj ud in Mir et al. (2015), *"Evolution of Mobile Wireless Technology from 0G to 5G"*, International Journal of Computer Science and Information Technologies, Vol. 6 (3) pp. 2545-2551.

Mois, G. Folea, S. & Sanislav, T. (2017), "*Analysis of Three IoT-Based Wireless Sensors for Environmental Monitoring*", IEEE Transactions on Instrumentation and Measurement, Vol. 66, Nº 8.

NASA (n.a.), "*Overview: Weather, Global Warming and Climate Change*," Accessed in 10/01/2020 https://climate.nasa.gov/resources/global-warming-vs-climate-change/.

National Research Council (2010), "*Advancing the Science of Climate Change,"* Washington, DC: The National Academies Press. pp.19-26; 83-90; 91-150; 151-180 & 401-420. DOI: 10.17226/12782.

NGMN (2015), "*5G White Paper*", Rachid El Hattachi/ Javan Erfanian (Ed.), Version 1.0.

OECD (2007), "*Climate Change Policies*," Policy Briefs, Climate Change Policies. Accessed in: 04/06/2020. http://www.oecd.org/env/cc/39111309.pdf

O'Donnel, B. (2020), "*5G Latency Improvements Are Still Lagging*", Forbes. Accessed in 21/08/2020 https://www.forbes.com/sites/bobodonnell/2020/02/18/5g-latency-improvements-are-still-lagging/#256bee648f10

O'Leary, Z. (2017), "*The Essential Guide to Doing Your Research Project*" (3rd Ed.). London: SAGE. ISBN 978-1-4739-5207-2.

Patel, K.K. & Patel, M.S. (2016), "*Internet of Things-IOT: Definition, Characteristics, Architecture, Enabling Technologies, Application & Future Challenges*", International Journal of Engineering Science and Computing, Vol. 6 Nº5.

Peterson, E.R. (2018), "*5G is the Key to Future American Competitiveness*", A. T. Kearney, Global Busines Policy Council (GBPC). Accessed in: 10/02/2020 https://www.kearney.com/web/global-business-policy-council/article/?/a/5g-is-the-key-to-future-american-competitiveness.

Rahman, M.I. (2012), "*Climate Change: A Theoretical Review,*" School of Geography and Environmental Science, Monash University. Melbourne, Australia. DOI: 10.7906/index.11.1.1.

Rao, S. K. & Prasad, R (2018), **"***Impact of 5G Technologies on Smart City Implementation*" In: Wireless Personal Communications, Vol. 100, No. 1. Pp. 145-159.

Roelich, K. & Giesekam, J. (2019), "*Decision Making Under Uncertainty in Climate Change Mitigation: Introducing Multiple Actor Motivations, Agency, and Influence*", Climate Policy, 19:2, 175-188, DOI: 10.1080/14693062.2018.1479238.

Rowley, J. (2002), "*Using Case Studies in Research*," Management Research News, Vol. 25 Nº 1. Pp. 16 - 27.

Sala, S. (2009), "*Information and Communication Technologies for Climate Change Adaptation, with a Focus on the Agricultural Sector"*, Università degli Studi di Milano Crop Production Department.

Sethi, P & Sarangi R.S. (2017), "*Internet of Things: Architectures, Protocols and Applications,"* Hindawi, Journal of Electrical and Computer Engineering, https://doi.org/10.1155/2017/9324035.

Street, R. (2010-2011), "*What Type of Information are Needed for Adaptation in Decision-Making,"* World Resource 2010-2011: Expert Perspectives. Accessed in 05/02/2020 https://www.wri.org/node/40272

Studinka, J. & Guenduez, A.A. (2018), "*The Use of Big Data in the Public Policy Process: Paving the Way for Evidence-Based Governance*", Smart Government Lab, Institute for Public Management and Governance, University of St.Gallen, St.Gallen, Switzerland.

Shodhganga (2015), "*Research Methodology*," In "An Empirical Analysis On Customer Relationship Management Practices in Selected Organized Retail Outlets Special Reference to Indore Region" [Shandilya, R. 2015], Chapter 9, pp.77-121, Shri Jagdishprasad Jhabarmal Tibarewala University, Faculty of Commerce & Management.

Swedberg, R. (2018), "*On the Use of Exploratory Research and Exploratory Studies in Social Science*, " Gerringm J. Elman C. & Mahoney, J. (eds)in "Producing Knowledge

Scheraga, J.D. Elbi K.L. Furlow, J. & Moreno A.R. (1996), "*From Science to Policy: Developing Responses to Climate Change,"* Climate Change and Human Health – Risks and Responses, Chapter 12. Pp. 237-266.

Sureshkumar P.H (2018), "*The Analysis of Different Types of IoT Sensors and security trend as Quantum chip for Smart City Management*," IOSR Journal of Business and Management (IOSR-JBM)20.1. pp. 55-60.

Singh, C. et.la. (2018), "*The Utility of Weather and Climate Information for Adaptation Decision-Making: Current Uses and Future Prospects in Africa and India*", Climate and Development, 10:5, 389-405, DOI: 10.1080/17565529.2017.1318744.

Tamsons, A. (2020), "*How 5G and the Internet of Things Can Create a Winning Business*", World Economic Forum, Global Agenda 5G.

The Royal Society (2020), "*Climate is always changing. Why is Climate Change of Concern Now?"* in Climate Change: Evidence and Causes [The Royal Society eds]. Access in 15/01/2020. https://royalsociety.org/~/media/royal_society_content/policy/projects/climate-evidence-causes/climate-change-evidence-causes.pdf

Vodafone (2020*), "Vodafone Business 5G E-book*", 5GWhitePaper, Vodafone Business. Accessed in 23/05/2020.https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwi53orModDsAhWrDWMBHfZKCDwQFjAAegQIBhAC&url=https%3A%2F%2Fwww.vod

afone.com%2Fbusiness%2Fmedia%2Fdocument%2F1508881379643%2Fvodafone-business-5g-ebook.pdf&usg=AOvVaw2sQhGTrskb-5ikE-qDsGQe

UN (2018), "*UN Secretary Generals: Strategy of New Technologies*," Accessed on 21/03/2020. https://www.un.org/en/newtechnologies/images/pdf/SGs-Strategy-on-New-Technologies.pdf

UN (1992)," United *Nations Framework Convention on Climate Change,"* Accessed on 13/01/2020. https://unfccc.int/files/essential_background/background/publications/htmlpdf/application/pdf/conveng.pdf

Wardekker, A. (2011), "*Climate Change Impact Assessment and Adaptation Under Uncertainty*," Utrecht University, Netherlands.

Warren, D. & Dewar, C. (2014), "*Analysis Understanding 5G: Perspectives on Future Technological Advancements in Mobile*". GSMA Intelligence. Accessed in: 02/10/2020 https://www.gsma.com/futurenetworks/wp-content/uploads/2015/01/Understanding-5G-Perspectives-on-future-technological-advancements-in-mobile.pdf

Wellstead, A. & Stedman, R. (2015), "*Mainstreaming and Beyond: Policy Capacity and Climate Change Decision-Making*," Vol.3. http:/dx.doi.org/10.3998/mjs.12333712.0003.003.

WMO (2019), "*WMO Statement on the State of the Global Climate in 2019*", WMO-No 1248. Geneva, Switzerland.

World Resource Institute (2011), "*World Resource Report 2010-2011: Decision-Making in a Changing Climate*", ISBN: 978-1-56973-774-3

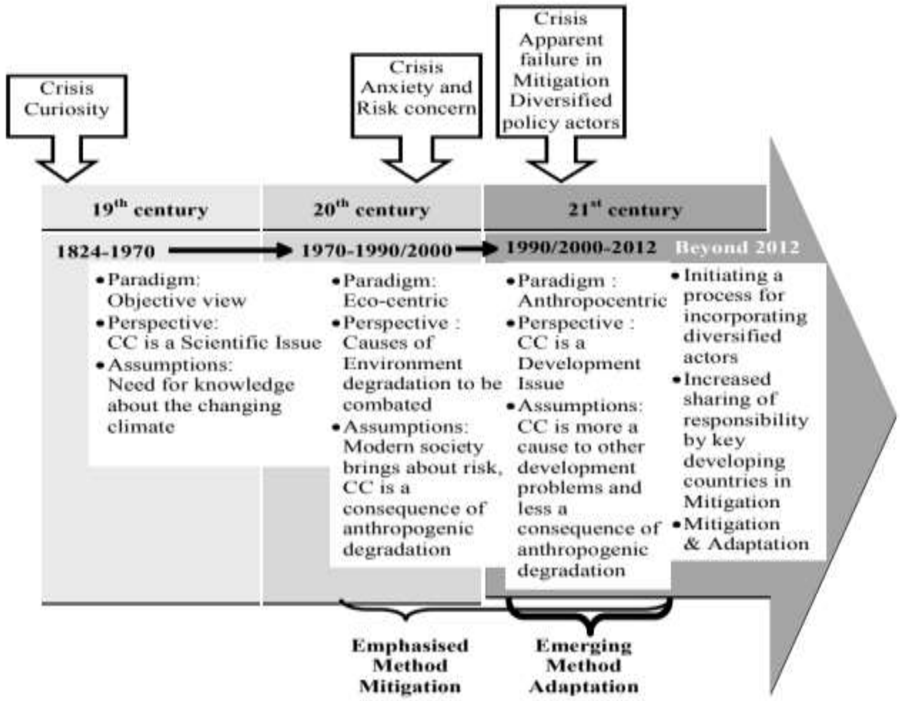
Yang, T. et.la. (2018), "*Cyber-Physical-System-Based Smart Water System to Prevent Flood Hazards,"* Journal *Smart Water* Vol, 3, Nº 1. https://doi.org/10.1186/s40713-018-0008-3.

Zambrano-Barragan, C. (2010-2011), "*Decision-Making and Climate Change Uncertainty: Setting the Foundation for Informed and Consistent Strategic Decision*", World Resource Report 2010-2011: Expert Perspective (Word Resource Institute eds.). Accessed on 01/02/2020. https://www.wri.org/node/36856

Chapter 8. Annexes

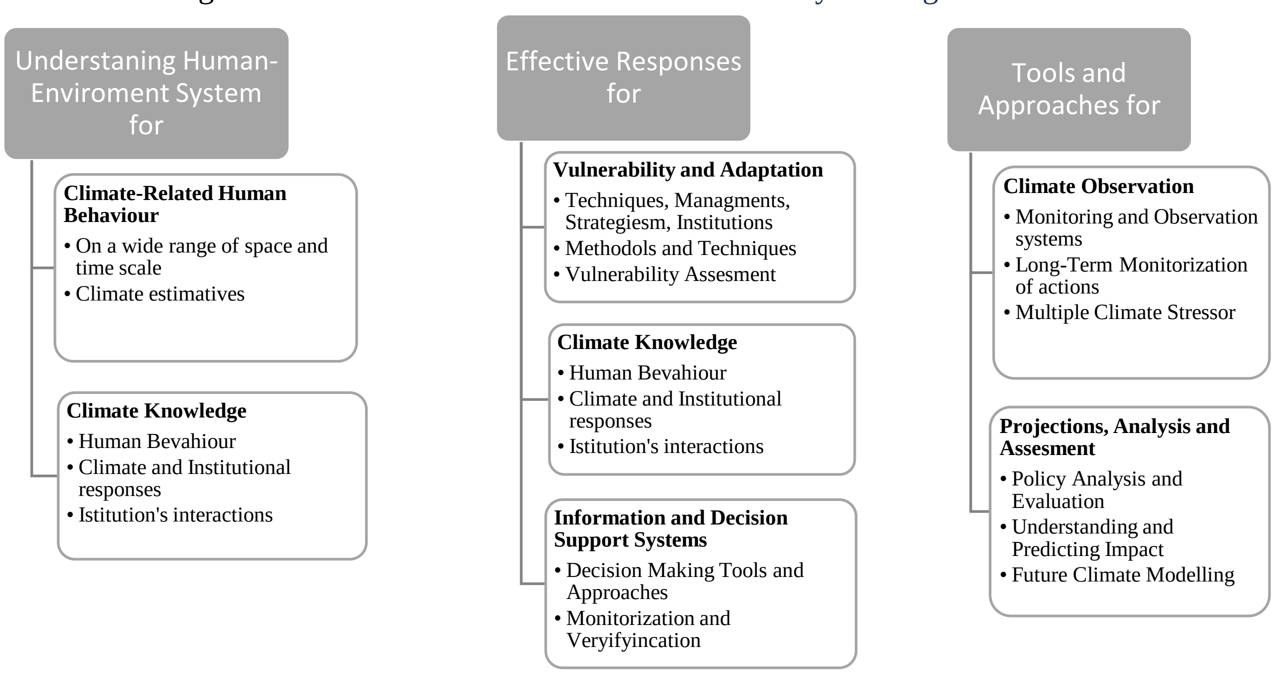
Annex A. Graphics and Tables

Figure A1.1. – Timeline of Climate Discourse Approach



Source: Climate Change: A Theoretical Review" (Rakhman, M.I. 2012)

Figure A1.2. - Areas of Interests for Climate Policy Making



Source: Based on National Research Council (2010), pp.92-150.

Figure A1.3. - Climate Change Characteristics and Policy Requirements

Climate Change Characteristics	Policy Requirements
Complexity	Innovation in technology, laws, and policies. The proliferation of Climate Knowledge
Conflict of Interest	Conflict resolution through the involvement of all afflicted actors. A partnership between International, Private, and Public Institutions.
Uncertainty	Flexible, adjustable, but robust policies. Further technological and infrastructural support for the policymaking process. Development of a climate policy portfolio
Dynamic changes	Malleable, robust, and dynamic policies.
Large Temporal and Spatial Scales	Involvement from all concerned actors into a non-short, oriented approach.
Irreversibility	Proactive response. Gathering and curation of climate-related data for the development of tendencies.

Source: Based on Makarau, A. (2010-2011); Govender, S. (2010-2011); Zambrano-Barragan, C. (2010-2011); Roelich, K. & Giesekam,J. (2019).

Figure A1.4 - Internet of Things Communication Infrastructures°

Communication Infrastructure	Data Rate	Range	Application	Power	Latency
6lowPAN	<= 250 kbps	Short Range 10 – 100 m	Monitoring and control	Low power	25<= 200ms (a)
Zigbee	<= 250 Kbps	Short Range 10 – 100 m	Home & Industrial monitoring and control	Low power	<= 200ms (b)
BLE	125kbps <= 2 Mbps	Short Range 15 – 100 m	Personal and Home Appliances	Low Power (c)	50 <= 400ms (c)
NFC	106 <= 424 Kbps	Very Short Range 0 – 1 m	Payment and Access	Very Low Power	N/A (e)
SigFox	100 – 600 Bps	Long Range 10 -50 Km	Street Lighting, Energy Meters	Medium Power	150-250 ms
Cellular (2G/3G/4G)	14.4. Kbps - 300Mbps (f)	Very Long Range	M2M	High Power	2-12 ms
WiFi HaLow	N/A (e)	<=1 Km	N/A (e)	N/A (e)	<=100 ms

Source: Based on Silicon Labs, (n.a.); Al-Sarawi et.la. (2017); Sethi, P. & Sarangim, S.R. (2017); Seferagic, A. etl.la. (2019) & Lenders, M. (2019).

(a)Values based around SDN Architectures (Miguel, L.F. M. et.la. 2018) and Scaling Fragmentation method (Lenders, M. et.la. 2019).

(b) This value is only applicable up to 192 node networks (devices). If the network, distance, and packet payload scale up, the latency will increase. The latency will max-out to undesirable levels if there is a broadcast interval lower than 1 second. (Silicon Labs, n.a).

(c) Values differ depending the number of devices that are interacting and the packet payload. The more BLE devices with independent piconets are interacting, it will lead to a spike in energy consumption and latency (Treuniert, J.J. et.la. 2017).

(e) Value not available.

(f) Values are based on all the Cellular generation, where the lowest value represents 2G (14.4 Kbps), the middle is 3G (14.4.-31Kbps) and the maximum value represents 4G (100- 300 Mbps) (Mohammad Meraj ud in Mir et al. 2015. Eze, K. Sadiku, M. & Musa, S. 2018).

Figure A1.5. – Cellular Network Generation Performance

Generation	Year	Features	Speed	Bandwidth	Latency	Energy
1G	1980s	Basic voice communication service. Analog Based	14.4 kbp/s	2-30kHz	N/A (a)	High
2G	1990S	Digital Standard and Voice Communication Services	9-14.4 kbps	30-200kHz	300-1000ms	High
3G	2000s	Voice, Data, and Multimedia services. Smartphone and streaming support	14.4 - 31 kbps	256kHz-1.25MHz	100-500ms	High
4G	2010s	Highspeed, HQ voice-over, HD Multimedia. Worldwide Roaming. 3D and VR support	100-300 Mbps	1.4-20 MHz	20-100ms	High
5G	2020s	Super-fast low latency network. IoT services, security, and surveillance. UHD multimedia, streaming, real-time data, and mobility	1-35 Gbps	700Mhz-Sub-1GHz	1-12ms	Low

Source: Based on Grigorik, I. (2013); Net-Informations (2020);; O'Donnel, B. (2020); Qualcomm (2020)

(a) Value not available.

Annex B. – Questionnaires Results

Annex B1. - Policymakers & Decision-Makers Questionnaire

Figure B1.1. – Characteristics and Issues of Climate Change

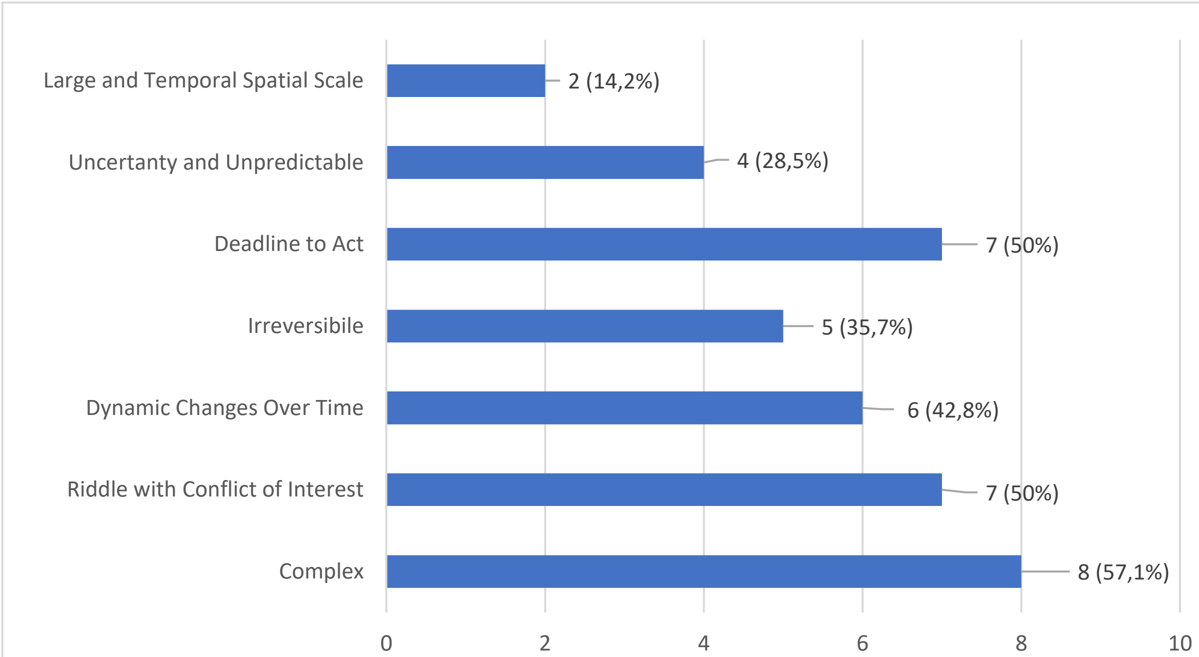


Figure B1.2. – Availability of relevant climate data for the development of climate policies and responses

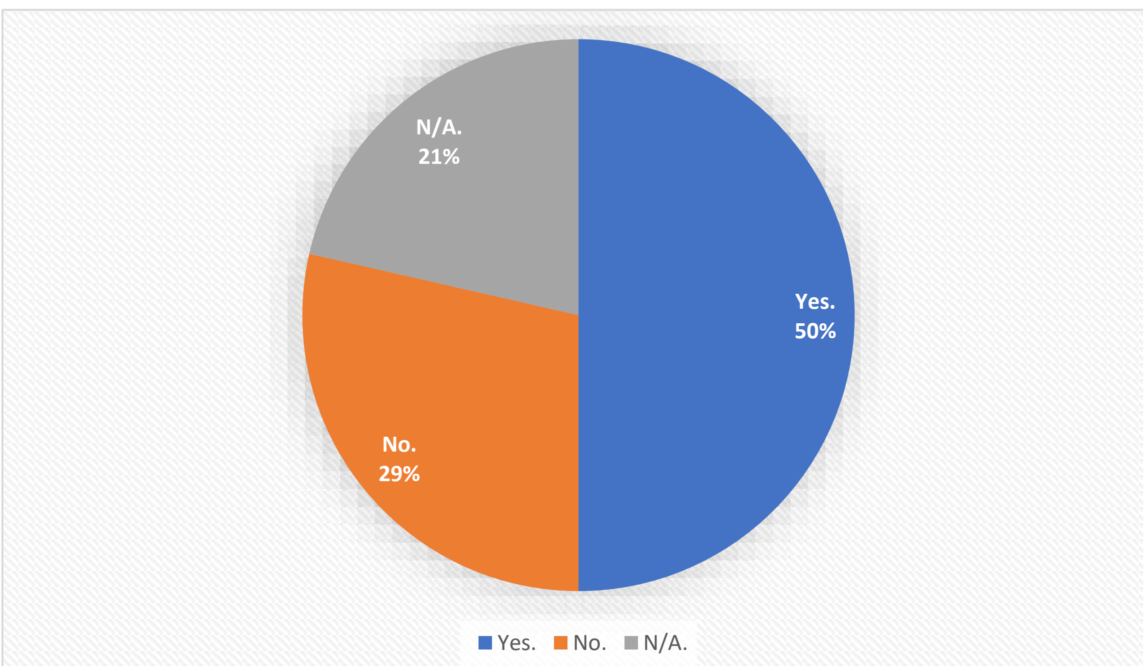


Figure B1.3. - Climate Data aid in shaping, informing, designing, and implementing the climate policy process

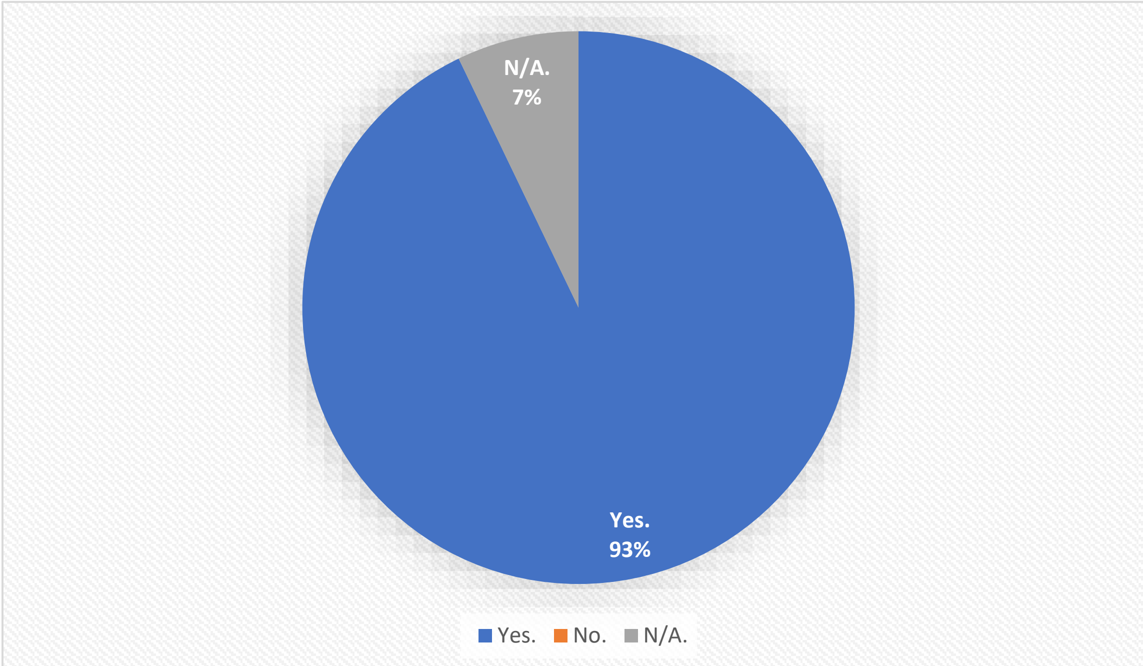


Figure B1.4. – Is Climate Data Available in a Comprehensible Way?

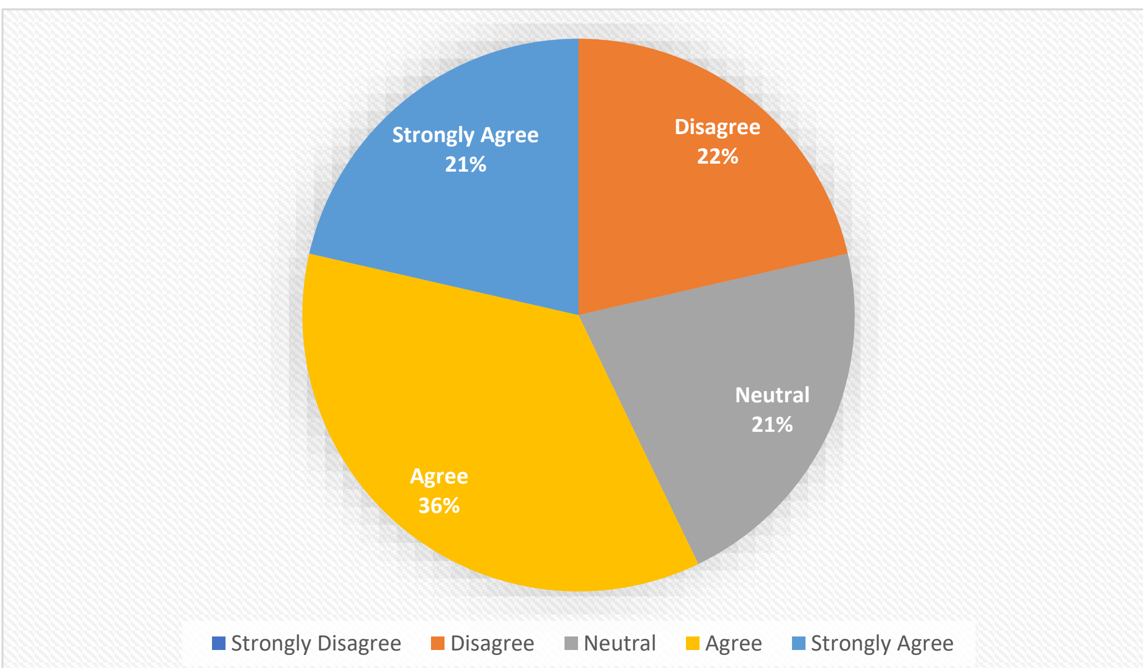
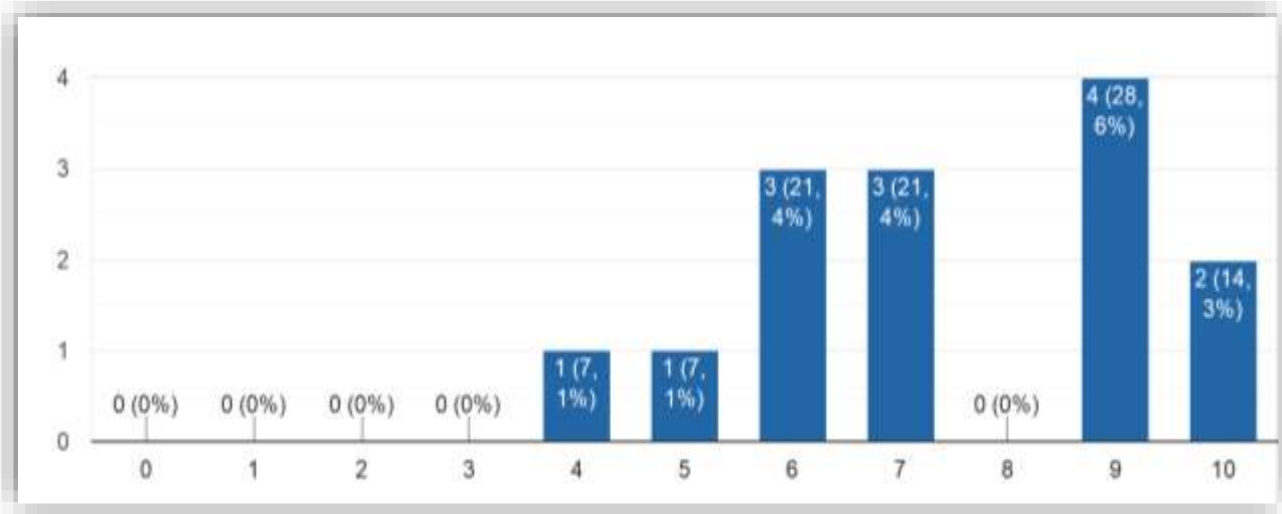


Figure B1.5. – Scale of Accuracy and Reliability of Climate Data



X = Accuracy and reliability Score ;Y = Nº of respondents

Figure B1.6. – Climate Policy and Response Outcome Evaluation

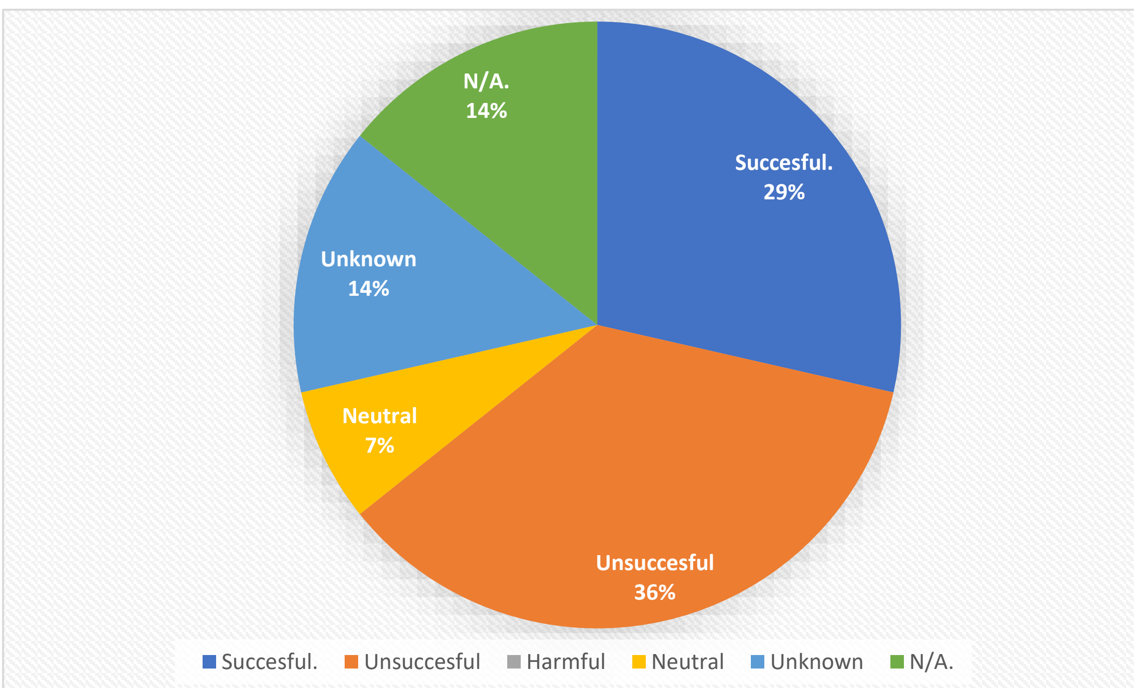


Figure B1.7. – Advantage in Real-Time Climate Data

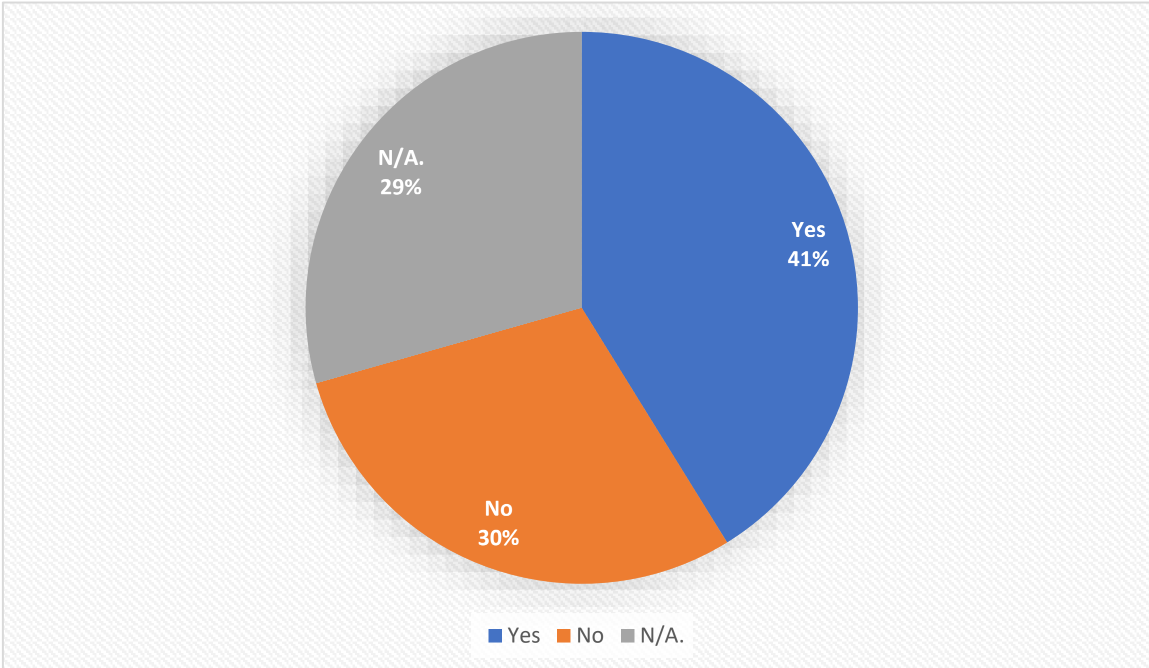


Figure B1.8. – Possession of Climate Policymaking Infrastructure, Instrument(s) and/or Tool(s)

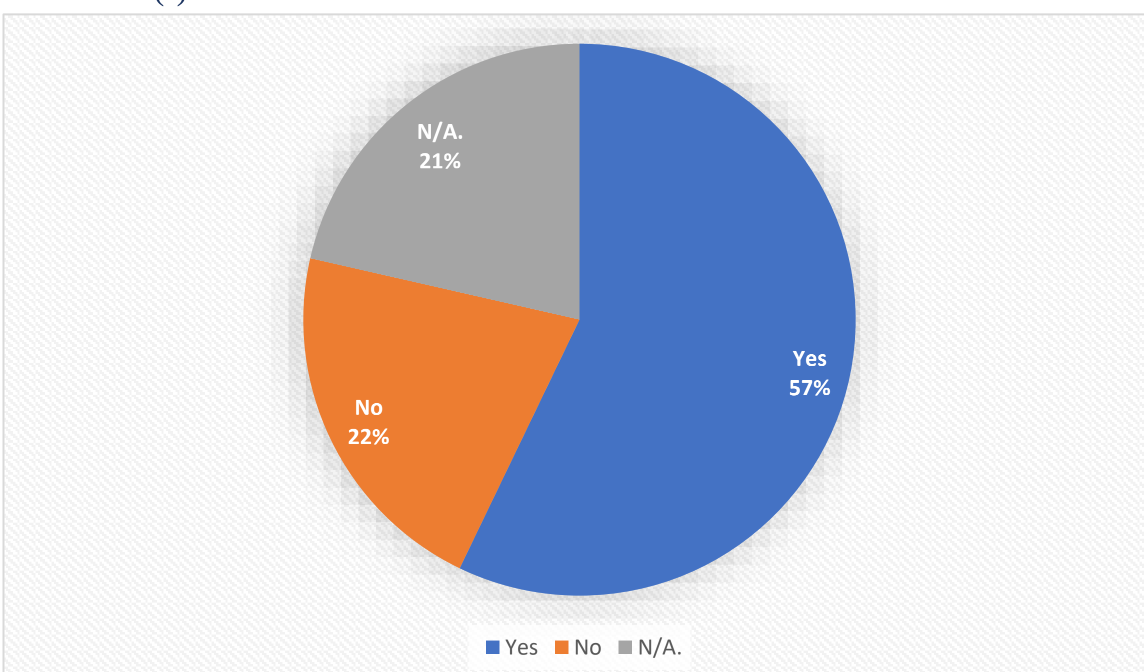
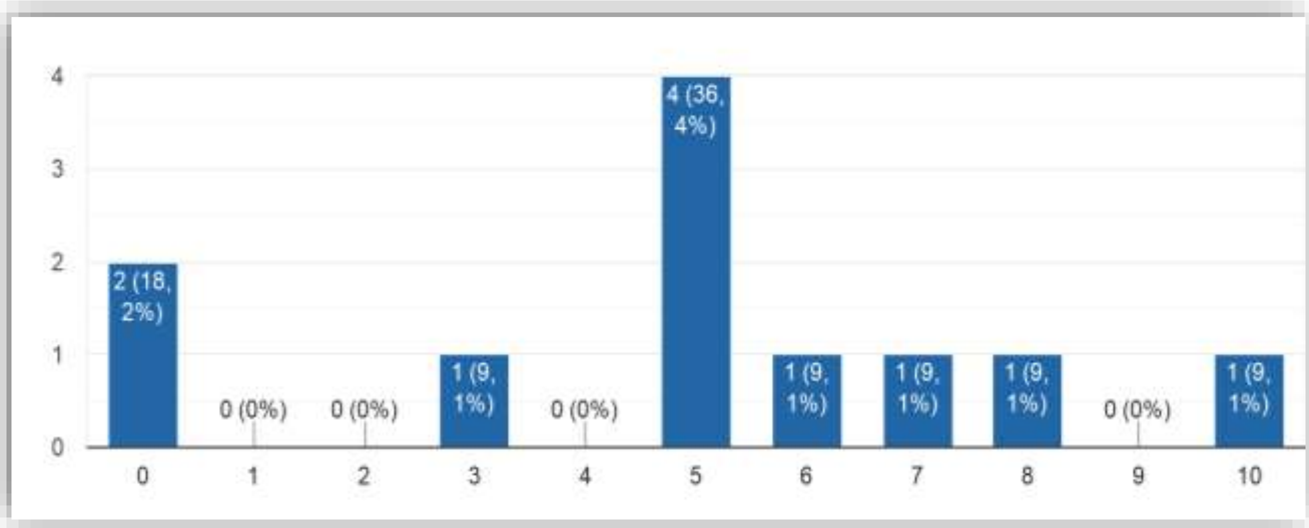
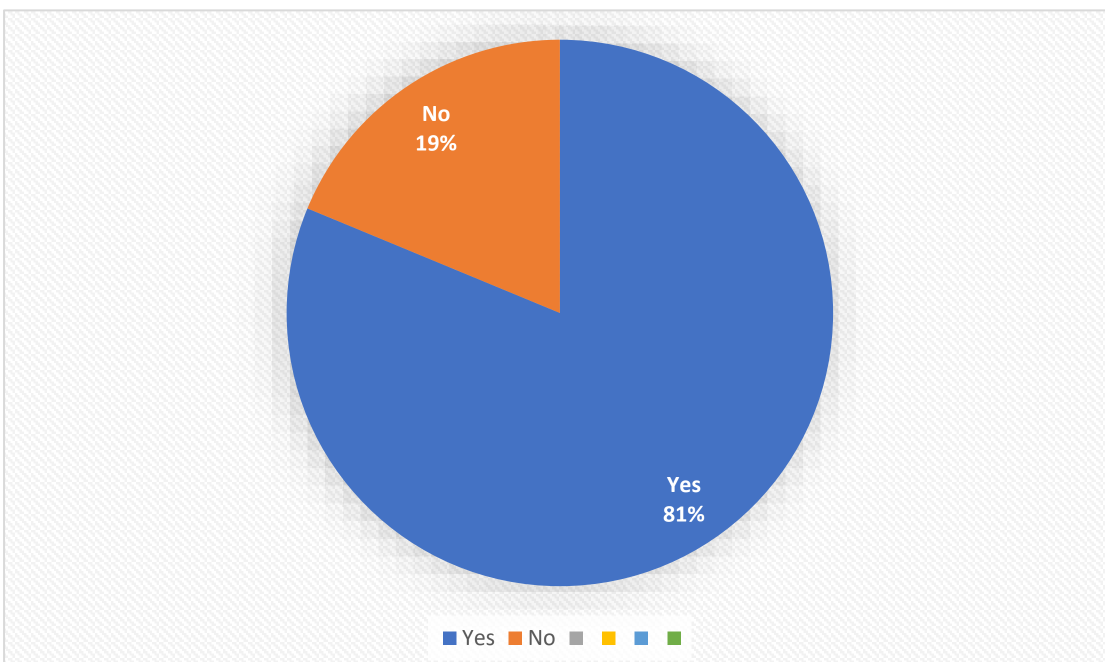


Figure B1.9. – Scale of Policy Instruments Reliability.



X = Scale of Reliability; Y = Nº of respondents

Figure B1.10. Climate policies must be flexible (…), durable (…), proactive (…), and robust (…). [Can] continuous monitoring and evaluation adapt or correct the desire policy outcome?



Annex B2. IoT and 5G Experts

Figure B2.1. – IoT Communication Infrastructure Preference

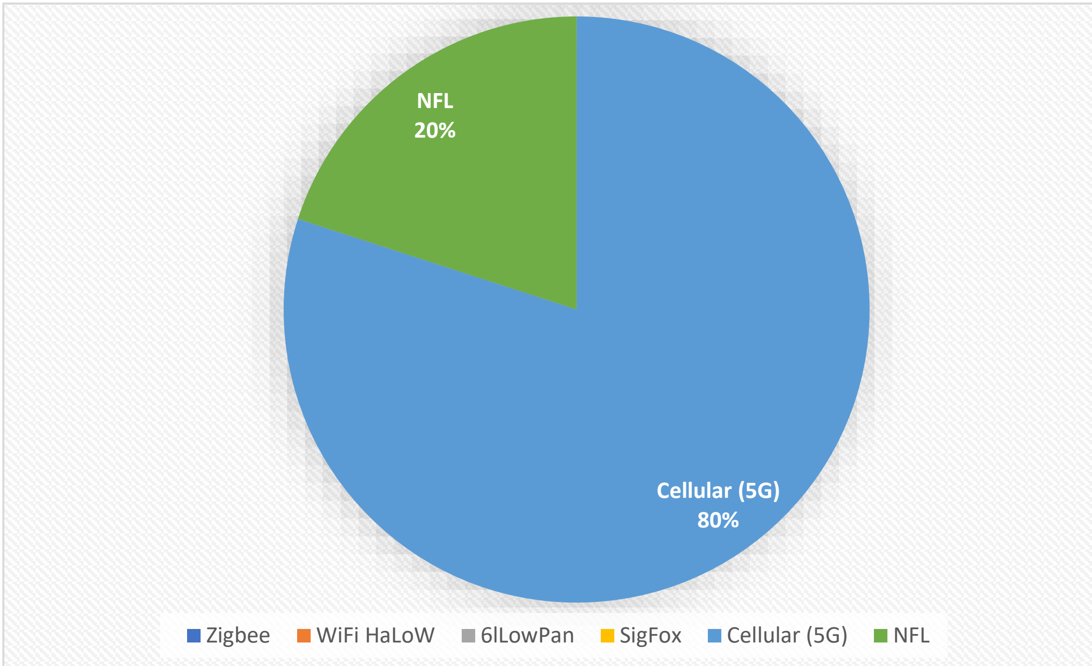


Figure B2.2. - Is real-time data advantageous for policymakers?

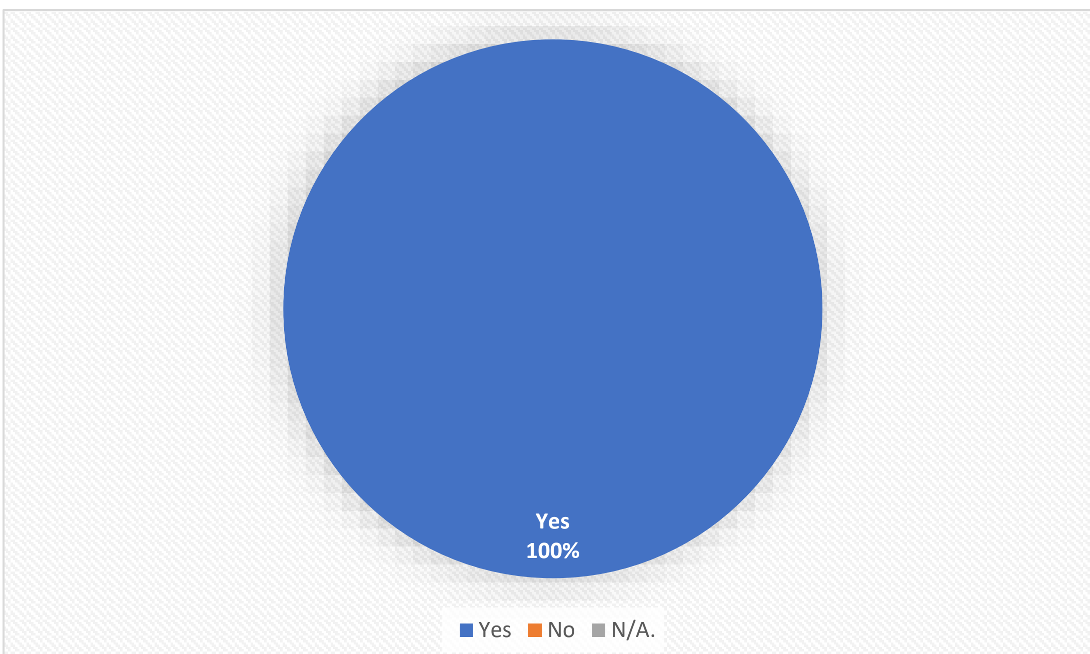


Figure B2.3. – Can 5G Network have an Impact on the Policymaking Process?

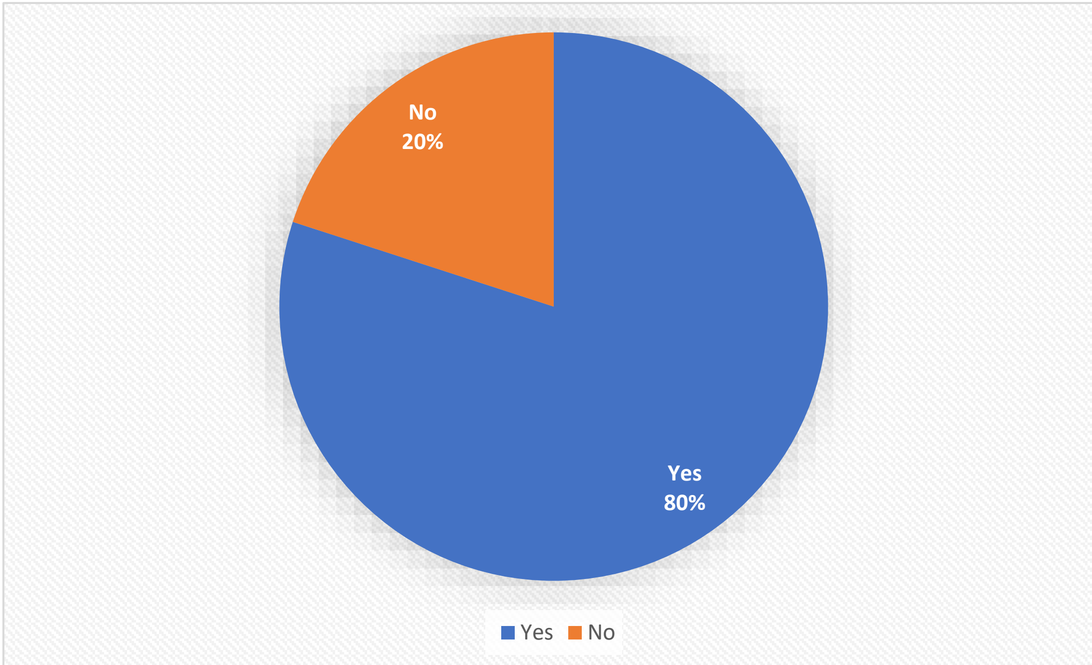
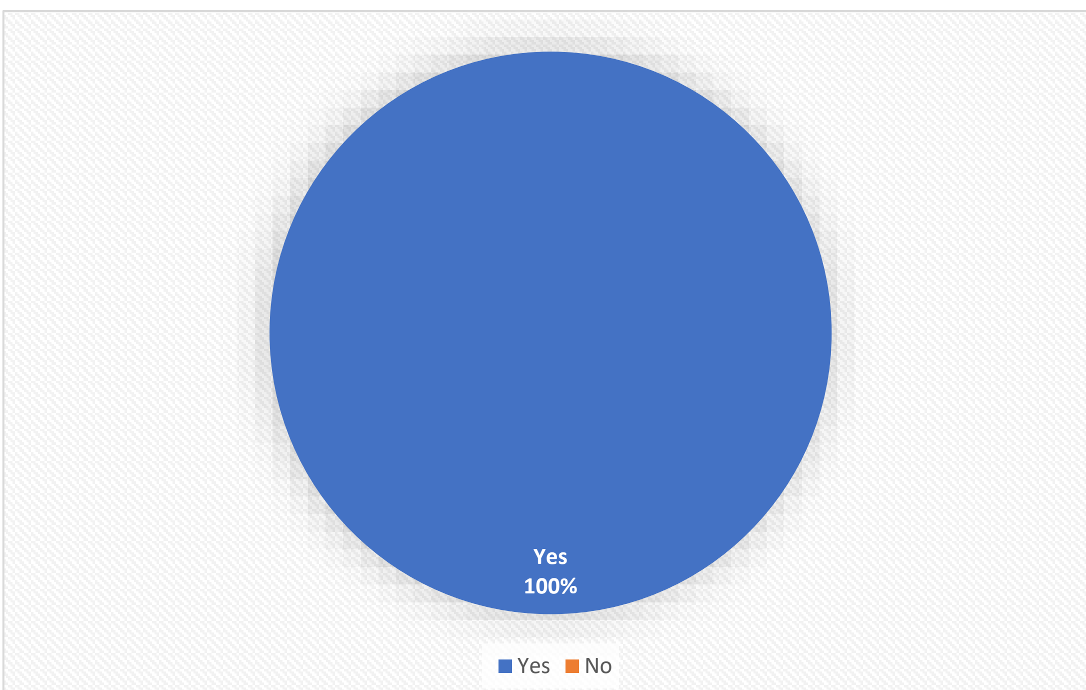
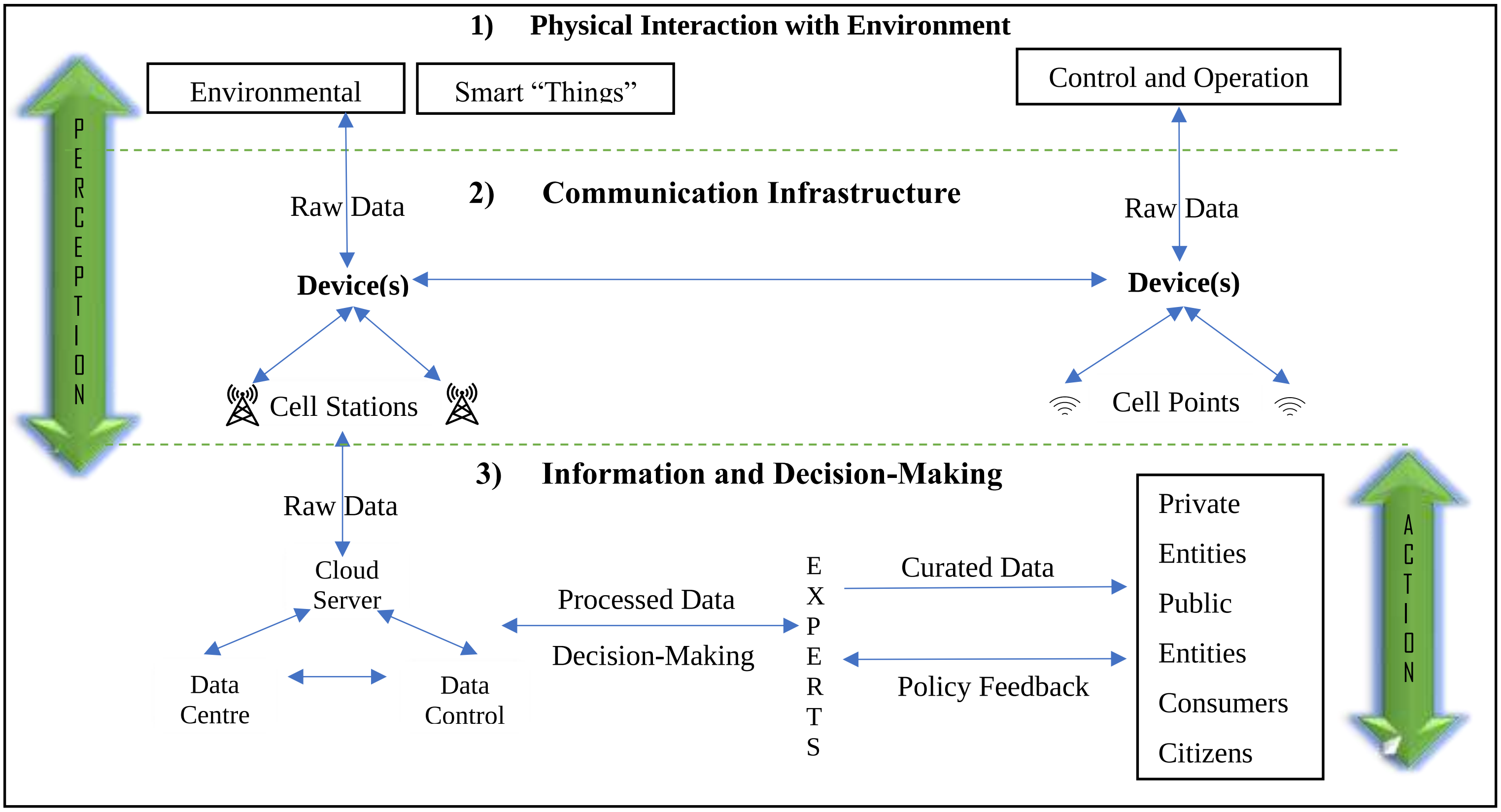


Figure B2.4. Climate policies must be flexible (…), durable (…), proactive (…), and robust (…). [Can] continuous monitoring and evaluation adapt or correct the desire policy outcome?



Annex C. IoT-5G CMIS Structure



Composition regarding the IoT-5G CMIS project proposal that is divided into three layers, a) physical one, compose with environmental sensors; b) Communication Infrastructure, compose by 5G network, and; c) The information and decision-making layers, where data is processed, curated, archive and passed to entities for further actions or feedback.

Annex D. Questionnaires

A. Policymaker's & Decisionmakers Questionnaire

Answer the following questionnaire within your own field of expertise:

Climate policymaking is currently riddled with problems caused by the unique characteristics and problems that climate change poses for policy and decision-makers. Climate change is defined by its uncertainty and its spatial and temporal scale, its irreversibility, the deadline to act (among others), etc. that hinder the policymaking process from tackling it.

Our exploratory research analyzes the climate-related policymaking process problems and knowledge gaps that plague this area. For this purpose, we research the potential of Information and Communication Technologies, like the Internet of Things powered with the upcoming 5G Cellular Wireless Communication system as a tool to tackle this policy issue, as well as developing means to *unite both private and public entities and institutions towards a common the goal, the development, and implementation of flexible, robust, and sound climate policy able to adapt to the ever-changing climate circumstance towards a more sustainable society*

We would like to invite you to participate in a research study that aims at collecting data for a project as part of the development of a master's dissertation on the issues of the climate policymaking process. Before you begin, take a few minutes to read why we invite you to participate and what will be done with the information you provide. This questionnaire asks you the characteristics and personal perspectives on climate change and the climate policymaking process. It could be enhanced by introducing an IoT-5G system directed towards the gathering and curation of climate-related data and activities and the analysis evaluation of climate-related policies.

In this research, we have decided to define climate data as "any information that contributes to the development of climate policies, from environmental and climate variables in the environment (e.g., soil quality, c02 levels, humidity levels, air impurities levels, water quality, etc.) to emissions inventories, meteorological data (e.g., unpredictable climate events), energy usage, and/or output, etc.).

Your individual privacy and confidentiality of the information you provide will be maintained in all published and written data analysis resulting from the study. The study is strictly anonymous. Your participation should take approximately 15 minutes. We ask you to fill it out with as much accuracy as possible. Please understand your participation is entirely voluntary, and you have the right to withdraw your consent or discontinue participation at any time without penalty.

1. What is your profession and area of expertise?

2. Choose the characteristics and issues of Climate change (two or more)

    a. Complex.
    b. Riddle with conflict of interest.
    c. Dynamic Changes Over Time (short, medium & long).
    d. Large and Temporal and Spatial Scale.
    e. Irreversible.
    f. Deadline to act.
    g. Uncertainty and Unpredictable.

3. From your perspective, what are the climate policymaking process issues besides the individual, political, and economic will? Are there other elements besides politics or economics that hinder your capacity in developing and implementing climate policies?

(Maximum of Three Paragraphs).

4. Is climate data relevant enough for the development of climate policies and responses?

    a. Yes.
    b. No.
    c. N/A.

    4.1. Please further explain your answer (Maximum of Two paragraphs).

5. Has climate data shaped, informed, design, and implemented in the climate policymaking process in any form?

    a. Yes.
    b. No.
    c. N/A.

5.1. If Yes, did the data change your perspective about the issue and potential policy options? (Maximum of Two Paragraph).

6. Would you agree that climate data is readily available/provided to the policymakers in a comprehensible and accessible manner?

    a. Strongly disagree
    b. Disagree
    c. Neutral
    d. Agree
    e. Strongly Agree

    6.1. On a scale of 0 to 10, how accurate/reliable would you grade this data [0= Unreliable; 10= very reliable]

    6.2. Following the evaluation of the policies and responses developed, has the data provided to policymakers and decisionmakers were:

a. Successful.
b. Unsuccessful.
c. Harmful.
d. Neutral.
e. Unknown.
f. N/A.

7. Is there an advantage of providing real-time data for the policymaking process?

a. Yes.
b. No.
c. N/A.

    7.1. Please further explain your answer.
    7.2. Would real-time data be more efficient than our current data? Or will slower data flow be sufficient?

8. Are there (or do you have) any infrastructure, instrument(s), and/or tool(s) that enables a follow-up process of the climate policies cycle (e.g., climate advice, adaptation process, etc.)?

   8.1 If yes, from a scale to 0 to 10 evaluated how often are use and their reliability, changed and/or terminated [0 = never; 10=always]

9. In your opinion, what kind of service/tools/instruments can we be developed for quality/usage in the area of climate change policymaking? (Between Two-Three Paragraphs).

10. Do you agree with the following statement? Elaborate if possible, within your area of expertise (Two paragraphs)

    "Climate policies must be able to be flexible, so policymakers can manage to meet, some if not all, new social, technical, climatic or environmental circumstances; durable, so they can be able to address the long-term effects of climate change; proactive, so they may meet all the objectives and avoid negatives outcomes; and robust, so they may have reached to all sectors as well as a global reach to deal with the systemic reach of climate change. Therefore, continuous monitoring and evaluation of these policies are essential to rapidly detect change(s) in assumption(s), variable(s), or/and uncertainties(s) to adapt or correct the desire policy outcome."

    a. Yes.
    b. No.

11. The Internet of Things and 5G projects and business concepts have revolted mostly around the automatization, monitoring, tracking, and enhancing services and products. Please, consider the following proposal and elaborate an opinion:

    "Products and services oriented to individuals, private and public sectors, as well as policy and decisions, are increasingly spinning around climate-related activities towards sustainable lifestyle and development. An IoT-5G system for the gathering, curating, and sharing environmental and climate-related data (e.g., C02 levels, Water Quality, Soil Quality), climate-related activities (e.g., Agrobusiness, Water Consumption, Energy Consumption, Environmental Tracking), and citizen/consumer interaction for the promotion, reinforcement, and development of climate policy and sustainable activities and products and services. If this type of service were available for decision and policymakers, would you consider investing and/or utilizing throughout the policy cycle.

B. IoT & 5G Experts Questionnaire

Please Answer the following questionnaire according to your own field of expertise:

Climate policymaking is currently riddled with problems caused by the unique characteristics and problems that climate change poses for policy and decision-makers. Its uncertainty defines climate change. It is a spatial and temporal scale. It is irreversible. It is the deadline to act (among others), etc. which hinders the policymaking process from tackling it.

In our exploratory research, we analyze and research the potential of Information and Communication Technologies, like the Internet of Things powered with the upcoming 5G Cellular Wireless Communication *system as a tool to tackle this policy issue, as well as developing means to unite both private and public entities and institutions towards a common goal, the development, and implementation of flexible, robust and sound climate policy able to adapt to the ever-changing climate circumstance towards a more sustainable society.*

We would like to invite you to participate in a research study that aims at collecting data for a project as part of the development of a master's dissertation regarding the IoT-5G system's impact on the climate policymaking process. Before you begin, take a few minutes to read why we invite you to participate and what will be done with the information you provide.

The purpose of this study is to examine the capability of IoT-5G systems to aid in the fight against climate change through its data-gathering abilities and its potential to impact the climate policymaking process for both private and public sectors.

This questionnaire asks you about the requirements and potential of an IoT-5G direct towards large rural, rural-urban, and urban areas (50 to 100 km), requiring the ability to handle moving devices and provide quick, reliable, and constant data flow and end-to-end response.

Your individual privacy and confidentiality of the information you provide will be maintained in all published and written data analysis resulting from the study. The study is strictly anonymous. Your participation should take approximately 10 minutes. We ask you to fill it out with as much accuracy as possible. Please understand your participation is entirely voluntary, and you have the right to withdraw your consent or discontinue participation at any time without penalty.

1. What is your profession and area of expertise?

2. From your perspective, which one of these communication infrastructure/protocol is best for deploying an IoT system.

    a. Zigbee
    b. WiFi HaLoW
    c. 6lowPan
    d. SigFox
    e. BLE
    f. Cellular (5G)
    g. NFL

    2.1. Explain your Choice (Maximum of Two paragraphs).

3. What if the IoT system required extensive range, mobility, real-time response, etc. (Maximum Two paragraphs).

4. Do you think an IoT-5G network system could provide real-time data that could translate into more efficient and calculated policy actions/responses/methods? (Maximum three paragraphs).

5. Is there an advantage of providing real-time data for the policymaking process?

    a. Yes.
    b. No.
    c. N/A.

5.1 Please further explain your answer.
5.2. Would real-time data be more efficient than our current data? Or will slower data flow be sufficient?

6. Do you think that the introduction of 5G within new services to evaluate the policymaking process could make a difference?

   a. Yes.
   b. No.
   c. N/A.

   6.1. If yes, provide an example of such (Maximum of Three Paragraphs).

7. What kind of service/tools/instruments can we be developed for quality/usage for policy climate change? (Between Two-Three Paragraphs).

8. Do you agree with the following statement? Elaborate if possible, within your area of expertise (Maximum Two paragraphs):

   *"Climate policies must be able to be **flexible,** so policymakers can manage to meet, some if not all, new social, technical, climatic or environmental circumstances; **durable**, so they can be able to address the long-term effects of climate change; **proactive,** so they may meet all the objectives and avoid negatives outcomes; and **robust,** so they may have reached to all sectors as well as a global reach to deal with the systemic reach of climate change. Therefore, continuous monitoring and evaluation of these policies are essential to rapidly detect change(s) in assumption(s), variable(s), or/and uncertainties(s) to adapt or correct the desire policy outcome."*

   a. Yes.
   b. No.

   8.1. Within your area of expertise, if possible, elaborate your answer (Maximum Two paragraphs).

9. To develop an IoT system that gathers climate-related data, what kind of sensors, actuators/dashboards, and communication Infrastructure are necessary for it to work. Please, explain your choice.

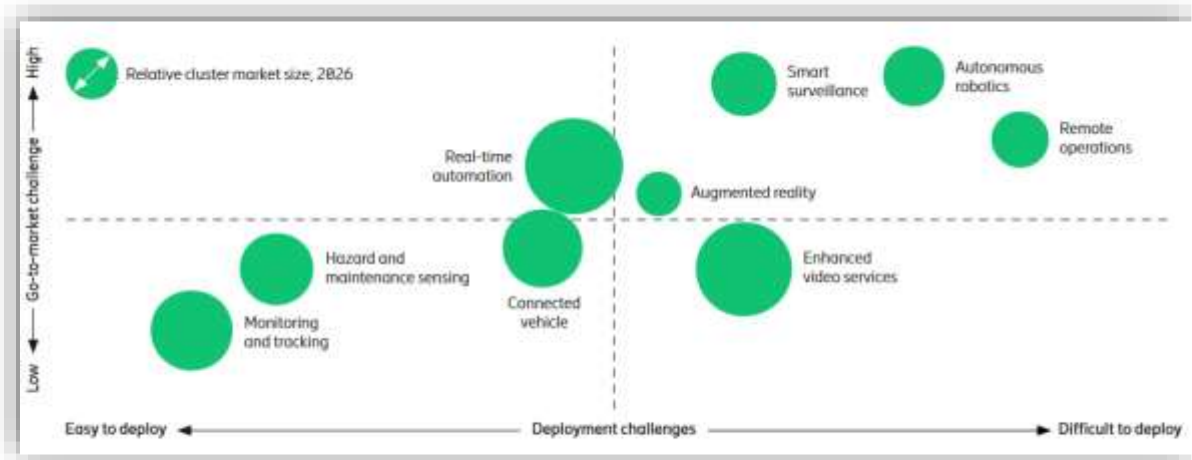
10. What kind of algorithm is best suited for this type of architecture?

11. An IoT and 5G base project and business have revolved around automatization, monitoring, tracking, and enhancing services and products. Consider the following project:

    "Products and services oriented to individuals, private and public sectors, as well as policy and decisions, are increasingly spinning around climate-related activities towards sustainable lifestyle and development. An IoT-5G system for the gathering, curating, and sharing environmental and climate-related data (e.g., C02 levels, Water Quality, Soil Quality), climate-related activities (e.g., Agrobusiness, Water Consumption, Energy Consumption, Environmental Tracking), and citizen/consumer interaction for the promotion, reinforcement, and development of climate policy and sustainable activities and products and services. If this type of service were available for decision and policymakers, would you consider investing and/or utilizing throughout the policy cycle."

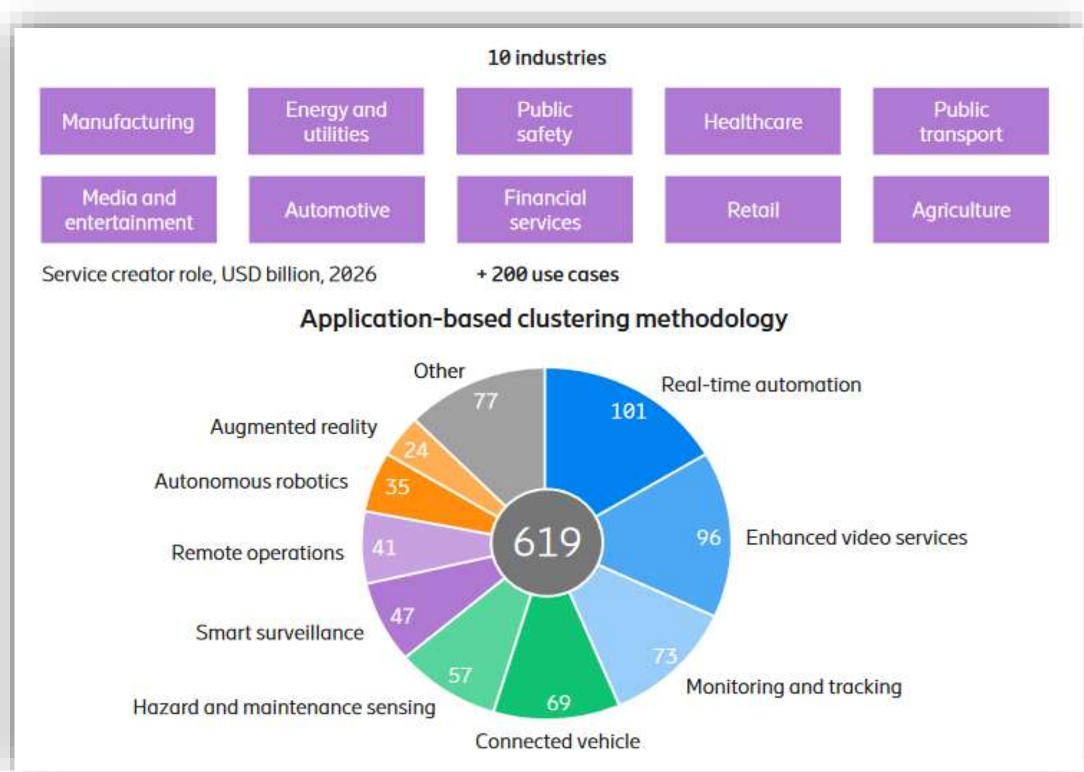
Annex E. IoT and 5G Potential

Figure E1. Cluster's Growth Opportunities



Source: Ericsson (2018), "*The Guide to Capturing the 5G Industry Digitalization Business Potential*"

Figure E2. IoT-5G Business Potential per Cluster



Source: Ericsson (2018), "*The Guide to Capturing the 5G Industry Digitalization Business Potential*"

Figure E3. Development of IoT-5G and Climate Change Relevance 230 SDG Agenda

SDG 1: No Poverty	1.1.	1.2.	1.3.	1.4.	1.5.	1.a.					
SDG 2: Zero Hunger	2.1.	2.2.	2.3.	2.4.	2.5.	2.a.	2.c.				
SDG 3: Good Health & Well-Being	3.1.	3.2.	3.3.	3.6.	3.7.	3.8.	3.9.	3.c.	3.d.		
SDG 4: Quality Education	4.1.	4.2.	4.3.	4.4.	4.5.	4.6.	4.7.	4.a.	4.b.	4.c.	
SDG 5: Gender Equality	5.b.										
SDG 6: Clean Water and Sanitation	6.1.	6.2.	6.3.	6.4.	6.5.	6.6.	6.a.	6.b.			
SDG 7: Affordable and Clean Energy	7.1.	7.2.	7.3.	7.a.	7.5.						
SDG 8: Decent Work and Economic Growth	8.1.	8.2.	8.3.	8.4.	8.5.	8.6.	8.9.	8.a.	8.b.		
SDG 9: Industry, Innovation and Infrastructure	9.1.	9.2.	9.4.	9.5.	9.a.	9.b.					
SDG 10: Reduce Inequalities	10.1.	10.2.	10.3.	10.4.	10.7.	10.b.					
SDG 11: Sustainable Cities and Communities	11.1.	11.2.	11.3.	11.4.	11.5.	11.6.	11.7.	11.a.	11.b.	11.c.	
SDG 12: Responsible Consumption and Production	12.1.	12.2.	12.3.	12.4.	12.5.	12.6.	12.7.	12.8.	12.a.	12.b.	12.c.
SDG 13: Climate Action	13.1.	13.2.	13.3.	13.a	13.b.						
SDG 14: Life Below Water	14.1.	14.2.	14.3.	14.4.	14.5.	14.6.	14.7.	14.a.	14.c.		
SDG 15: Life on Land	15.1.	15.2.	15.3.	15.4.	15.5.	15.7.	15.9.	15.a.	15.b.	15.c.	
SDG 16: Peace, Justice and Strong Institutions	16.7	16.b									
SDG 17: Partnership for the Goals	17.1.	17.2.	17.3.	17.5.	17.6.	17.7.	17.8.	17.9.	17.14.	17.16	

IoT and/or 5G Development Relevance — Climate change Relevance — All Variables

Source: Based on Saravia-Matias, L.S. & Hormann, P.A. (2019), "*Lo Rural y el Desarrollo Sostenible en ALC. 2030*"

Note: The following link contains the details of the 196 goals of the 2030 Sustainable Development Agenda.
https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework_A.RES.71.313%20Annex.pdf

Annex F. Pool of Experts

Climate Change and Policymaking Experts		
Number	**Area of Expertise**	**Profession**
2	Climate Change and Climate Policy	Climate Change and Sustainability Consultant
2	Sustainable Urbanism	Head of the office for accelerating the urban transition
4	Climate Change and Engineering	Environmental Engineering (working with stakeholders, e.g., Municipalities, Ministry of Environment, Private Entities)
1	Climate Change, Policy, and Innovation	An official of the European Commission, DG for Climate Action
1	Climate Change and Innovation Policy	Director of Conservation and Policy; expertise: environmental policy, marine conservation, science-policy interface, policy advocacy
3	Climate Change and Climate Policy	Academics in Public Policy, environment and/or Climate Change (PhDs)
1	Climate and Policy	Economist

IoT and 5G Experts		
Number	**Area of Expertise**	**Profession**
1	Telecommunication Systems	Academic Professor
1	Telecommunication and ICTs	Senior Scientist in Telecommunications
1	Telecommunication Systems	Telecommunication Consultant
1	IoT Systems and 5G Networks	Telecommunication Technical Support
1	IoT Systems	Telecommunication Sales and Commerce Director