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APPLICATIONS OF REAL-TIME ECONOMY: CONCEPTUAL FRAMEWORK FOR SYMPATHETIC FEEDBACK SYSTEM TO REDUCE CARBON EMISSIONS

Master's thesis

HAGM, Technology Governance and Digital Transformation

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ABSTRACT

The world is facing plethora of challenges. Several of them have been mapped by the UN, resulting in a number of Sustainable Development Goals (SDGs), but remain unresolved. This thesis addresses two of them with its results: #12 "Ensure sustainable consumption and production patterns" and #13 "Take urgent action to combat climate change and its impacts" by synthesising real-time economy phenomenon and cybernetic viable system model.

For thematic inception, thick description is provided for both real-time economy as a concept as well as for 'Project Cybersyn' that houses cybernetic viable system model. Allegedly, the term 'real-time economy' first appeared in an article in 2002, describing how a company used real-time data to react instantaneously to changes in their business, however, one of the first attempts to harness real-time economy principles date back as far as 1970s, when Chile experimented with cybernetics to steer its socialist economics using timely information made available bottom-up for the decision-makers. This was done with a help of British theorist and cybernetician, Stafford Beer.

The author studies commonalities and differences between the real-time economy concept and the viable system model, coming up with a proposition how to tackle climate change by infusing the two and harnessing blockchain technology to create sympathetic feedback system for effective carbon emissions reduction. A conceptual model framework is provided.

Keywords: real-time economy, viable system model, climate change, carbon reduction, SDGs

INTRODUCTION

Background

During relatively short period of Master's studies – two years – the world has witnessed two grand scale events with a global impact: the Coronavirus disease pandemic, caused by the SARS-CoV-2 virus in first months of 2020, and an outbreak of unprovoked war, when Russian army invaded Ukraine in the early hours of 24 February 2022. The disease is causing seasonal epidemic waves and the war is still regrettably ongoing when authoring this thesis.

At the backdrop of these acute issues, the world also facing unresolved chronic challenges that have not been effectively tackled with despite technological advancements – be it world hunger or climate change. For example, paradoxically a little less than 10% of the world's population goes to bed with an empty stomach while developed countries are trying to solve food waste issue. All this while the global average temperature is rising at critical rate, paving a way to the next mass extinction. Yet, neither of the problems are anything new.

Already in 1972, the Club of Rome published its famous report *The Limits to Growth*. It caused a lot of public interest as well as criticism although the authors pre-emptively recognized, that "there may be much disagreement with the statement that population and capital growth must stop soon. But virtually no one will argue that material growth on this planet can go on forever" (Meadows, Meadows, Randers, & Behrens, 1972). And indeed, the issue of economic growth within natural limits has been brought to light ever more intensively from an environmental perspective as worrying signs of climate change can be seen and felt.

Exactly fifty years have passed since the report without considerable changes. After several international climate conferences and political commitments, the UN has come up with a number of Sustainable Development Goals (SDGs) for more precise action plan e.g., #12 "Ensure sustainable consumption and production patterns" (see Appendix 1) and #13 "Take urgent action to combat climate change and its impacts" (see Appendix 2) (UN, 2022). These underpin local and regional attempts to address global sustainability challenges, like the Green Deal in Europe.

Problem statement

Although the initial research plan was to expand on real-time economy topic from the e-governance perspective as an underlying building block for effective *algocracy*[1] the author addresses sustainability and climate change with this thesis at hand. The world is still facing serious challenges that could be called wicked problems (Rittel & Webber, 1973) which often need innovation-based complex solutions – or *Moonshot missions* (Mazzucato, 2018). This gives a slightly wider context and an imperative study vector for consideration. Therefore, given the outset of this research, the author asks: how to bridge the gap between economic functionality and environmental aspirations? To rephrase it in the form of problem statement – this thesis attempts to answer the question: how to shift from wasteful economic growth model with a heavy impact on the climate to an economic growth that uses limited natural resources consciously in a sustainable manner with as small as possible environmental footprint in the form of CO_2 emissions.

In a 'perfect world' the economic entities should interact with each other in a way that the system remains intrinsically sustainable and is able to survive externalities, but the question remains – *how?* – as the current growth is on an environmental lease. Usually, the most optimal economic choice depends on the best available information. Such an economic system should provide adequate feedback mechanisms that enable *sympathetic* reaction by its entities to retain overall system level *homeostasis*, similarly to living organisms who respond to external (environmental) as well as internal (sensory) stimuli. Reference to biology is not accidental or arbitrary, and reasons for that will be uncovered in the coming pages below.

The current economic system can be seen to act in an *ouroboros*[2] manner, seemingly unbeknownst. As it has been going on for at least 50 years – *two generations* – it must be addressed expeditiously, not only theoretically, but with practical solutions, to safeguard habitable environment for the future generations. This is the main underpinning objective of this thesis.

Object of research & research questions

This thesis focuses on *real-time economy* (RTE) phenomenon as a central object of research through which the possible solutions to tackle climate change is sought. Considering relative novelty of RTE as a subject matter, this thesis aims to serve two purposes: first, to continue

[1] Algocracy – governance system which is organized and structured on the basis of algorithms (Danaher, 2016)
[2] Ouroboros – an ancient symbol depicting serpent which devours its own tail

exploration of the phenomenon, and second, to provide a (thick) description (Geertz, 1973) how to harness RTE concept outside its original context, expanding its implementation potential to use-cases that have been rather vaguely referred to so far.

Relative novelty in this regard means that although the conceptual basics and building blocks have been around for more than two decades, wider knowledge about it varies significantly. Thus, it attempts to both *enrich* the academic discourse as well as to *furnish* conceptual viability with examples of adjacent application of blockchain technology. This can be translated into following research question to optimize it for the thematic context:

> **How could real-time economy (RTE) concept be harnessed to address the Sustainable Development Goals (SDGs) and contribute to carbon (CO_2) emissions reduction?**

According to Sandra Van Thiel (2014) sub-questions reflect the intermediate steps that can facilitate reaching the ultimate target of answering the main research question. Following sub-questions for the purpose of description and discussion thus are:

1) What is real-time economy and its functional principles?
2) What to learn from RTE practice in retrospect?
3) Which RTE-based solution could be used to reduce emissions and how?
4) How to address SDGs by applying RTE-based solutions?

A sound question may therefore arise among readers: if this phenomenon has not established itself during generations of economic academicians and practitioners, is it even a viable object of research and not merely an arbitrary interpretation of modern digital solutions? As a response to this critique, author has used qualitative methods to study commonalities and differences of other initiatives in the wider timeframe.

Methodology

This paper falls into the category of *social science research*. Thus, it attempts to follow the main goals of social research. Ragin & Amaroso (2011) list seven main goals while arguing that *no researcher can tackle all seven goals at once, at least not in the same study*: 1. Identify general patterns and relationships, 2. Test and refine theories, 3. Make predictions, 4. Interpret culturally or historically significant phenomena, 5. Explore diversity, 6. Give voice, 7.Advance new theories.

As the thesis does not particularly intend to make predictions (3) nor advance any new theories (7), these goals are pre-emptively omitted. The central research focus will be on interpreting *technologically* significant phenomena (4) and to a lesser extent identifying general patterns and relationships (1). Other goals, however, are going to be reflected upon to different extent. Evidently, even the goal itself holds slight interpretation by the author to best fit with the purpose of the thesis. These goals will be evaluated in the conclusion.

Considering both RTE and 'Project Cybersyn' as *phenomenologically* significant cases in an information era, *non-experimental research design* is applied (Brown & Hale, 2014). Irrespective of the number of cases, in-depth interdisciplinary information is gathered and synthesized to provide a *thick description* for the purpose of the underlying goal to provide a proposition. Alas, as a word of caution, such studies tend to have high internal validity but low external validity (*Ibid*.). Therefore, qualitative research methods will be used throughout the study with only hints to available secondary quantitative data (e.g., available impact assessment) to illustrate the phenomena. The aim is to study early attempts of real-time economy (in non-digital environment) and synthesize it with contemporary initiatives that have sprouted from very practical business-to-business interaction. A comparison of the two studied concepts will be provided accordingly.

Based on author's personal experience in the subject matter, several Master's study programme level assignments (e.g., essays) were carried out in relation with the topic. Thus, the underlying research strategy is *in-depth exploratory research* throughout the period of studies in the Technology Governance and Digital Transformation programme.

This thesis is divided into three chapters. Chapter 1 presents the theoretical framework with its sections dedicated to RTE phenomenon (including origins of the term and definition) and the 'Project Cybersyn' (along with its peculiar interplay of technology and politics). Chapter 2 is *retroductive* empirical part (an interplay of induction and deduction) providing an infusion of studied phenomena and reaching to a proposition to answer the research question through both problem-theory as well as problem-solution fitness analysis. Chapter 3 is dedicated to discussion followed by conclusions.

1. THEORETICAL FRAMEWORK

This chapter gives an overview of the theoretical framework. Considering two underlying aims of this research, i.e., "first, to continue exploration of the phenomenon, and second, to provide a (thick) description how to harness RTE concept outside its original context, expanding its implementation potential to use-cases that have been rather vaguely referred to so far," it will: 1. review latest literature and research regarding RTE and expand on the aspects that have been discarded or are falling short for answering the research question(s); 2. conduct a qualitative research on the *theoretical* framework literature and infuse it with more technical literature regarding *technological* framework that could facilitate the second aim (i.e., thick description).

Therefore, the literature could be notionally divided into three batches for the research: 1) primary literature, specifically dealing with the real-time economy phenomenon and/or concept; 2) secondary literature, which are either dealing with RTE building blocks or functional technology; 3) supportive literature that help with the synthesis and expanded theoretical description of the RTE phenomenon. This is to map out the theoretical and practical viability of RTE for addressing SDGs and climate change.

1.1. Real-Time Economy: origins & definition

1.1.1. Origins of "Real-Time Economy"

This section is dedicated to answering the first sub-question: "What is real-time economy and its functional principles?" A brief excursion will be made on the subject, pointing out key insights, milestones and initiatives that have played significant role in developing the RTE concept. It is important to point out from the outset, that the term – real-time 'economy' – does not refer to a new economic model, but rather a set of principles that make up a digital ecosystem between economic entities (actors). This will be explained and looked at in detail in the following pages.

To start with the primary sources of theoretical framework, academic literature will be observed first. This will enable to backtrack to earliest possible literature about RTE for the sake of exploratory research. One of the most recent academic research projects was conducted by Tallinn University of Technology specifically about RTE definition and implementation opportunities (Krimmer, et al., 2019). Authors claim that first ideas around RTE were developed two decades ago but the concept is still relatively unknown in policy and research (*Ibid.*, 9). Therefore, an exploratory study on the concept was conducted by systematic literature review and by employing a *meta-synthesis* method for such qualitative research (Walsh & Downe, 2005). This is an imperative prescription also for the current paper to ensure methodological continuity for the sake of main aim of exploratory research.

The resulting final research report about RTE definition and implementation opportunities admits that the 'real-time economy' as a term is relatively new in the academic literature, as only 47 academic articles qualified from the initial query result of 323. This was the basis for in depth analysis *to develop an understanding of the possible definitions of RTE, the benefits associated with the concept, its key building blocks and enablers as well as barriers* (*Ibid.*, 10). Additionally, it presents other forms of terms used in a similar meaning – including "now economy". Author's own observation is that the "real-time economy" has been used in tight conjunction (or even synonymously) with the "real-time enterprise" (Kuhlin & Thielmann, 2005), ultimately sharing the same abbreviation of RTE and adding complexity to comparative research. In this regard the latter will be omitted from the scope of this thesis, but not fully disregarded as it shares the same origin as well as key functional principles.

Despite novel sounding term, it arguably celebrates its 20th anniversary of neologism, as allegedly Ludwig Siegele (2002) introduced it in his article "Real-Time Economy: How about now?" This article demonstrated how real-time information, collected from different units of organization, was aggregated, and used for management purposes in the General Electric company to react instantaneously to changes in their business. This piece of information, however trivial it may seem, plays an important role in understanding the next section and possibly the true roots of RTE as a conceptual mechanism, and thus, origin of the phenomenon itself. This means that the concept has been around for a while but has not gained wider acknowledgement as recognized by Krimmer et al. and corroborated by Kivisild (2021). It is worth to note that earlier academic research has not been much about the phenomenon, but more about the 'building blocks' that constitute the concept in its current meaning.

A recent empirical study carried out in Estonia about the awareness of RTE revealed that roughly about 20% of the respondents (out of 176) are familiar with it (*Ibid*.). As the survey was specifically addressed to entrepreneurs with an aim to assess their stance towards automated and fast (or real-time) interaction with the state and business partners, it means the knowledge about the real-time economy and RTE-based management of an enterprise is in reality considerably lower. This is for two reasons: the concept has been around especially in the business administration context (i.e., real-time enterprise), and the survey was likely biased towards those respondents who were interested in the subject, thus *aware* of it. But what does the term mean; how can it be defined?

1.1.2. Definition

Siegele had used the term 'real-time' in his article to denote a 'new' type of economy, where physical location is less relevant than in the traditional economy emphasizing the potential of emerging information and communication technologies to reduce process latencies to a minimum (2019; Siegele 2002). This understanding started to establish itself among the early evangelists of the RTE phenomenon. The "Real-Time Economy program" was originally founded in collaboration of two Finnish organizations in 2007: Aalto University School of Business and Tieto Corporation (About RTE, n.d.) with the creation of a competence centre dedicated to RTE-related research. Around 2008, when the earliest academic papers were published on practical applications of the RTE (Theses, n.d.) the first fully furnished (narrow) definition of RTE was proposed which is still in parallel use:

> "Real-Time Economy is an environment where all the transactions between business parties are in digital format, increasingly automatically generated, and completed in real-time both from business and IT-processing perspectives." (Real-Time Economy Competence Center, 2021)
>
> *vs.*
>
> "Real-Time Economy is an environment where transactions of all sorts are digital, increasingly generated automatically and completed in real-time without store and forward processing." (Penttinen, 2008a)

This definition certainly lived up to the standard as it has been continuously used with minor alterations until 2018, when a slightly specified version of the initial definition was established by one of the founding members of the Finnish RTE program, Bo Harald (2018):

> “The Real Time Economy is an environment where financial and administrative transactions connecting citizens, business and public sector entities are:
>
> (i) in structured standardized digital form
>
> (ii) increasingly generated automatically, and
>
> (iii) completed increasingly in real time without store-and-forward processes.”

Although this retrospective overview of the previously established definitions may seem trivial, it gives an insight into the development of the phenomenon, coming from a broad construction – almost visionary – to more precise and concrete, defining its most important functional properties. As a result of rigorous academic research Krimmer et al. (2019, 13) propose the following overarching definition of RTE along with supportive description about its main impact and conceptual incentive:

> “Real-Time Economy is a digital ecosystem where transactions between diverse economic actors take place in or near real-time by way of an increasingly automated exchange of digital, structured and machine-readable data in standardized formats.
>
> The resulting acceleration of information exchange and improved access to information is expected to reduce process latencies, save resources and transaction costs, increase organizational efficiency and business competitiveness, increase the speed and quality of decision-making, improve transparency, and stimulate economic and social innovation.”

It is worth to take note that the early definition of RTE has remained almost the same for a decade since first introduction. ‘Structured’ and ‘standardized’ were later added for technical precision of its underlying process and the type of transactions was defined as ‘financial and administrative’. It is then after thorough academic research, when vague notion ‘environment’ became ‘digital ecosystem’ giving more precise technological boundary while keeping most important elements of its functionality, i.e., ‘automation’, ‘structure and machine-readable data’, ‘standardization’. (See Table 1 below)

Table 1. Evolution of Real-Time Economy definitions (from left to right)

RTE Competence Center	Penttinen	Harald	Krimmer et al.
Real-Time Economy is an environment where all the transactions between business parties are in digital format, increasingly automatically generated, and completed in real-time both from business and IT-processing perspectives.	Real-Time Economy is an environment where transactions of all sorts are digital, increasingly generated automatically and completed in real-time without store and forward processing.	Real-Time Economy is an environment where financial and administrative transactions connecting citizens, business and public sector entities are (i) in structured standardized digital form, (ii) increasingly generated automatically, and (iii) completed increasingly in real time without store-and-forward processes.	Real-Time Economy is a digital ecosystem where transactions between diverse economic actors take place in or near real-time by way of an increasingly automated exchange of digital, structured and machine-readable data in standardized formats.

Source: Author, based on Real-Time Economy Competence Center (2021; Penttinen, 2008b), Penttinen (2008a), Harald (2018), Krimmer et al. (2019)

The latest definition has an important amendment and a key addition with a high importance to this thesis: it addresses diverse economic actors – broadening the scope of conceptual stakeholders from ‘business parties’ to ‘economic actors’ – and imposes ‘structured and machine-readable’ data as prerequisite property for the data transaction. The same definition characteristics – i.e., *functional principles* – are also prerequisites to the proposed RTE-based solution to address climate change. This will be discussed in detail in section 2.2 below.

Since Siegele’s case overview of the RTE practice in an enterprise, the concept has made several iterations. These iterations have been ‘recorded’ in numerous initiatives and projects to advance the RTE concept. It gained particular momentum through *Internet of Business* projects in Finland and Estonia since 2016 (ITL, 2022). A close cooperation between Nordics and the Baltics started with a few round-table events held in Tallinn and Helsinki between 2018-2019 followed by specific projects and prototyping of RTE-based solutions.

These iterations along with the nascent academic activities in the Aalto University (Penttinen, 2008a) can be translated into incentives that have driven the evolution and development of the phenomenon. These incentives can be grouped into three dominant perspectives on RTE which originate from the need of a certain practical application: 1) financial perspective; 2) business network perspective; and 3) extended perspective (Krimmer, et al., 2019, 10-12).

The *financial perspective* will be omitted from further investigation in this study as it falls out of the scope of this thesis. Both *businesses network* perspective as well as *extended perspective* will certainly be of interest for the purpose of following meta-synthesis towards formulation of a conceptual proposal. As the extensive qualitative meta-synthesis on the limited literature is already carried out in the context of the research on RTE definitions and implementation opportunities, the author will not replicate nor repeat it, but for illustrative purposes these two perspectives along with their definition characteristics is presented in Table 2.

Table 2. Perspectives on RTE in literature

Business network perspective	Extended perspective
• RTE is the network where real-time enterprises perform their activities. • *RTE is a network where real-time enterprises collect real-time information in order to monitor their status and improve reaction times to unexpected events.* • RTE enforces cross-organizational software integration. • RTE optimizes value generation practices on cross-organizational level. • RTE facilitates real-time business administration practices. • RTE improves communications channels between participants. • *RTE facilitates real-time practices for exchanging data and documents.* • RTE eliminates process latencies. • *RTE enforces uniform design and communication standards at a cross-organizational level.*	• RTE represents a virtual environment where transactions are performed as close as possible to real-time. • *RTE environments connect citizens, businesses and government.* • RTE environments facilitate financial and administrative transactions. • RTE environments permit transactions to be executed in real-time. • *In an RTE environment, transactions are structured and standardized in digital formats.* • *In an RTE environment, transactions are generated automatically.*

Source: Krimmer et al. (2019); author's revision, emphasis added

This section provided ample overview of the origins of the RTE term and the evolution of the definition and contributed to answering the first supporting research question: “What is *real-time economy* and its functional principles?” As can be seen from the analysis of available literature, the phenomenon is mostly business centric – focussing on optimized and efficient management of a company by digitising paperwork, digitalizing processes and bringing about digital transformation across networks of interaction for a mutual benefit.

1.2. Project Cybersyn: Operations Room revisited

1.2.1. How to address complex issues – historical recourse

This section is dedicated to one historical initiative, a concrete case of technology governance that from author's point of view is undeservedly dismissed from the discourse of RTE phenomenon. After conducting a review of the core literature mapped by Krimmer et al. in RTE research paper (e.g., Siegele, 2002; Agassi, 2005; Kuhlin & Thielmann, 2005; Reichwald et al., 2005; Penttinen, 2008b; Harald, 2018; etc.), there were no references to this case as an attempt to implement essentially RTE-based governance system for the purpose of real-time management of state economy. Thus, it revisits "Project Cybersyn" through *phenomenographical* perspective and should be treated as author's contribution to the RTE discourse. This section is of key importance in addressing one of the underlying aims of this research, i.e., "to continue exploration of the phenomenon." It uncovers some of the previously dismissed etymological references to the RTE.

From that outset, this section will also reassess the claim that *the concept of "real-time economy" is still in its infancy, lacking well-established and comprehensive definition to cover various components of the RTE* (Krimmer et al., 2019, 10). Therefore, it will be a continuation of the descriptive study on RTE and its functional principles, i.e., search for an answer to the first sub-question: "What is real-time economy and its functional principles?"

As the previous section was an excursion on trails of RTE genesis in its modern approach, this section is a balancing excursion on trails of Chilean history, which holds hints to possibly earliest implementations of RTE-based concepts dating back to 1970s. This piece of history is fortunately recorded by the main theorist, Stafford Beer himself, and retold by Eden Medina in great detail (2006; 2014). As Medina has noted, *technologies are historical texts; when we read them, we are reading history* (*Ibid*.).

When Salvador Allende was democratically elected as a president of Chile, he decided to change the nation's course and history by "Chilean road to socialism." As he took the office in November 1970 he promised to implement "worker participation" in the planning process of nationalised industry, but this turned out to be a technological challenge in early '70s, especially in a narrow strip of land in the South America with a span of more than 4000 km from North to South (Morozov, 2014).

Although Chile's economy had already started to deteriorate due to politically motivated reforms while also being cut off by the United States for Allende's chosen socialist path, the government viewed the situation far from 'unsolvable' (Medina, 2006). To address the issue, Allende had tasked state development agency to administer the newly nationalized enterprises that formed the backbone of Chile's economy. This is when one of the one of the agency's technocrats sent a letter to British cybernetician, Stafford Beer, with a proposal to *implement on a national scale – at which cybernetic thinking becomes necessary – scientific views on management and organization*; to which Beer replied enthusiastically by the chance of being able to test his ideas, believing into his success without hesitation (Medina, 2006, 581).

Beer was targeted as an advisor for the fact that he had specialized on *management cybernetics* (Beer, 1967) which fit the profile of Chile's economic problems stemming from nationalization of industrial enterprises that needed to be put back on track. As Beer had studied and worked in psychiatry, he metaphorically compared company (an organization) to an organism struggling to survive in a changing environment: "…it must adapt itself to its economic, commercial, social and political surroundings and learn from experience." (Beer, 1967, 17, as cited in Medina, 2014, 25). In this regard he was primarily concerned with the study of 'exceedingly complex systems' compared to systems with less complicity (see Table 3).

Table 3. Simple, complex, and exceedingly complex systems

Systems	***Simple***	***Complex***	***Exceedingly complex***
Deterministic	Window catch	Electronic digital computer	Empty
	Billiards	Planetary system	
	Machine-shop lay-out	Automation	
Probabilistic	Penny tossing	Stockholding	The economy
	Jellyfish movements	Conditioned reflexes	The brain
	Statistical quality control	Industrial profitability	The company

Source: Beer (1967 in Medina, 2014, 26); author's rendition with highlights of topic relevance

According to Beer, 'exceedingly complex systems' were the economy (as a whole), the brain, and the company, *like a human brain* as a central processing unit between the external environment and the management system to respond external stimuli for its survival; such systems *defied the limits of reductionist mathematical analysis*, limiting the study to be probabilistic – i.e., never with 100% certain results (*Ibid.*).

1.2.2. Viable System Model

This sub-section takes a closer look at how such exceedingly complex systems can be addressed. Beer constructed his value proposition onto ‘Viable System Model’ (VSM) – one of his central concepts encompassing cybernetic control mechanisms for the purpose of system level ‘homeostasis’, *a quality desired by all viable systems*, especially biological. Beer defined VSM as:

> “a system that survives. It coheres; it is integral. It is homeostatically balanced both internally and externally, but has none the less [*sic*] mechanisms and opportunities to grow and learn, to evolve and to adapt – to become more and more potent in its environment … capable of independent existence.” (Medina, 2014, 34)

It is best described as ‘self-adjustment’ mechanism to cope with externalities, which is also common in mechanical world through the laws of physics. (Medina, 2006; 2014). Beer certainly saw enterprises (organizations) as homeostats whose main goals is *survival*, relying on feedback loops which in principle based on human neurological system (Morozov, 2014). He drew up a five-tier VSM (see Figure 1), including both *sympathetic* as well as *parasympathetic* feedback system for self-adjustment capability to survive. (Beer, 1972).

System 1 referred to ‘sensory’ level (enterprises as organs of economy), as it is in direct contact with the outside environment and mostly capable of autonomous functionality; *System 2* acted as a cybernetic ‘spinal cord’ (communications system for rapid data exchange); *System 3* is a ‘monitoring’ mechanism for System 1 (management) as well as for the collective interaction between sensory level entities; *System 4* provides a vital link between ‘voluntary’ and ‘involuntary control’ (an information gateway between government and production level systems); *System 5* is ‘collective brain’ (chief executive level, i.e. the government) which decides upon issues that have not been solved within the collective functionality and self-adjusting capability of Systems 1-3. (Medina, 2006, 585; 2014, 37-38).

This seemingly highly vertical organizational structure is often misunderstood by the critics of Beer’s concept of VSM. Conversely, finding a right balance between centralized and decentralized control system was one of the major concerns in his writings as shown by the categorization of system complexities.

While traditional science was able to handle simple and complex systems, it fell short in managing exceedingly complex ones in Beer's opinion – this is where cybernetics could provide a helping hand. Historically the cybernetics has clear links to military through the aspect of 'command and control' which is associated with domination. Beer saw it as an asset of self-regulation: *an ability of a system to adapt to internal and external changes and survive*. This is where subsystems ought to be 'black-boxed' with a sufficient amount of autonomy to perform and react to externalities with only occasional higher level system intervention necessity when subsystems were failing. (Medina, 2014, 26-28). Thus, in reality, the VSM had to be *sufficiently decentralized* and *autonomous* in order to function by the principles of cybernetics and 'laws of nature'.

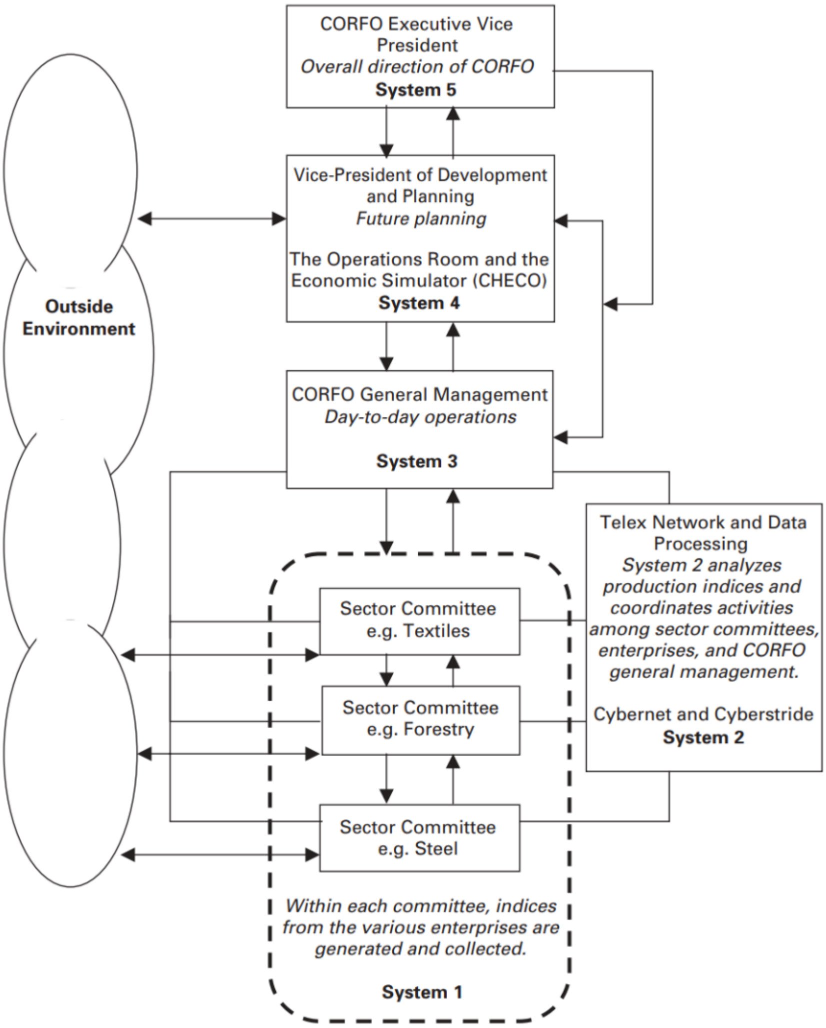

Figure 1. The Chilean State Enterprise drawn as a five-tier viable system model[3]
Source: Medina (2006, 591)

[3] CORFO – *Corporación de Fomento de la Producción* – Chilean development agency at the time.

This VSM concept resulted in four sub-projects to manage the system as envisioned: 'Cybernet' (an early version of intranet, or an 'Internet of Business' to be more precise), 'Cyberstride' (a data processing and exchange unit), 'CHECO' (short for Chilean economy, ought to be a reference model for simulations of future economic behaviour upon changes in input), and 'Operations Room' (as the name refers, a physical room for executive level decision-makers). These were the main building blocks for the system that was named 'Project Cybersyn' (aka Synco[4]) which is an amalgam of 'cybernetics' and 'synergy' (Medina, 2006, 587-590). The vision did not stop there. Beer also wanted to expand information feedback system to a representative sample of citizens to capture their *pleasure or displeasure with televised political speeches* [back] *to the government or television studio in real time* – a 'people's project' called 'Project Cyberfolk' with similar algedonic system that was believed to facilitate rapid response to public demands (Medina, 2006, 599).

Considering the level of technological development of Chile at the time, Project Cybersyn is an outstanding example of a *mission-oriented* attempt to reverse the flow of river rather than to swim against the current. This was illustrated by Beer's inspirational gesture of sharing Richard Bach's "Jonathan Livingston Seagull," who followed the dream of mastering art of flying against the wishes of the flock (Barrionuevo, 2008). It was a 'sink or swim' moment for Beer, too, according to his own memories, whereas he was convinced that "[i]t is perfectly possible … to capture data at source in *real time* [emphasis added]," except the team tasked for the cause didn't have the necessary machinery, programs nor knowledge how to process such a plethora of information at the time even if they had it (Morozov, 2014). Nevertheless, this historical example can be considered as an early attempt of 'Big Data nation' with the help of nascent RTE-based solutions.

This reference to the RTE is not arbitrary. Engineers from the taskforce of Project Cybersyn were developing a software to read the signals directly from the telex machines with a help of a computer in real time, hoping that *eventually it would eliminate the need for human operators to collect the data from telex machines and re-enter it into the mainframe for processing* (Medina, 2014, 135). This coincides to a great extent to the earliest definitions of RTE with a reference to automatic completion of transactions data "in real-time without store and forward processing" (see RTE definition above).

[4] Synco – *Systema de Información y Control* – Information and Control System

This historical overview of the Project Cybersyn demonstrated its direct links to RTE concept and its functional principles. A comparison of their core features is provided in the next section. This completes phenomenographic part of the thesis and answers first supporting research question, i.e., “What is *real-time economy* and its functional principles?”

1.3. Technological convergence of Real-Time Economy and Project Cybersyn

1.3.1. Comparative analysis of the concepts

In this section the technological convergence of the two systems will be assessed to answer the second sub-question, i.e.: “What to learn from RTE practice in retrospect?” In this regard a key point of interest would be principal prerequisites for the effective deployment of the system whereas the case of Project Cybersyn was included in the theoretical framework. Below is a comparative table of main characteristics of both previously studied concepts (see Table 4).

Table 4. Main differences between Project Cybersyn and Real-Time Economy concepts

Comparative aspect	Project Cybersyn	Real-Time Economy concept
Type of deployment	Monolithic *political* project with dependent sub-projects	Modular *practical* initiative with independent sub-projects
Purpose	Homeostasis (based on ‘viable system model’ of real-time data exchange)	Efficiency (based on omnidirectional data exchange between units of economy in appropriate timeframe)
Functionality	*Nowcasting* and decision-making upon real-time economic (production) data	*Nowcasting*, automated bookkeeping, reporting, taxation, declaring, etc., potentially carbon tracking
Prerequisites	1. Input/output indices 2. Standardized format 3. Information exchange channel 4. Telex devices network 5. Managerial/political decision	1. Structured M2M[5] data 2. Standardized format 3. Data exchange layer 4. ICT infrastructure 5. Policy/regulation
Governance	Centralized	Decentralized
Management	Decentralized	Mixed
Network structure	Vertical (proprietary)	Horizontal (distributed)
Feedback	Sympathetic (recursive)	Directional (confirmative)
Area of functionality	Within state	Cross-border/borderless

Source: Author’s interpretation
Notes:

‘Prerequisites’ is a list of intrinsic elements for the system to function based on author’s deduction from the literature review of both cases. This is not an exhaustive list and can be elaborated further in follow-up research.

[5] M2M – Machine-to-machine, referring to machine-readable

Despite seemingly different concepts, both share a core functional presumption: *real-time data exchange*, and surprisingly similar list of prerequisites regardless of their generational differences. Another considerable similarity is the system's *nowcasting*[6] potential. This aspect has been at the centre of interest for both economics and statistics, especially in the field of monetary policy as timely availability of economic data is crucial for expeditious decisions (Giannone, Reichlin, & Small, 2008; Mazzi & Montana, 2009; Mazzi, Moauro, & Ruggeri Cannata, 2016).

This comparison begs to draw attention to their key differences, which have significant socio-economic implications. First, the Project Cybersyn was deployed by highly political impetus and aspiration to make planning economy a viable economic model, as other variations of it have been failing so far. In its essence it is a *monolithic* technological formation which departs diametrically from the *modular* digital RTE concept, which has been decentralized from the start – bringing about the change through the voluntary mutually beneficial implementation process for economic entities (i.e., businesses).

Other characteristics play less significant role and are highly of techno-deterministic nature. This means that during the period of Project Cybersyn's deployment, there were no other feasible solutions, as the governance and management model derived from the socialist economic model whereas technology was reliant on scarce equipment and non-existent ICT infrastructure. However, this differentiating comparison does not imply that the concepts preclude each other.

1.3.2. Socio-technological implications – lessons from the past

The main barriers to RTE implementation have been extensively studied by Krimmer et al. (2019). Therefore, they will be presented here in a generalized manner. Similarly, to the initiation of *centrally* implemented Project Cybersyn, also the *decentralised* RTE seems to be suffering from *scarcity of resources.* additionally, three other groups of top-level barriers were identified: *1. technological, 2. organizational, 3. legalistic* (*Ibid*., 15-16). Thus, the difficulties mentioned in the literature review are common and intrinsic to other digitalization initiatives. In this regard the Project Cybersyn shares both technological as well as organizational barriers, but to a lesser extent legalistic barriers, as the project had top-level (presidential) blessing.

[6] *Nowcasting* – originates from meteorology ('forecasting') referring to prediction of the present, the very near future, or the very recent past state of an economic indicator.

Thus, based on the lessons of the past it can be concluded that the RTE is an embodiment – a manifestation – of the general digitalization process of both the economy as well as the society. From that perspective it can be considered as a normal 'side-effect' of digital transformation with an impetus stemming from aspirations towards more efficient operation of economic entities, resulting in diverse list of benefits, "[h]owever, the success of ambitious digitalization projects such as RTE often depends on specific national contexts and countries' ability to build an ecosystem interconnecting all relevant stakeholders." (Krimmer et al., 2019). The same applies to full also to the success rate of Project Cybersyn, although was deemed to fail due to both internal and external reasons.

This short historical detour is important also for two additional reasons: first, to indicate that the economy (or any other 'exceedingly complex system') is not able to perform and survive under unidirectional command without adequate feedback, and second, in (pivotal) trying times, the role of single individuals (e.g., Beer) increase significantly. One could say that the Project Cybersyn became a reality because of a very specific confluence of ideas and people as well as particular technological and political moments (Medina, 2014). This created fertile ground for tackling a "wicked problem" of the time.

From that experience the mastermind of Project Cybersyn concluded with 'Five Principles for the People toward Good Government' with the help of technology, as it *belongs to the people*: *1) end to bureaucracy, 2) greater transparency, 3) increased personal responsibility, 4) clearer government organization, and 5) planning for the future* (Medina, 2014, 135). From this one could argue that Beer was decades ahead of his time, as the 'zero bureaucracy' type of initiatives mostly took off since early 2000s.

2. REAL-TIME ECONOMY SOLUTION FOR SDGS

This chapter focuses on the sustainability aspect of the real-time economy to answer the main research question: "*How could real-time economy (RTE) concept be harnessed to address the Sustainable Development Goals (SDGs) and contribute to carbon (CO_2) emissions reduction?*" Section 2.1 provides an explanation how certain conceptual aspects of this phenomenon could tackle the climate change by synthesizing theoretical framework of real-time economy with practical concepts and historical lessons learned from the Project Cybersyn, whereas section 2.2 provides relevant problem-solution fit analysis. The suggested proposition attempts to address two SDGs with climate change related importance: #12 "Ensure sustainable consumption and production patterns" (see Appendix 1) and #13 "Take urgent action to combat climate change and its impacts" (see Appendix 2). An indicative list of corresponding addressee targets which could benefit from such a system is provided for in Appendix 3.

2.1. Proposition: sympathetic feedback system

This section intends to answer the research sub-question: "Which RTE-based solution could be used to reduce emissions and how?" For that to understand, one needs to go back to the VSM suggested by Beer, which relied on self-adjusting property of a complex system that was able to react to external stimuli without direct decision-making process from executive level. In this case, *sympathetic feedback system* refers to biological autonomous nervous system that helps to maintain homeostasis and survival of the organism. As the current thesis is not for the field of medical science, it does not analyse and discuss its functionality in neurological detail. It is an illustrative reference with technological feasibility to converge the proposition with Beer's VSM.

When infusing VSM and RTE it becomes evident that the formulation of the sub- question needs to be rephrased, as the system becomes 'VSM-based' from 'RTE-based' as the RTE is a mere set of functionalities (and tools) that enable the VMS to function. A suggestive proposition is thus generated and derived from such infusion, resulting in an emulated version of the original VMS proposed by Beer (see Figure 2 below).

It proposes that the sensory part (system 1), which interacts with the outside environment (i.e. economic actors, like businesses and consumers) is reliant on the blockchain solution to *capture and forward* the individual effort of the actor in an RTE-based manner to the country-specific emissions database, which enables to make calculations against the reference table (system 3), which is dependent on the higher level decisions and references stemming from the *actual* environment and its indices. System 2 is most close to centrally managed distributed data exchange layer, like X-Road in Estonia. As a result, this system would embody a VSM-based solution with RTE-functionality that enables to apply algedonic measures, like algedonic signals of Cybersyn (see image below).

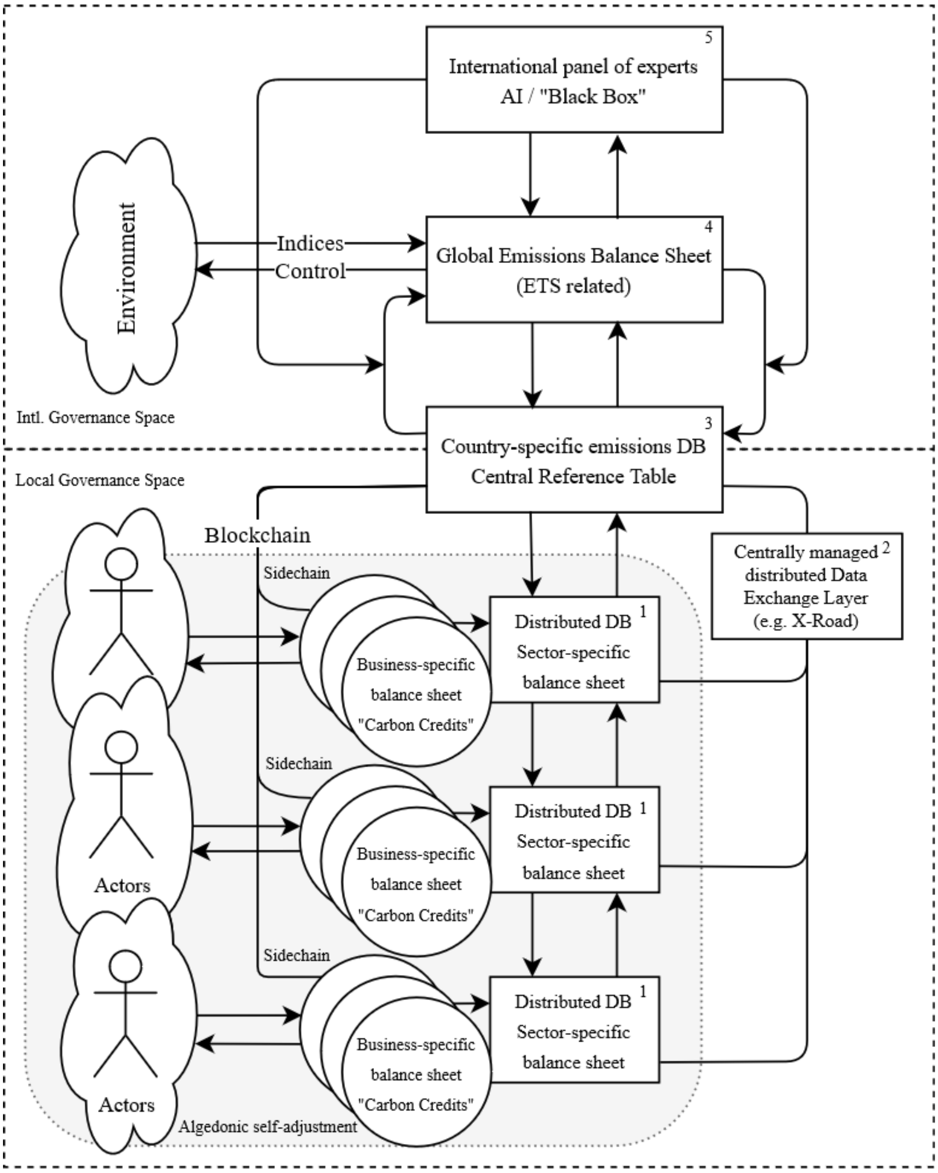

Figure 2. Sympathetic feedback system for emissions reduction
Source: Author's vision based on Stafford Beer's 'Viable System Model' (Medina, 2006)

It is already known for a fact that the X-Road data exchange layer solution is directly contributing to the SDGs[7], proving this systems integration and implementation potential into proposed VSM-based solution. For now, though, the #12 goal is missing from its use-case portfolio, hinting further development requirement in the field of responsible consumption and production, where the author sees highest potential and effect (Nordic Institute for Interoperability Solutions, 2022).

Why such a system is necessary? It has been stated that carbon offsetting is not enough to reach ambitious climate goals, as it can only be supplementary to real efforts to reduce emissions (Hilaire, et al., 2019). While Beer believed that his vision of algedonic meters would provide a new channel of communications that was able to capture citizens' or workers' implicit satisfaction, otherwise nearly impossible to grasp by the host, in a bottom-up manner and in real time (*Ibid*., 91). The same principle applies to the envisaged system above. By including the end-users of products and services into a unified information field encompassing necessary information about the effects of their activities, it would be possible to guide them towards more environmentally cautious choices without the need to even grasp their stance towards climate change.

Such 'nudging' would entail carbon trading and the use of top-level carbon registries. Within the EU it means Emissions Trading System[8] which would fall into the System 3 level box of sympathetic feedback system. This would bring a relatively incomprehensible system closer to the grass roots level of economic activity. Considering theoretical conceptual background, more technical questions arise. To put it simply: even if the data is available (and retrievable) from value chain "nodes" and steps in supply chain, then how to collect, store and make it available in a trusted manner, so that the data about CO_2 could be credibly aggregated and accounted for. Often blockchain technology is used to answer related questions in terms of technological choice.

Table 5. Different aspects between AI and Blockchain

Aspects	Artificial Intelligence	Blockchain
Nature	Centralized	Decentralized
Access	Closed	Open
Transparency	Black Box	Transparent
Approach	Probabilistic	Deterministic

Source: Singh et al. (2020)

[7] See more: https://x-road.global/sustainability
[8] See more: https://ec.europa.eu/clima/eu-action/eu-emissions-trading-system-eu-ets/union-registry_en

From the simplified comparison of the AI and blockchain properties (aspects), it can be concluded that blockchain technology could serve the purpose of collecting and aggregating CO_2 data for the follow-up use for feedback systems. This claim is assessed below with two illustrative examples of proposed solutions with similar aspirations (see Figure 3 & Figure 4 below).

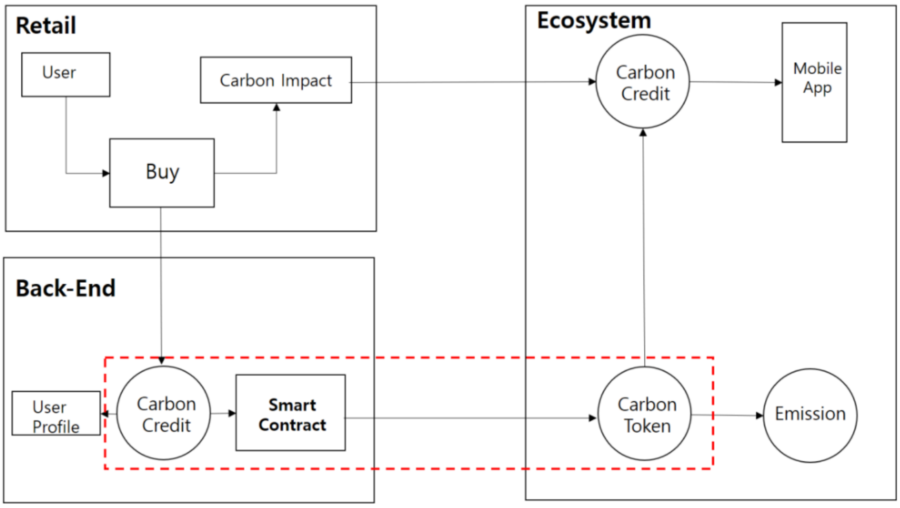

Figure 3. Smart renewable energy and P2P (Peer-to-Peer) blockchain service
Source: Kim & Huh (2020)

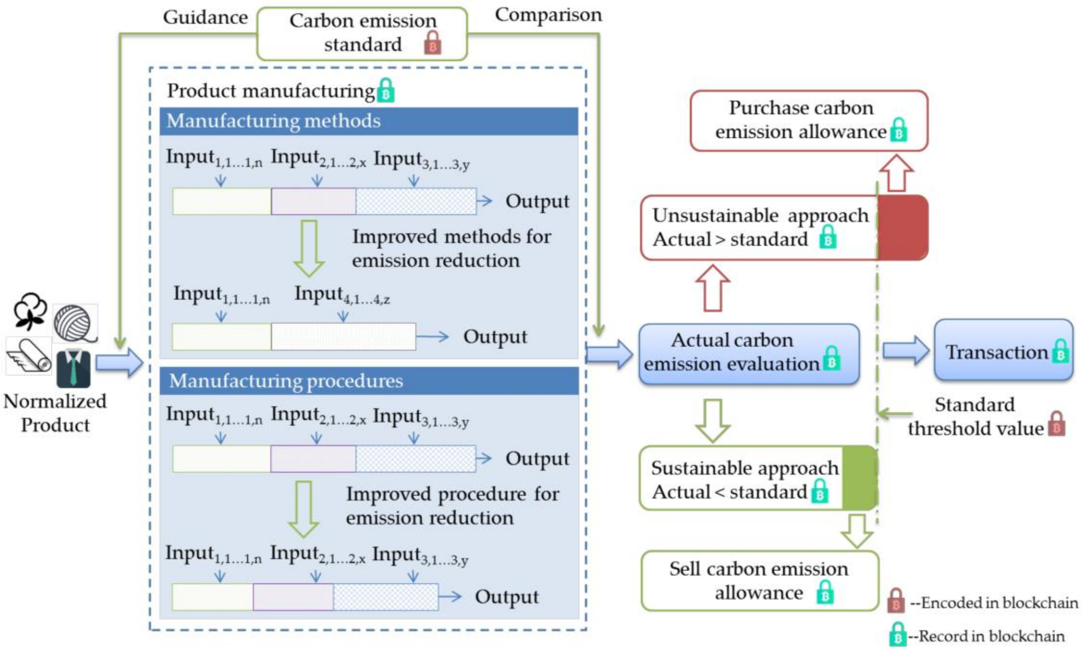

Figure 4. The emission link of the blockchain supported emission trading scheme
Source: Fu, Shu, & Liu (2018)

In Figure 3 a smart carbon credit (Patel, et al., 2020) tokenization is presented. Such a system would provide the economic entity a sufficient control over his/her actions to influence the output of carbon emissions by selecting those economic entities (businesses) that have implemented measures which are less impactful (less emissive) compared to the referenced "carbon emission standard" (see Figure 4). In such a structure, distributed factory networks would form a *real-time enterprise* (Reichwald, Stotko, & Piller, 2005) which could be easily integrated into sympathetic feedback system.

The underlying principle would be collected relevant data about emissions throughout both the value chain and the supply chain of every single product (or a service provided) for end-users, i.e., economic entities that consume something. Understandably there will be data gaps and missing parts along the way of data collection, but these could be filled in with generic (default) calculable reference values.

In principle, the data about a product-related (or a service) impact can be collected or calculated throughout the value chain, depending on its raw materials and transportation used for delivering those goods or services to end-users as previously assessed by the author during the studies (Roos, Sicat, & Arizandieta, 2020). The specifics and methods of such data collection deserves separate technical research. There are already live initiatives for generation and collection of such environmental impact information about specific and generic products (OKEE, 2022).

Author admits that the specific mechanism, how to link an individual to the sympathetic feedback system, is yet to be found, but it can be either through proprietary apps or a 'citizen account' which is centrally managed as part of *System 1* in the VSM. Thus, incentivization can be either a direct benefit (e.g., token-based credits) or other utilities (e.g., tax adjustments).

Although this thesis tries to avoid deep-dive into technicalities of blockchain technology, it is necessary to expand on some aspects of it to provide sufficient understanding of the proposed solution for the issue at hand. As we can see from the proposition, there are multiple economic entities behind one specific *sector* of economic activities that should have different set of reference values to follow and trade with. For that to function, a solution of 'sidechains' could be proposed. Pegged sidechains enable bitcoins (Nakamoto, 2009) and other ledger assets [like carbon credits] to be transferred between multiple blockchains" (Back, et al., 2014). Thus, providing such a parallel system to be feasible in the VSM context (see Figure 5 below).

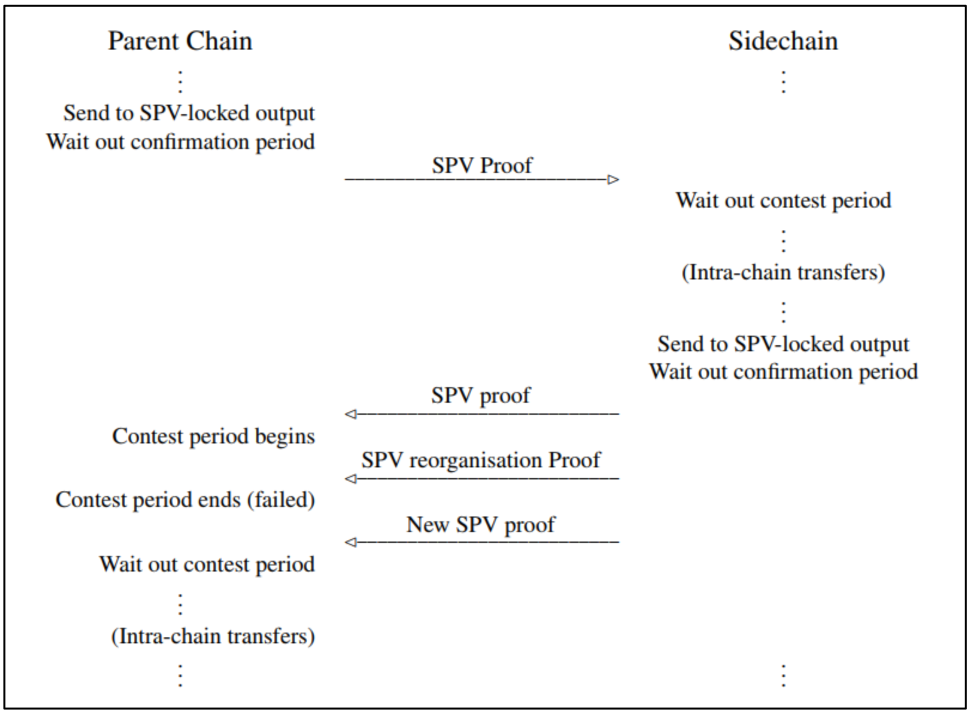

Figure 5. Example two-way peg protocol[9]
Source: Back, et al. (2014)

As the intention of this thesis was to provide a conceptual framework, it will not provide ready-made solution for direct implementation. For a more detailed technical framework, follow-up research with practical examples by blockchain technology experts is necessary. On a conceptual level the necessary building blocks appear to be available and reflected upon in relevant research.

Certainly, the question then arises: what about developing countries that do not hold such technological capacities? Lin (2010) has pointed out that *as strategies for achieving sustainable growth in developing countries are re-examined in light of the financial crisis, it is critical to take into account structural change and its corollary, industrial upgrading. Economic literature has devoted a great deal of attention to the analysis of technological innovation, but not enough to these equally important issues*. Considering material limits to growth (Meadows et al., 1972), this is not only a matter of developing countries, but also developed countries, especially in the context of contemporary economic crisis of exogenous nature, e.g., COVID-19 and imminent climate change that can lead to next great extinction. Thus, the discussion needs to continue to find sufficiently scalable and inclusive system to cover both developed as well as developing countries.

[9] SPV stands for *simplified payment verification proof*

2.2. Problem-solution fit: a cybernetic fusion of VSM and RTE

This section briefly addresses the problem statement made in the introduction and proposes a solution that takes into account both the functional applications of RTE (see 1.1) as well as underlying functional principles of the Project Cybersyn (see 1.2). It answers the sub-question: "How to address SDGs by applying RTE-based solutions?"

The question itself implies to the necessity of what the relevant SDGs are which need to be addressed in the context of this thesis. As stated in the introduction, SDGs are divided into a number of globally significant goals that require collective endeavour. The scene-setting background brought forward two out of seventeen, that deem to be relevant under the title: "Ensure sustainable consumption and production patterns" (SDG #12) and "Take urgent action to combat climate change and its impacts" (SDG #13). (UN, 2022)

SDG #12 is to a great extent self-explanatory: it drives for the sustainable consumption and production.[10] It is inspired by the fact that the global "material footprint" has increased by 70% between 2000 and 2017. This means significant increases in a relatively short period of time in modern history. As a contemporary side-effect, electronic waste continues to proliferate and is not disposed of responsibly, which results in about 7.3 kg of e-waste per person out of which only 1.7 kg is properly recycled. To achieve this goal, several targets have been set with specific indicators for reference to track the global process. (See also Appendix 3).

SDG #13 is also self-explanatory, but far more complex: it asserts with an urgency that the climate crisis continues on a largely unabated course.[11] In 2020 the global average temperature was at 1.2º C *above* pre-industrial baseline, which is "woefully off track to stay at or below 1.5º C as called for in the Paris Agreement" (*Ibid*.). It states that the greenhouse gasses are still rising, although the emissions require shifting of economies towards carbon neutrality. In this regard it is already scientifically stated and proven that mere shifting towards carbon neutrality is not enough to stay at or below the 1.5º C threshold and for that a full-fledged assessment of negative emission technologies that remove carbon dioxide from the atmosphere is crucial (Hilaire, et al., 2019).

[10] See more: https://sdgs.un.org/goals/goal12
[11] See more: https://sdgs.un.org/goals/goal13

As the Earth's climate can be considered as 'exceedingly complex system' according to Beer's categorization for its coupling components across a vast range of scales and multitude of variables that can cause the famous 'butterfly effect' (New Institute established…, 2022), it can be derived that the RTE-based system to reduce carbon emissions can only be with probabilistic functionality.

From the available research there are clear benefits and possibilities to support environmental agendas: "The transformation of analog [*sic*] services into digital formats permits reducing operational processes with a high level of residual carbon footprints. For example, research in the field shows that the shift from paper-based invoices to e-invoices can have a significant environmental impact by reducing the carbon footprint by 63%" (Krimmer et al., 2019, 23). A separate study on the economic impact of real-time economy was conducted by Tieto Estonia AS (Tieto Evry, 2020), which found that switching to real-time economy solutions in selected processes would save over 210 million EUR and over 14 million working hours per year, and reduce greenhouse gas emissions in Estonia by over 27,000 tonnes per year (*Ibid*., Roos, 2020, 71), supporting also the sustainability principles.

These examples indicate that there are both direct and *induced* positive effects on climate change by implementing RTE solutions; direct effects referring to reducing of business activities that intrinsically have an environmental impact (e.g., printing of invoices and sending them by mail instead of e-invoicing), whereas induced effects refer to specific initiatives and applications that are specifically developed for that purpose (Tenhunen & Penttinen, 2010).

As *the success of ambitious digitalization projects such as RTE often depends on specific national contexts and countries' ability to build an ecosystem interconnecting all relevant stakeholders* (Krimmer, et al., 2019) it is necessary to consider alternative options to bridge the gap between connected and unconnected entities. Connectedness, especially from the data sharing point of view, depends mainly on the two interlinked circumstances: *technical feasibility* (i.e., possibility to connect to the network) and *regulation* (will *vs*. obligation). For obvious reasons, these circumstances vary significantly in international context along with the level of technological and digital development. Thus, the question remains: to blockchain, or not to blockchain. Yet there are a number of examples have proven blockchain technology to be the most suitable solution for verifiable complex problem solving.

Clearly there are broader application potential in such RTE-based (or VSM-based) concepts. As put by the author himself: “On top of these self-evident quantifiable facts, real-time economy-based tools can help with faster crisis management or even prevent problems that arise during this pandemic by providing real-time overviews of medical products, food supplies, and essential goods. However, the full potential of real-time economy will be achieved only through continued international cooperation and investments into both intellectual and material capabilities.” (Roos, 2020).

As a result, the proposed VSM-based sympathetic feedback system provides to be feasible with the help of RTE-based solutions for integration and timely data exchange purpose. To do it effectively, three important functional preconditions were found. First, cross-border functionality of CO_2 data aggregation; second, transparency – a credible (trackable) and intelligible allocation of (sustainable) emission credits; and third, provide incentives for the economic entities to implement and act by the feedback system.

In principle, such a system could be used internationally and functionally for trade in goods services even for countries who do not hold technological capacity to implement such a system within their field of governance. For that reference values could be used to fill the gap by extracting statistical information of their economy.

To conclude this part of the study, ‘Five Principles for the People toward Good Government’ were proposed by Stafford Beer: *1) end to bureaucracy, 2) greater transparency, 3) increased personal responsibility, 4) clearer government organization, and 5) planning for the future* (Medina, 2014, 135). From author’s point of view, such an RTE application would contribute to all of the above-mentioned principles: leading to less bureaucracy through automation, providing transparency regarding carbon statistics, increasing personal responsibility towards sustainability, providing clearer government organization through VSM and providing a tool for better planning for the future ahead.

3. DISCUSSION

Based on personal experience, author searches for workable solutions from the RTE concept to address the issue in the context of technology governance and digital transformation with this thesis. The literature review suggests that the RTE phenomenon is of recent nature and earliest references to the term reverts to early 2000s (Siegele, 2002; Krimmer, et al., 2019) implying to its close ties to information age and digital transformation. From an extended literature review conducted by the author, an unsuspected contender emerged, having all the intrinsic features of an RTE-based concept.

Although this particular case is of completely different impetus – a revolutionary one – it exhibits very similar high techno-economical potential and ambition with particularly high level of intrinsic complexities to that of rationalist RTE phenomena. What's even more remarkable is the fact that this case dates to pre-information age era with its roots, being at the 'edge of tomorrow' of its own time in the early 1970s (Barrionuevo, 2008; Morozov, 2014). From a phenomenological and etymological point of view this fact rewrites the evolutionary history of RTE phenomenon by pushing its genesis back by 30 years: it is the case of 'Project Cybersyn'.

Interestingly, both the acknowledgement of *limits to growth* as well as introduction of a microprocessor – marking the beginning of information age – coincide with one particular piece of Chilean political, but also technological history. Although Cybersyn's impetus was anything else than technological, it plays a significant role in the discourse of technology governance and digital transformation. Eden Medina (2006; 2014), who retold the story of two intersecting utopian visions – political and cybernetic – interprets technologies as historical texts. In this regard, that piece of history provides two valuable lessons for the discussion: first, the aspirations towards real-time economy stretch far beyond what has been considered as starting point of the phenomenon, and second, cybernetics is indispensable for bridging technology with non-technological challenges to provide sympathetic feedback system with the aid of technology.

Author's main concern revolves around one of the greatest global challenges that has been addressed and highlighted repeatedly in recent history: *anthropogenic climate change*. It was first brought to global limelight by the Club of Rome with the "Limits to Growth" (Meadows, et al., 1972) just before the 1973 global energy crisis caused by substantial petroleum shortages as well as elevated world prices. The same natural resource is one of the main culprits of human activity related carbon emissions that are causing gradual increase of the global average temperature and pushing Earth's homeostatic state to the limits. Yet, it is the same resource in the form of 'cheap energy' that has also enabled human civilization to thrive for the past economic super-cycles, or more precisely, *techno-economic paradigms* (Perez, 2002; 2010a; 2010b).

The problem with anthropogenic climate change is that it lacks timely and adequate feedback and reaction. Human population as an 'organ' (*a temporally short-sighted sensory collective*) of the 'superorganism' – Earth – fails to respond adequately and continues as usual, ignoring imminent risks. This can be due to different debatable reasons which deserve separate research on their own:

- general ignorance and denial of anthropogenic climate change;
- lack of, or outdated technologies for sustainable production and energy consumption;
- lack of incentives to make more sustainable choices (e.g., prices);
- lack of information about the environmental impact of choices;
- intangible (delayed) impact of inconsiderate *modus operandi*.

This non-exclusive list of possible reasons is purely subjective and illustrative, but easily addressed with the help of *sympathetic feedback system*. Such a system with necessary transparency (e.g., data verifiability) can also help with raising awareness, but mostly to inform and incentivise towards more sustainable and less emissive choices.

By infusing these early cybernetic aspirations with modern technological achievements, an ideal conceptual mix could be derived to address a viability issue of an exceedingly complex system, like climate. By implementing RTE-based solutions across the board of economy (also an exceedingly complex system), a holistic 'digital ecosystem' is created by and for its entities. This ecosystem can then be turned into a *viable system model* with an intrinsic sympathetic feedback mechanism for self-adjustment purposes – to act upon real-time internal and external stimuli and survive by maintaining homeostasis of economic and environmental tandem.

VSM-based solution with RTE functionalities reflects and facilitates core cybernetic principle to "collect as much relevant data from as many sources as possible, analyse them in real time, and make an optimal decision based on the current circumstances rather than on some idealized projection" (Morozov, 2014). This could be interpreted differently in the context of the 'exceedingly complex problem' at hand – i.e., climate change. On an individual level one could argue that *current circumstances* could be trivial or even misleading on an individual (personal) level of *algedonic* feedback system because conversely to what the science says, an individual (or an enterprise managed by an individual) can have a different cognitive perception to that of the objective one. E.g., the weather is perceived colder than expected at the level of economic actor perception, which is normally the basis of that individual's algedonic decision.

At the same time, it can be looked at from another perspective: from the current circumstances of an *exceedingly complex system* (climate) itself. By collecting historical data of key indices that affect the climate change the most, necessary reference variables can be deduced and applied in algedonic manner for the sensory level (individuals and enterprises) to adjust their behaviour for the purpose of system's survivability. For that reason, an idealized external projection is necessary for the economic entities to react to.

Modern technologies like AI and blockchain have already proven to be effective in solving (big) data related complex issues. This includes for example suggestions how to solve SDG related zero hunger goal (Cervantes Sanchez, 2021). Both technologies appear to be feasible in facilitating the functioning of a proposed sympathetic feedback system to manage emissions related data, irrespective of the specific blockchain. And indeed, 'Big Data' has the potential to mitigate such 'wicked problems' (Ketter, Peters, Collins, & Gupta, 2016) that have turned into SDGs – including sustainability, climate change and feeding the growing world population being some of the most acute examples (Metsis, 2020).

So, the question for the future is, how to become sustainable and cope with economy's increasing frequency of interactions (including business transactions) at the same time? In the author's opinion, instead of investing into a myriad of regulations there is a need for investment into RTE-based applications to cope with increasing frequency of *digitalized* economy to bridge the gap between economic aspirations and environmental reality. In this regard the concept of RTE mixed with cybernetic principles might provide a helping hand.

CONCLUSION

This thesis is techno-philosophical exploratory research in the context of broader systems theory with proposals for practical applications of real-time economy concept in the *algocratic* nature of technology governance and digital transformation forming a thick description of the two. It is a phenomenological contribution to the discourse related to real-time economy phenomenon, its definition and functionalities, searching for applications to tackle one of the most pressing global challenges – the climate change. As a result, it proposes conceptual *sympathetic feedback system* for economic entities to reduce carbon emissions by tracking and aggregating CO_2 data from the supply and value chains and linking it to carbon registries.

Author admits that it is not universally conclusive as the RTE concept is still open for research and debate, especially from the practical application's perspective. It's an invitation for further discussion for the sake of better future amidst grand economical fluctuations, deep transitions of techno-economic paradigms as well as 'black swans' in their notorious glory. By harnessing digital technologies together with cybernetic principles, the *Moonshot missions* might become more feasible than previously thought, and this thesis attempts to conceptually prove it.

The main scientific contribution of this thesis is summarized as follows:

- it contributes to the academic discussion about *real-time economy* by creating new (lost & found) linkages to historic initiatives with clearly similar aspirations, thus rewriting current conception of its formation;
- it strives to raise awareness about the phenomenon in the context of technology governance and digital transformation, inviting readers to continue research on the phenomenon and its practical applications;
- it highlights importance of interdisciplinary approach to address grand challenges, such as global climate change;
- it proposes a conceptual framework of a VSM-based solution with RTE functionalities to create a sympathetic feedback system for bottom-up CO_2 reduction.

This research paper is divided into two interlocutory chapters followed by a discussion to reflect on key findings and elaborate on author's proposition how to address climate change with a help of scrutinised technological concepts. It follows two underlying research objectives: first, to continue exploration of the phenomenon, and second, to provide a (thick) description how to harness RTE concept principles outside its original context, expanding its implementation potential to use-cases that have been rather vaguely referred to so far.

A qualitative research method was therefore chosen by applying rigorous interdisciplinary meta-synthesis of available academic literature as well as other indirectly related scientific studies resulting in an infusion of real-time economy phenomenon and cybernetics, techno-economic paradigms in the context of technology governance and application of blockchain technology as a viable option for the cause as a landmark of digital transformation.

The core research question of this thesis was answered with the help of relevant sub-questions that helped to (re)define the real-time economy, explore its historical conceptual roots, and explain possible implementation logic by building on the currently available digital technologies. From the literature review it became apparent that the real-time economy as a phenomenon is clearly a 'product' of *information revolution* with its roots in cybernetics – a result of conscious technology governance choice and an evolutionary tool of digital transformation whereas the viable system model was a result of *cybernetic logic* for economic problem solving.

This thesis managed to reflect on most research goals. Most prominently, it *interpreted historically significant phenomena* – i.e., real-time economy concept and Project Cybersyn – forming a phenomenological extension to the current discourse. Additionally, it *identified general patterns and relationships* of the real-time economy phenomenon in earlier initiatives like Project Cybersyn in the wider context of technology governance and digital transformation.

To some extent it *tested and refined theories* related to the origins of real-time economy concept, providing new insights of its viability in sustainability domain, hopefully *giving voice* in twofold way: raising awareness about the subject matter from theoretical and practical perspective, and retelling the story of Project Cybersyn while emphasizing its importance in the technology governance and digital transformation discourse.

Author concludes that the real-time economy concept together with viable system model principles is a viable framework for a *sympathetic feedback system* to bring about bottom-up behavioural change among economic entities, from governments to businesses, from societies to individuals. Carbon offsetting is not enough to reach ambitious climate goals set in targets of SDGs and keeping the average temperature below the critical threshold upon which cataclysmic events may follow. In this regard it is vital to raise the awareness of individual footprint and incentivise conscious decision-making to limit the environmental impact by reducing anthropogenetic CO_2 emissions.

To do it effectively, three important functional preconditions were found. First, cross-border functionality of CO_2 data aggregation; second, transparency – a credible (trackable) and intelligible allocation of (sustainable) emission credits; and third, provide incentives for the economic entities to implement and act by the feedback system.

From technology governance and digital transformation discourse perspective it would be valuable to conduct research on three decades, 1970-2000, to have a better understanding of why 'Project Cybersyn' type of initiatives did not get enough traction to be deployed as the technological feasibility was exponentially growing since the introduction of a microprocessor in 1971, marking the beginning of 'Information Age'.

Author believes that the real-time economy concept together with cybernetic principles would provide perfect combination to pursue 'green growth' which has deemed questionable if not impossible by critics. By capturing the relevant environmental impact information throughout the supply and value chain and making it available for the end users through algedonic measures, it can bring about bottom-up socio-economical change through more conscious consumer behaviour and production practices of the industry. Would it be a new 'invisible hand' to guide the economy? Only *real-time* will tell.

This thesis is a tribute to Anthony Stafford Beer

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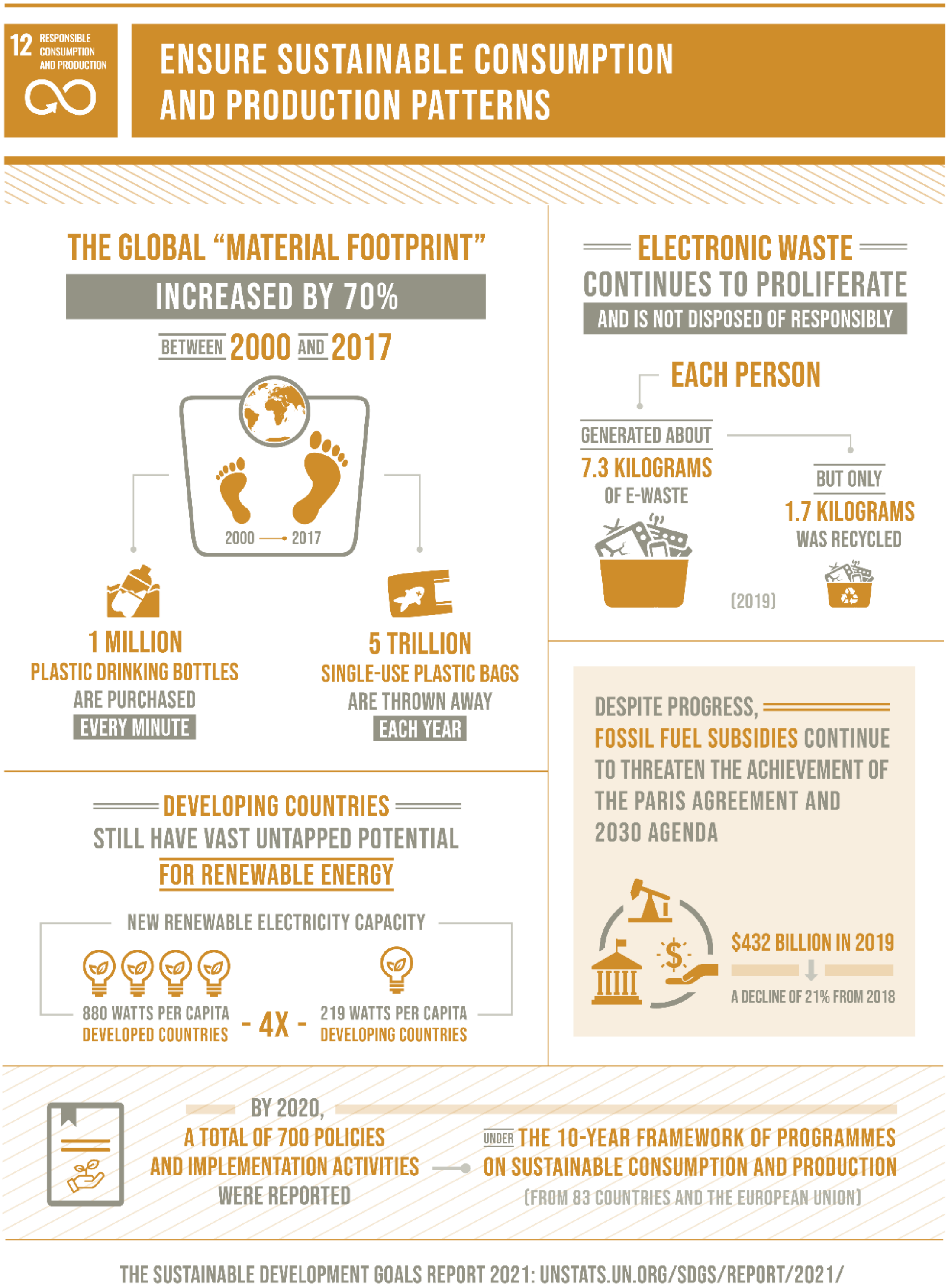
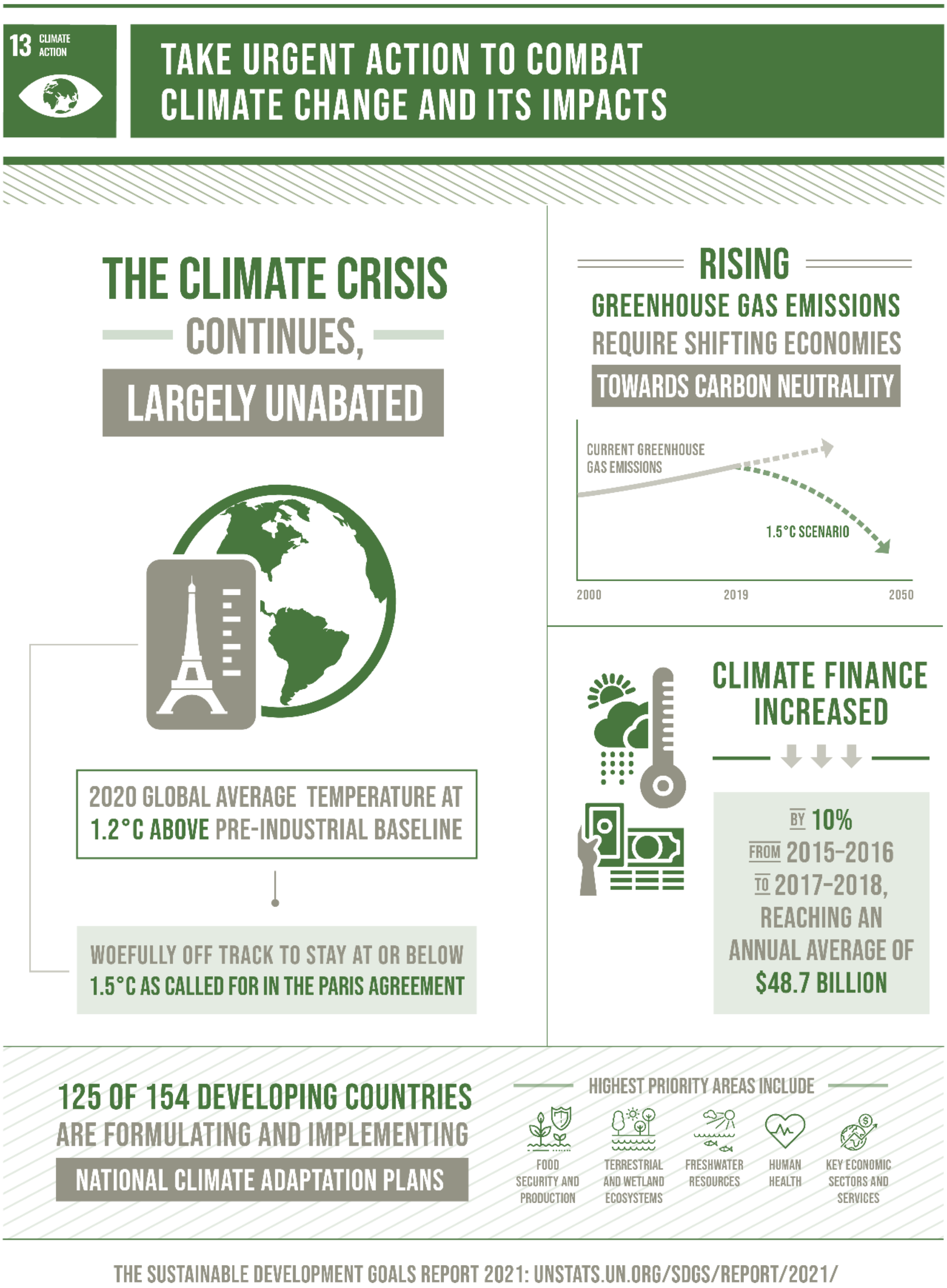
APPENDICES

Appendix 1. SDG 12: Responsible consumption and production factsheet



Appendix 2. SDG 13: Climate action factsheet



Appendix 3. SDG targets and indicative RTE solution correspondence table

SDG Target	Yes	No
12. Ensure sustainable consumption and production patterns	**(8)**	**(3)**
12.1 Implement the 10-year framework of programmes on sustainable consumption and production, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries	X	
12.2 By 2030, achieve the sustainable management and efficient use of natural resources	X	
12.3 By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses	X	
12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment	X	
12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	X	
12.6 Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle	X	
12.7 Promote public procurement practices that are sustainable, in accordance with national policies and priorities	X	
12.8 By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature		X
12.a Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production		X
12.b Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products	X	
12.c Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities		X
13. Take urgent action to combat climate change and its impacts*	**(3)**	**(2)**
13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries		X
13.2 Integrate climate change measures into national policies, strategies and planning	X	
13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	X	
13.a Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible		X
13.b Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities	X	

Source: UN (2022); author's presumptions

* Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change

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