SUSTAINABILITY HACKING:

CONCEPTUAL DEVELOPMENT AND EMPIRICAL EXPLORATION

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DECLARATION

This dissertation is the result of my own work and includes nothing, which is the outcome of work done in collaboration except where specifically indicated in the text. It has not been previously submitted, in part or whole, to any university of institution for any degree, diploma, or other qualification.

In accordance with the Department of Engineering guidelines, this thesis does not exceed 65,000 words, and it contains less than 150 figures.

Paulo Savaget

Cambridge, May 2019

ABSTRACT

Sustainability Hacking: conceptual development and empirical exploration

Paulo Savaget

Systemic humanitarian, environmental, and socio-political problems are impeding current and future generations from meeting their very basic needs. The speed and scope of mainstream responses to the world's most pressing problems are limited by agency failures and by the 'rules of the game'.

In this context, this research contributes to theory and practice by formulating and exploring the concept of *Sustainability Hacking*, a particularly advantageous change driver in situations where information is limited, resources are scarce, stakes are high, and decision-making is urgent.

This research was conducted through 3 sequential stages. First, the researcher has systematically reviewed the literature on sociotechnical system change for sustainability. This review exposed and discussed 15 theoretical foundations that shape what changes are perceived as desirable and attainable, as well as how to navigate between all the coexisting pathways to drive positive change. By examining these foundations, it became possible to pinpoint opportunities for future contributions.

Among them was the idea of investigating the meaning, characteristics and potential implications of Hacking as a change driver of sociotechnical systems. These were revealed in the 2nd research stage, after interviewing self-declared *Hackers* and cybersecurity experts to understand how they used the term and how they pursued their desired systemic changes. This stage provided the definition, as well as 9 dominant characteristics of System Hacking.

The term refers to exploring unconventional solutions to a problem within sociotechnical systems. 'Unconventional' here means deviating from embedded institutions, i.e. the rules of the game in a society. Institutions represent sources of stability, coherence, and continuity of systems, while simultaneously shaping public expectations of what changes are viable and the heuristics of how they should be pursued. Differently from conventional approaches, system Hackers are not aiming at changing rules, neither are they passively complying with them. Instead, they work around the 'rules of the game' to accomplish 'good-enough' results promptly.

The 3rd research stage consisted of investigating and working with Sustainability Hacks, i.e. System Hacks addressing pressing sustainability problems. This was performed through a combination of Action Research and Case Studies. Benefitting from a diverse database of 19 cases, the researcher conducted a cross-case analysis, which provided comprehensive observations on the 15 main similarities and 10 differences that constitute the key analytical variables of Sustainability Hacking. Furthermore, the analysis derived 5 Archetypes that can be used as frames of reference to provide guidance for practitioners evaluating possibilities of addressing pressing sustainability problems, as well as to support future academic contributions in this nascent field of research.

DEDICATION

Dedicated to the nobodies:

"Who are not, even when they are.
Who do not speak languages, but dialects.
Who do not have religions, but superstitions.
Who do not create art, but handicrafts.
Who do not have culture, but folklore.
Who are not human beings, but human resources.
Who do not have faces, but arms.
Who do not have names, but numbers.
Who do not appear in the history of the world, but in the police blotter of the local paper.
The nobodies, who are not worth the bullet that kills them"
(Eduardo Galeano, El Libro de Los Abrazos, p.52) [1]

[1] My translation, from Spanish to English.

ACKNOWLEDGEMENTS

Privilege finds a way of blinding the privileged – and academics are no exception. The idea of meritocracy is a fetishized delusion that pleases a few while legitimizing inequality. In a world where the vast majority of the population cannot aspire to do a PhD, acknowledging privileges here is not only desirable: it is also a matter of analytical rigor.

I am confident that my PhD was only possible due to a system of privileges, i.e. to all the things that have happened *to* me. I wish I could pinpoint the ones related to my gender, sexual orientation and skin colour, but these are too many. Neither can I remember all those seemingly unimportant events that steered my trajectory: that teacher who got me out of trouble, the invisible humans who cooked my food, and the many times I was granted a second chance.

I am the only signing this document, but this thesis is neither entirely my own nor mine to own. However, due to my cognitive inability, I can only exemplify with a few memories that are now orbiting around my mind. I am unsure if these memories will ever fall into the cracks of my brain. It feels good to know I will always be able to find them here.

In my mom's words, my parents raised me 'with roots and wings'. That is why they cried and smiled, at the same time, when I was about to board my flight to the U.K. Also explains why their house will always feel like home. Much more than affording the best education available in a radius of many kilometres, I am very fortunate to have been raised by some of the most inspiring, knowledgeable and caring people I have ever met. I remember fondly of my mom passionately reading aloud Greek mythology during lunch, and my father vehemently discussing politics after dinner. They have – consciously or not – raised 2 nerds. Does Freud explain that, mom?

Talking about the other nerd… Yesterday, I asked my brother to help me translating a particularly difficult epigraph from Portuguese to English. His response included: a very accurate translation and a banter on how his PhD thesis was superior to mine. Typical of him! My brother has helped and criticised me for the past 30 years. He was my first peer reviewer.

It was also thanks to him and to my equally nerdy sister-in-law that I came to Cambridge to meet Steve, a.k.a. the Big Boss, to discuss the possibility of doing a PhD under his supervision. Only knowing him from his publications – yet very aware of the stereotypes of Cambridge academics – I imagined him wearing a tweed suit and politely keeping himself distant from his students. I met, instead, an academic wearing shorts and socks that were not matching. Despite looking a bit grumpy, he was clearly very caring with his supervisees. What a great first impression! After over 3 years, I could not have been happier. Even among the highly privileged sample of PhD students in Cambridge, I feel very lucky for having had his mentorship and friendship.

Besides Steve, many other mentors have profoundly changed my academic trajectory. The meetings with Carlos, where he stretched me out of my comfortable zone, pointing at opportunities I wasn't aware of and explaining how to best pursue them. The meetings at Nisia's house, where I learned how to approach problems differently and serenely, while eating pão de queijo. The many mind-blowing conversations with Liliana, Xará, Andy, and Duda, who supervised my previous degrees. When with them, I had the impression I was absorbing knowledge through osmosis, just for being 'there', with the ones who had much to share.

But not only mentors. I have a huge support network! That brings me back to a memory from my early childhood. I was a toddler and my mom was driving me to school. After seeing a homeless child on the street, I asked her: 'Where is his mom? Where is his dad? Where is his nanny?'. I was so unknowingly privileged that I could not conceive a life without a support network such as mine. In fact, until now, I can't imagine how my life would have been if I did not count with the love and support from my nanny, grandparents, aunts, uncles, cousins, in-laws, friends, and many others in Brazil.

That support system has grown massively, since in Cambridge. That reminds me of when I first arrived here. I was forced to make friends with other nerds while gorge scrambling, kayaking or trying to lick my elbow. Since then, friendships grew organically and completely moulded my experiences during this PhD. I have so many friends that I could plot them in a Venn diagram: a) the best huggers; b) the best writing buddies; c) the best travel buddies; d) the best for exercising with; e) the best to chat over coffee or beers; f) the best to share a meal with; g) the best experts in gifs and memes; and h) the ones at the intersections of the options above. All of them are the best.

More support came from my scholarship, Gates Cambridge. I can remember vividly the thrill of reading the email that granted me a fully-funded offer … The involuntary goose bumps, accompanied by a silence. The one needed to digest something life-changing. Then reading it again, paying attention to the details, to make sure the offer was real. Without Gates, this PhD would not have started. And without the Sustainability Hackers – who opened their minds and, in some cases, their houses for me – this PhD wouldn't have been completed. I am very grateful and I hope this work makes justice to their contributions.

Not the least is Ju, my much-loved partner. In this recollection of memories, her name comes last. She transcends the past, since she is the one who is most present and without whom I can't imagine a future.

DISSEMINATION

Savaget, P., Carvalho, F., 2016. Investigating the regulatory-push of eco-innovations, in: *Sustainable Design and Manufacturing*. Chania, Greece, pp.27-37.

Savaget, P., 2016. Passivity, Utilitarianism and Techno-Determinism in Science and Technology Policy, in: *Globelics 2016*. Bandung, Indonesia.

Savaget, P., 2017. Hacking System Change, in: *Interdisciplinary Ph.D. Workshop in Sustainable Development*. Columbia University, New York, United States.

Savaget, P., Acero, L., 2017. Plurality in understandings of innovation, sociotechnical progress and sustainable development: An analysis of OECD expert narratives. *Public Understanding of Science*, 27 (05), pp.1-18.

Geissdoerfer, M., Savaget, P., Bocken, N.M.P., Hultink, E.J., 2017. The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, 143, pp.757-768.

Geissdoerfer, M., Savaget, P., Evans, S., 2017. The Cambridge Business Model Innovation Process. *Procedia Manufacturing*, 8, pp.262-269.

Calvente, A., Kharrazi, A., Kudo, S., Savaget, P., 2018. Non-Formal Environmental Education in a Vulnerable Region: Insights from a 20-Year Long Engagement in Petrópolis, Rio de Janeiro, Brazil. *Sustainability,* 10, pp.42-47.

Savaget, P., Chiarini, T., 2018., Evans, S 2018. Empowering Political Participation through Artificial Intelligence, in: *Academy of Management*. Chicago, United States.

Savaget, P., Chiarini, T., Evans, S., 2018. Empowering political participation through artificial intelligence. *Science and Public Policy*, scy04, pp.1-12.

Savaget, P., Henderson, C., Evans, S., Savaget, P., 2018. Catalysing access to Over-the-Counter Medicines in Remote Areas by Emulating Value Chains and Steering System Change, in: *Globelics 2018*. Accra, Ghana.

Savaget, P., Geissdoerfer, M., Kharrazi, A., Evans, S., 2019. The theoretical foundations of sociotechnical systems change for sustainability: a systematic literature review. *Journal of Cleaner Production*, 206, pp.878-892.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. Introduction

"After visiting the Wonderland, Alice entered in a mirror to find the world upside down. If Alice was reborn in our days, she wouldn't need to go through a mirror: it would be enough to approach a window".
(Eduardo Galeano, Las Patas Arriba, p.1)[2]

1.1. Introduction to the Chapter

This thesis formulates the concept of Sustainability Hacking, situated within studies on sociotechnical system change for sustainability, and explores it empirically. This chapter gives the reader a taste of the issues and concepts addressed in this document.

Section 1.2 introduces some pressing sustainability problems, which ultimately motivated this PhD research. This is followed in Section 1.3 by a brief discussion on change drivers capable of steering sociotechnical systems towards more socially desired directions. Section 1.4 familiarises the reader with the core contribution of the thesis: the concept of Sustainability Hacking formulated and empirically explored by the research. Section 1.5 describes the target audience of this work. Section 1.6 depicts the research problems and research stages, which serve as frames of reference for the research design. Chapter 1 is concluded in Section 1.7 with an outline of the content of each of the remaining chapters.

1.2. Pressing Sustainability Problems

Sustainability is often described as the balanced integration of social inclusiveness, environmental protection, and economic progress, benefiting current generations without jeopardising future generations of meeting their needs (Brundtland, 1987; Elkington, 1999). This term is deliberately vague, accommodating a variety of expectations for development, and opening up scope for heterogeneous responses to distinct contexts and to the complexity of coexisting challenges (Kates *et al*. 2005; O'Riordan, 1993). By recognising the scarcity of natural resources, and the plurality of expectations and potential responses for development, sustainability helps to compare and decide which goals should be prioritised, the means that

[2] My translation, from Spanish to English.

can – and should – be deployed to accomplish them, and the responsibilities of each stakeholder (Savaget and Acero, 2017).

This conceptual vagueness has been allowing sustainability to increasingly enter and gain prominence into the agendas of policymakers, industrialists, and non-profits since the second half of the 20th century. Instead of merely setting and pursuing common – and often uncontested goals (such as economic growth) – sustainability narratives enact a wider scope for plural understandings and expectations on what is to be developed, what is to be sustained, for how long, and for the benefit of whom (S. Jasanoff, 2010).

Along these lines, academics working on sustainability have introduced various frameworks challenging simplistic understandings of development, which often disregard social and environmental aspects and fetishize economic growth (e.g. Jackson, 2009). These frameworks often focus on unpacking sources of decision-making tensions, as well as on discussing the extent of our ignorance, whereby managerial and policy interventions can only be seen as path-dependent, adaptable experiments.

Furthermore, the adjective 'pressing' underlines the importance of prioritising what matters the most and the most urgent problems. This is, nonetheless, intrinsically subjective, given that priorities depend on agents, contexts and the multiple understandings and aspirations for development. For example, what should be the top-priority for the government of Uganda: HIV control, fighting hunger, environmental protection, or boosting agriculture? What measures should be implemented to meet their priorities? Therefore, by focusing on problems of a 'pressing' nature, the researcher firstly highlights the need of investigating circumstances in which decision-making seems urgent, and, secondly, the agency of different players both in appraising problems and deciding how to act accordingly.

1.3. Steering Sociotechnical System Change

It seems rather consensual that incremental changes are not sufficient to address all current, let alone future sustainability challenges (Brundtland, 1987; Sachs, 2015). These challenges require substantive changes in the functioning of sociotechnical systems. This term refers to the co-evolving social and technical aspects that are interconnected in complex structures and that are analysed according to arbitrarily defined boundaries. Given that a system is more than the sum of its parts, the most important property of system thinking is the ability of seeing 'wholes' in order to analyse integral components, their respective interconnections and the functions delivered by the system (Senge, 1990; Charnley, Lemon and Evans, 2011).

Sociotechnical systems are constantly changing. However, the competences required to intentionally steer changes towards more desired directions are far from trivial. Unsustainable characteristics of prevalent sociotechnical systems are often part of mutually-reinforcing dynamics that encompass, for instance, technologies, social behaviour, and policies. Steering change is, therefore, essentially complex and uncertain.

Along these lines, studies have investigated how to intentionally steer system change. They have covered, for example, the characteristics and determinants of sustainable innovations, capable of leapfrogging unsustainable technological paradigms (Hart and Milstein, 2003; Partidário, Lambert and Evans, 2007; Seyfang and Smith, 2007; e.g. Cooperrider, 2008); directionality when changing systems, the bounded rationality of agents and their diffused agency (Dovers and Handmer, 1993; Leach, Scoones and Stirling, 2007; Stirling, 2008, 2009, 2014; Eames and McDowall, 2010; e.g. Borrás and Edler, 2015); and the highly institutionalised features acting as enablers or constraints of positive change (Nelson and Winter, 1982; Geels and Schot, 2007; e.g. Farla *et al.*, 2012; Markard, Wirth and Truffer, 2016).

Furthermore, mechanisms of steering change often rely on the development of science, technology and innovation. These, nonetheless, present profound sources of tension, as they can be seen, simultaneously, as the causes of and solutions to problems (Žižek, 2011). On one hand, past technological trajectories led to unintended environmental consequences, their resulting benefits have not reached all stakeholders equally, and expectations of sociotechnical progress are intrinsically plural and often disputed (S. Jasanoff, 2010; Sachs, 2015; Savaget and Acero, 2017). On the other, these change drivers of sociotechnical systems are not unfrequently portrayed as the main sources of hope in tackling sustainability challenges (Cohen, 1997, 2006). Therefore, business people and policymakers alike expend great effort both on the generation and diffusion of innovations as well as on anticipating every possible scenario through the design of long-term, coordinated governance involving multiple agents and expectations (Smith, Stirling and Berkhout, 2005; van Zeijl-Rozema *et al.*, 2008; Perez, 2012; Borrás and Edler, 2015).

1.4. Preview of Sustainability Hacking

Recognising that steering sociotechnical system change is critical to address pressing sustainability problems, the researcher started his PhD by systematically reviewing literature on this topic. This review, portrayed in Chapter 3, exposes and discusses 15 theoretical foundations that shape how we understand sociotechnical system change for sustainability, i.e., what changes are perceived as desirable and attainable, as well as how to navigate between all

the coexisting pathways to drive positive change. By examining these foundations, it became possible not only to shed light on the most up-to-date theoretical developments, but also to pinpoint opportunities for future contributions to theory and practice. Among these foundations, two have highly influenced the following steps of this research.

The first consists of the observation that the analysis of sociotechnical system change for sustainability largely revolves around the generation and diffusion of innovations capable of replacing predominant and unsustainable alternatives. The theoretical implication is that the analytical focus lies on the products, processes, services or business models capable of replacing the predominant unsustainable alternatives in the marketplace. The complication associated to this theoretical foundation is that, as innovations inevitably revolve around commercialisation, roles of a diverse set of interconnected agents (e.g. companies, governments, and individuals) are investigated accordingly. The analysis of sociotechnical system change tends, therefore, to be market-centred. The examination of this foundation led the researcher to start enquiring what steps individuals and organizations can take at the micro-level that may not materialize through the marketplace, but which may still be capable of changing sociotechnical systems.

The second theoretical foundation consists of the observation that long-term governance, with stakeholder engagement, is the standard approach to deal with wide-scale system-level changes. The implication of this foundation to theory and practice is that a wide range of possibilities needs to be assessed, various agents coordinated, and multiple actions planned and adapted to changing contexts. However, the complication associated to this is that the speed and scope for tackling complex sociotechnical problems are limited by agency failures, resulting from the complex coordination of multiple agents for deliberation. As a result, initiatives are analysed, designed and planned with care, but are often either sluggishly operationalised or are not brought to fruition. This reflection motivated the researcher to question what purposeful actions, conducted by agents who do not have ownership or accountability of the power structures of sociotechnical systems, can be pursued to leverage wide-scale system change ‘here and now’.

The researcher has thus observed that literature on sociotechnical system change for sustainability shies away from questions such as: ‘how can an individual take agency of deep sociotechnical changes?’; ‘how can systemic problems be addressed when information is limited, resources are scarce, stakes are high and decision making is urgent?’ and ‘how can agents circumvent traditional heuristics for systemic change?’ By asking these questions, the researcher had the idea of examining ‘Hacks’ in complex computational systems as potential sources of inspiration to address this void.

The meaning and main characteristics of '*System Hacking'* were then unpacked after interviewing self-declared *Hackers* and cybersecurity experts to understand how they used the term and how they pursued their desired systemic changes. The term refers to exploring unconventional solutions to a problem within complex systems. 'Unconventional' here means deviating from embedded institutions, i.e. the rules of the game in a society (North, 1990). Formal and informal rules shape activities that will likely be undertaken, the solutions to be prioritized, and the strategies of stakeholders. Institutions thus represent sources of stability, coherence, and continuity of systems, while simultaneously shaping public expectations of what changes are viable and the heuristics of how they should be pursued (Ostrom, 2000; Hodgson, 2005).

Institutional theory indicates that tacit and explicit rules of the game limit the scope of potential responses (North, 1990). For example, if lack of infrastructure is a bottleneck for an underdeveloped healthcare system, the conventional response is to invest in infrastructure. Given their complexity, these actions either take a long time to be undertaken or are often put aside. Unconventional solutions are, in contrast, pragmatic and resourceful actions diverging from the expected heuristics and rules of the game – without infringing upon existing laws – to deliver good-enough results. In other words, system Hackers are not aiming at changing the rules of the game, but neither are they passively complying with them: they are purposefully ignoring or bypassing rules to pursue alternative routes and reach immediate solutions. By defying rules, they can then address problems that are highly engrained and difficult to tackle by mainstream means.

After contrasting to other concepts of sociotechnical system change, the researcher has then identified the main contributions of the concept of System Hacking, subsequently focusing on exposing how it could be particularly promising to address pressing sustainability problems. The main reasons are that System Hackers are: less constrained by those formal and informal rules responsible for agency failures and, consequently, the persistence of an undesirable status quo; by focusing on good-enough solutions, they can experiment to alleviate problems or break systemic inertia; they are less impacted by coercive power relationships or scarcity of resources; and they do not face great barriers to entry and, as a result, their initiatives are quickly scalable.

Having defined and understood the dominant characteristics of System Hacks, the researcher subsequently started to empirically investigate those Hacks addressing pressing socioenvironmental problems in the real world, i.e. Sustainability Hacks, through a combination of Action Research and Case Studies.

An example came from the non-profit ColaLife. It started with the question: "Coca-Cola seems to get everywhere in developing countries, yet life-saving medicines do not. Why?". The

organisation has since piggybacked Coca-Cola's value chains to deliver locally produced, available and affordable diarrhoea treatment both through public and private sectors. It is now available in 14 districts of Zambia, increasing uptake between 2015 and 2017 from less than 1% to 53% across the intervention districts of rural areas, with no change detected in the comparators.

This is only one of the 19 cases in my database, from 9 countries, hence providing great breadth of insights for exploring the understanding of Sustainability Hacking. This database comprises several unconventional solutions to pressing sustainability problems, such as detecting corruption in Brazil through artificial intelligence; using blockchain for humanitarian aid in Nepal; providing safe abortion services in international waters for women residing in countries where abortion is illegal; and addressing caste prejudice in India through housing policies.

Benefitting from this vast database, the researcher then conducted a cross-case analysis, which has provided comprehensive observations on the main similarities and differences across cases, that constitute the key analytical variables of Sustainability Hacking. Furthermore, the analysis derived 5 archetypes that can be used as frames of reference to provide guidance for practitioners evaluating possibilities of addressing pressing sustainability problems, and to support future academic contributions in this nascent field of research.

1.5. Target Audience

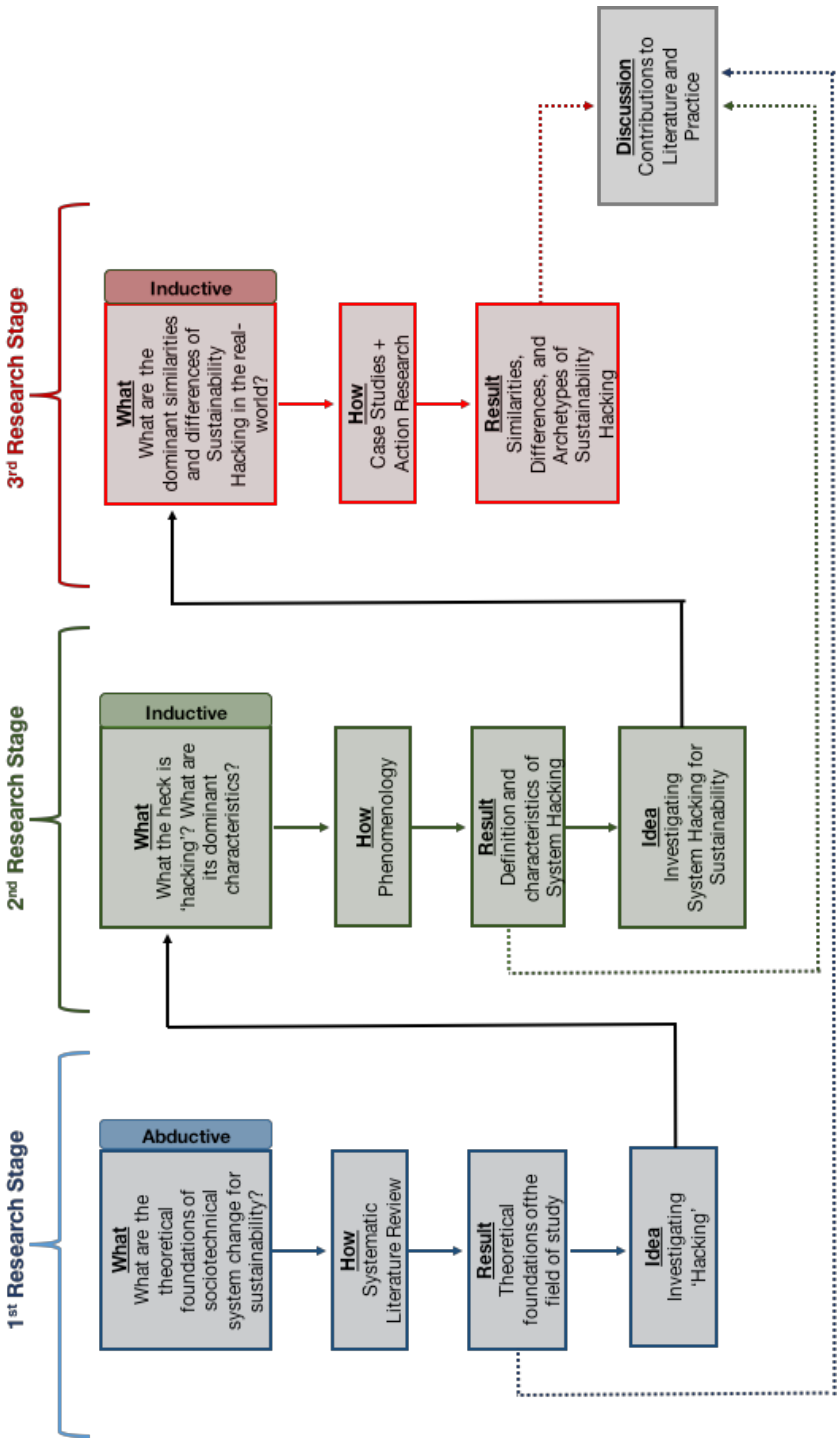
Never before have academics studied 'Hacking' to understand and promote real-world impact on a wide range of pressing sustainability problems. This opens up a new field of study, contributing towards a better understanding of the drivers of system change. Due to the interdisciplinary nature of this work, its contributions to theory are multi-folded. It is relevant to areas of sustainability science, system thinking and design, innovation studies, and institutional theory, to cite only a few. Practitioners keen on tackling pressing sustainability challenges can also benefit from the knowledge reported in this thesis. That includes individuals, governments, intergovernmental organisations, companies, and organisations of the third sector, independently of the regions where they operate.

1.6. Outline of Research Problems and Research Stages

This section briefly outlines the research stages, designed to address their respective research questions – as portrayed in Figure 1. These stages were directly interconnected and

sequential. It is important to highlight that the research had not been fully designed at the outset: subsequent steps were defined according to the results of the prior ones. Furthermore, the philosophical stance, research strategies, methods and tools deployed (scrutinised in Chapter 2), as well as the thesis structure (detailed in the next section) use these 3 stages as frames of reference.

Figure 1: Outline of Research Stages



This research started by questioning the foundations guiding theoretical development in the field of sociotechnical system change for sustainability. The researcher's intent was to reflect upon the ontological and normative foundations grounding theoretical development in the field to identify possibilities of contributing beyond gap filling. Towards this goal, a systematic literature review was employed. By doing that, it was possible to reveal novel and ambitious research opportunities.

Among them was the idea of investigating 'Hacking' as a change driver of complex systems. Given that this topic was rather unexplored, the researcher was then compelled to investigate 'what is Hacking', and its dominant characteristics. These questions were addressed through a Phenomenon-driven approach, collecting data from self-declared Hackers and cybersecurity experts, leading to the elaboration of a definition and the explanation of the main characteristics of system Hacking. This process of conceptual development opened up scope to reflect on the multiple mechanisms of influencing change towards more socially desired directions.

At this stage, the potential of investigating Hacking in sociotechnical systems motivated by socioenvironmental goals (i.e., Sustainability Hacking) became evident. The researcher has then moved on to the 3rd and last methodological stage, delving on questions on the dominant similarities and differences of Sustainability Hacking in the 'real-world'. These were addressed through a combination of Case Studies and Action Research with a total of 19 cases. The analysis revealed sets of similarities, differences and archetypes of Sustainability Hacking.

By combining the sequential results of this 3-staged process, it became possible to discuss the contributions of this PhD to literature and practice.

1.7. Thesis Structure

This thesis is divided in 6 Chapters, including this introduction. The contents of the remainder are summarised below. It is important to highlight that the structure has been designed with 3 core chapters, sequentially portraying the results and reflections obtained for each research stage portrayed in the previous section. The other 3 chapters consist of the introduction, research design, and a discussion of the results combined with concluding remarks.

- ✓ Chapter 2 – Research Design

Explains how the research was designed and executed, and justifies the methodological choices of this work. It describes the research design layers that serve as a frame of reference

for the methodological design; discusses philosophical stances and justifies the one adopted; pinpoints the research approaches and arrangements, clarifying the circumstances and reasons why they were employed; and scrutinises the strategies, procedures and techniques used in each of the 3 research stages of this work.

✓ Chapter 3 – Literature Review

Addresses the research question of the 1st research stage through a systematic literature review. It outlines the identified research areas, their main contents and references; builds narratives exposing their main sources of agreement and tension; reveals the dominant ontological and normative foundations at the core of the literature; and reflects upon the shortcomings of these foundations, pinpointing novel research avenues that can contribute to the field, including the possibility of exploring the idea of 'Hacking'.

✓ Chapter 4 – What the Heck is Hacking?

Investigates the research questions of the 2nd research stage through exploratory interviews. It outlines the connotations of the term 'Hacking'; derives the definitions of 'Material Hacking' and 'System Hacking', and justifies the focus of the researcher on the latter; describes the 9 dominant characteristics of System Hacking; contrasts the novel concept with a selection of change drivers, exploring its implications to literature; and explains the relevance of System Hacking to address socioenvironmental problems.

✓ Chapter 5 – Sustainability Hacking in the Real World

Tackles the 3rd (and final) research question through a combination of Case Study and Action Research with 19 cases. It walks the reader through the stepwise cross-case analysis, demonstrating how cases were gradually examined and contrasted, and how the lists of similarities and differences across cases were progressively built upon. The results of the final analysis consisting of 15 similarities and 10 differences are then portrayed, and 5 Archetypes of Sustainability Hacking are derived to guide future endeavours in theory and practice.

✓ Chapter 6 – Discussion and Conclusion

Discusses the concept of Sustainability Hacking. It synthetises the most notable contributions of this thesis both to literature and 'real-world' action; elaborates on the potential uses of the Archetypes of Sustainability Hacking for theoretical development and for practitioners; contemplates grey areas of this research that emerge as potential avenues for

future contributions; and concludes by reflecting if a Hack can save the world and on the strengths and weaknesses of this thesis.

2. Research Design

"These ambiguities, redundancies and deficiencies remind us of those which doctor Franz Kuhn attributes to a certain Chinese encyclopaedia entitled 'Celestial Empire of Benevolent Knowledge'. In its remote pages it is written that the animals are divided into: (a) belonging to the emperor, (b) embalmed, (c) tamed, (d) sucking pigs, (e) sirens, (f) fabulous, (g) stray dogs, (h) included in the present classification, (i) frenzied, (j) innumerable, (k) drawn with a very fine camelhair brush, (l) et cetera, (m) having just broken the water pitcher, (n) those that from afar look like flies".

(Jorge Luis Borges, El Idioma Analítico de John Wilkins, p.86)[3]

2.1. Introduction to the Chapter

This Chapter presents the research design and justifies the methodological choices of this work. It starts with the recognition that there is no single, 'right' way of investigating phenomena. Academic investigations are entrenched with values, assumptions and different understandings of nature; hence carrying different social, economic and political interests (Leach, Scoones and Stirling, 2007). They are inextricably influenced by ontological understandings (i.e. views on the nature of reality), subjective imaginations of potentially attainable futures (Jasanoff and Kim, 2009), and normative aspirations (Stirling, 2009). Implying that knowledge is "free and autonomous, allowing the unfettered pursuit of the truth" (Pestre, 2008, p. 111) would then undermine the plurality of co-existent understandings, visions and expectations that are intrinsically interwoven with scientific inquiry (Latour and Woolgar, 1986).

This researcher's philosophical stance thus opposes treating methodological designs as value-neutral or self-evident. The research design is hereby described as a set of well-informed *choices.* It takes into account worldviews underlying the ontological and epistemological research design, the strategies and approaches deployed for academic inquiry and investigation, and the techniques and procedures used to collect and analyse data (Saunders, Lewis and Thornhill, 2009). The criteria informing methodological decision-making are scrutinised in this Chapter, clarifying how the strengths and weaknesses of different options were assessed, contrasted and outweighed.

[3] My translation, from Spanish to English.

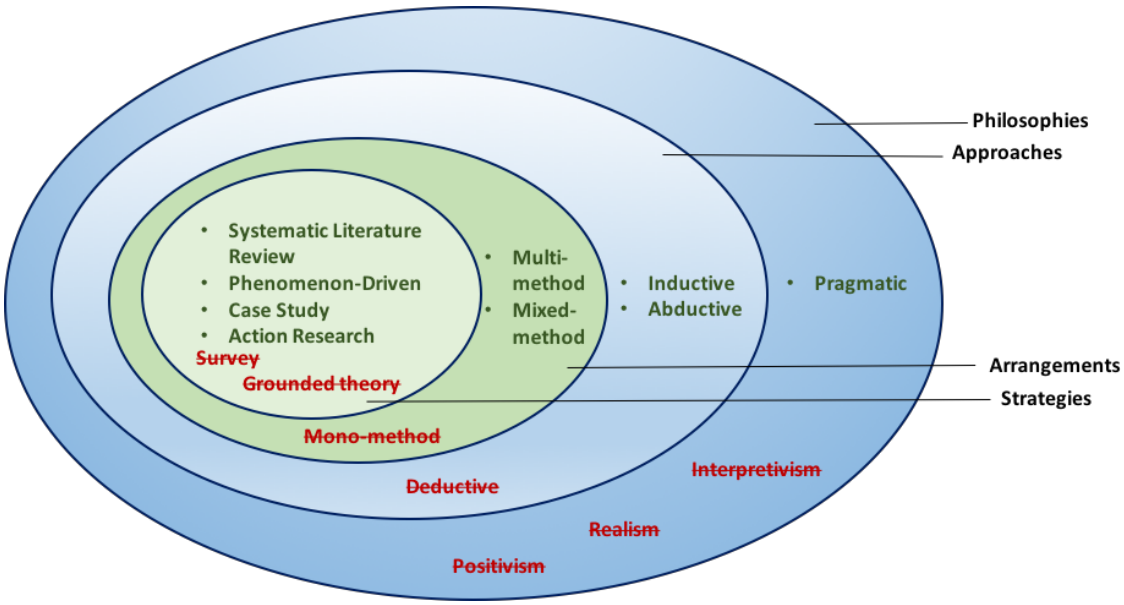
2.2. Structure of the Chapter

The remainder of this Chapter is structured as follows. Section 2.3 describes the research design layers that serve as a frame of reference for the methodological design of this thesis. Section 2.4 discusses philosophical stances, justifying the one that has been adopted for this work. Section 2.5 pinpoints the research approaches and 2.6 highlights the adopted research arrangements, clarifying the circumstances and reasons they were employed in this research. Section 2.7 is the longest of the Chapter, scrutinising the strategies, procedures and techniques employed in each of the research stages. Section 2.8 concludes by providing a summary of this Chapter.

2.3. The Research Design Layers

The following sections of this Chapter present the decisions taken for each layer of the 'research onion' (Figure 2), adapted from Saunders et al (2009). This is deployed as a holistic frame of reference to represent the design of this research. Font in green represents the methodological choices that were incorporated into this research and in red exemplifies some options that were assessed but dismissed.

Figure 2: Research Onion



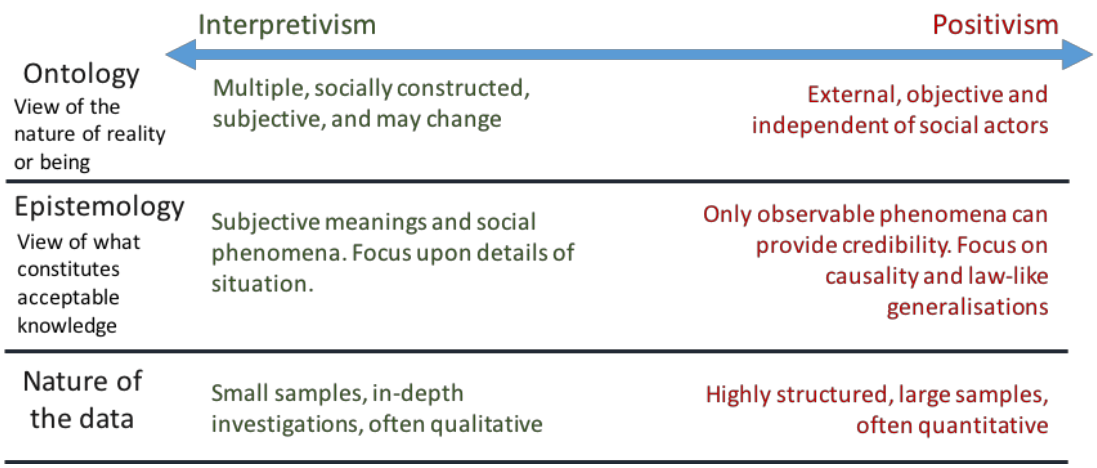
Source: adapted from Saunders et al (2009)

This multi-layered design is aligned with the observation from Guba and Lincoln (1994) that questions of research methods are of secondary importance to the ones referring to belief systems and worldviews underpinning the investigation. The tools and methods for sampling, processing and analysing data are, therefore, only described after covering the variety of research philosophies, approaches, arrangements and strategies that were assessed and chosen in face of the research questions that I aimed at answering. Furthermore, since there are 3 sets of research questions, decisions varied across research stages. These choices are justified in the following sections, progressing inwardly until finally scrutinising the techniques and procedures for collecting and analysing data for the 3 stages of this research.

2.4. Philosophical Stance

Research philosophy primarily addresses questions of the nature of what we know (i.e. ontology) and what is acceptable and preferable for scientific development (i.e. epistemology). Philosophical stances are often portrayed in social sciences as ranging from positivism at one extreme to interpretivist at the other. In a nutshell, the former holds the ontological view that researchers are external, objective and independent actors, and that epistemological credibility derives from law-like generalisations, reducing phenomena to their simplest elements. It emulates approaches of natural sciences, building hypothesis upon theory and testing them through data (Remenyi *et al.*, 1998). The latter holds a relativist ontology (i.e. the notion of multiple coexisting realities), and a subjectivist epistemology (i.e. understandings derive from the interaction between the knower and the unknown or subject) (Denzin and Lincoln, 2008). Figure 3 contrasts the most notable differences across these methodological stances.

Figure 3: Comparison of Research Philosophies



Source: Adapted from Saunders et al (2009)

This apparent dichotomy between positivism and interpretivism may lead to the trap of thinking that one research stance is better than the other. The starting point of this research design was the recognition that different philosophies can be better for different things, depending on the characteristics of the research – most notably, the questions that are being addressed.

In fact, this research does not fall neatly into only one of these two philosophical domains. For example, the 1st stage of this research, investigating the theoretical foundations of sociotechnical system change for sustainability, adopted a hybrid approach. On one hand, it follows a highly structured methodology for collecting and processing data that facilitates replication: an approach that is often associated to positivism (Gill and Johnson, 2002). On the other, it shies away from hypothesising to adopt, instead, an exploratory approach towards the analysis of data that resonates more with interpretivism. The intricacies of research stages are detailed in the subsequent sections of this Chapter. For now, this example only aims at illustrating that the philosophical stance was intentionally hybrid, trying to incorporate features that seemed to be the most adequate to address the research questions.

There are some widely recognised philosophical stances that fall within that spectrum. Realism is one that seems closer to the positivistic end. Although it recognises the significance of social construction of knowledge (i.e. influence of values, worldviews and culture upon scientific endeavours), it also assumes that what the senses show as reality is the truth and that objects have an existence independent of the human mind, hence leading to a focus on objectivity for credibility. The researcher did not follow this approach. The demand of remaining as objective as possible was too limiting, especially for the 2nd and 3rd stages of this research that aimed at exploring very novel research avenues to contribute beyond gap spotting. Social phenomena are far too complex and rich insights would have been lost if this complexity was reduced to generalisations. Furthermore, the nature of the research questions required the researcher to enter the social world (i.e. the multiple realities) of research subjects to understand and interpret from their own points of view (Saunders, Lewis and Thornhill, 2009).

By asking questions that were essentially open-ended, under-researched and context-dependent, this research required a hybrid approach tending to interpretivism. The perception of this researcher aligns with Kaplan's (1964, p. 24): that the "most important contribution that methodology can make to science is to help unblock the roads to inquiry". A pragmatic approach is the one that believes that choosing between sides of a spectrum is somewhat unrealistic in practice. Investigation is interpreted as a continuing process, in which problematic situations may emerge, be recognised and interpreted. Throughout this process, doubts are

resolved by critical reasoning and assessed in light of their practical consequences (Shields, 1998). Therefore, a pragmatic approach is based on the understanding that the most important determinant of adopted ontologies and epistemologies is a subjective assessment of how appropriate they are for answering a particular research question (Saunders, Lewis and Thornhill, 2009).

Similar to a pragmatic stance, mine is the one that it is perfectly possible to work with variations of ontologies and epistemologies. Rather than identifying the 'essence of truth', the concern here was on 'what matters' for further contributions to theory and practice. Theories, from the outset of this research (1st stage), were partially used as research directives: i.e. what can be done by this researcher that can configure as a substantial contribution? When insights were progressively revealed and reflected upon, new research questions could then be framed and, by following a pragmatic approach, new evaluative assessments could be performed about the appropriate strategies, approaches and tools. The following sections scrutinise how this work has employed a variety of methods that were progressively appraised and selected throughout the 3 stages.

2.5. Research Approaches

There are 3 approaches to developing theory: deduction, abduction and induction, as summarised in Table 1. Whereas deductive approaches are associated to philosophies tending to the positivistic side of the spectrum, induction and abduction are often connected to interpretivism.

Table 1: Comparison of Research Approaches

	Deduction	Induction	Abduction
Logic	In a deductive inference, when the premises are true, the conclusion must also be true	In an inductive inference, known premises are used to generate untested conclusions	In an abductive inference, known premises are used to generate testable conclusions
Generalisability	Generalising from the general to the specific	Generalising from the specific to the general	Generalising from the interactions between the specific and the general
Use of data	Data collection is used to evaluate propositions or hypothesis related to an existing theory	Data collection is used to explore a phenomenon, identify themes and patterns and create a conceptual framework	Data collection is used to explore a phenomenon, identify themes and patterns, locate these in a conceptual framework and test this through subsequent data collection and so forth
Theory	Theory falsification or verification	Theory generation and building	Theory generation or modification; incorporating existing theory where appropriate, to build new theory or modify existing theory

Source: Van Fossen (2018, p. 72)

The 1st stage of this research was abductive. A systematic literature review was conducted to reveal the theoretical foundations of sociotechnical system change for sustainability. As scrutinised in a following section of this Chapter, data was collected by following a set of pre-established criteria. These criteria are based on premises (e.g. most cited papers present the most influential foundations) and used to generate testable inferences. The generalisation (i.e. theoretical foundations) occurred from the reflection upon the interactions of the specific (i.e. coded textual extracts) and the general (i.e. main research areas). Data was collected and used to infer patterns. The aim was to open up room for adding or modifying existing theory.

Given my pragmatic stance, the ideas obtained at the end of the 1st stage (i.e. investigating 'Hacking') and 2nd stage (i.e. investigating 'System Hacking for Sustainability') reflected results from earlier stages. These ideas, obtained after analysing the results of previous research questions, can be thought of as 'working hypotheses'; a term deployed by Dewey (1938, p. 142) to refer to ideas that are "taken to be provisional" and may lead to "discovery of other critical facts". They provide a direction of inquiry, without necessarily configuring an ultimate

destination (Shields, 1998). Accordingly, Kaplan (Kaplan, 1964, p. 88) describes that these 'working hypothesis', portrayed in Figure 1 as 'ideas', serve as guides to organise further investigation: "The working hypothesis is not a guess at the riddle, a hunch as to what the answer might be. It is an idea…about the next steps that may be worth of taking".

Furthermore, not only have these provided guidance on the topic to be explored, but also assisted to understand the approaches that would best fit that line of inquiry. Shields (1998) describes how working hypotheses serve as diagnostic tools to define the best fitting approach. For example, when a medical doctor examines a sick patient, generalisation occurs from the general (i.e. body) to the specific (i.e. cause of health problem) through a deductive approach (e.g. asking medical history). A detective, on the other hand, uses working hypothesis as a guide to solve crimes. By following an abductive approach, detectives identify themes and patterns, inferring by connecting the specific (e.g. characteristics of a crime) and the general (e.g. context where it occurred).

Whereas the 1st research question was addressed by an abductive approach, induction has shown to be the best approach to address the working hypothesis that emerged throughout the research. The 2nd and 3rd stages were, in fact, designed according to the lack of plausible existing theory (Edmondson and Mcmanus, 2007), since 'Hacking', and 'Sustainability Hacking', are complex, context-dependent, under-researched, and open-ended phenomena. Inductive methods were then the most appropriate to provide a deep and detailed comprehension. As scrutinised in subsequent sections of this Chapter, inductive and exploratory approaches were employed with the intent of building a nascent area of research. Generalisation occurred from the specific (e.g. individual perceptions or case descriptions) to the general (e.g. definitions and dominant characteristics), and evidences were analysed to identify patterns (e.g. dominant traits, similarities, differences) and create a conceptual framework (e.g. archetypes of Sustainability Hacking).

2.6. Research Arrangements

This layer refers to whether the researcher uses a single or multiple method(s) for research, and whether they are quantitative or qualitative. Research combining at least one quantitative and one qualitative method is called mixed-methods; and research that is only quantitative or qualitative but deploys multiple research strategies is called multi-method. Given my pragmatic stance, the chosen strategies were identified as the most appropriate to address the research questions.

Quantitative research is informed by an objectivist epistemology, seeking to develop explanatory snapshots of a reality. It tends to emphasise the big picture, as well as the causal relationships between isolated variables. Researchers put distance between themselves and what is under investigation. Qualitative research, alternatively, is based on constructivist epistemologies, exploring dynamic interpretations of reality. It prioritises in-depth comprehension, instead of generalisability (hence, the focus on 'quality', not on 'quantity'). Qualitative researchers recognise that they are inexorably connected to the known, given their own values, interests, and premises.

There is a vast array of methodological choices available both for quantitative and qualitative research, of which many were assessed by this research. The 1st stage consisted of mixed-methods, although primarily qualitative. It has used quantitative approaches for sampling and to provide a horizontal understanding of the literature in the field of sociotechnical system change for sustainability, while qualitative approaches were employed to analyse the content of the sample of documents. The 2nd and 3rd stages presented multi-method, qualitative arrangements. Although the researcher remained open to a diverse set of methodological choices, as the research progressed it became clear that quantitative data would add little or no value to the research. Exploratory, qualitative methods were identified as the best suited to explore data on the open-ended, context-dependent and nascent topics of 'Hacking' and 'Sustainability Hacking'. The chosen strategies, techniques and procedures are scrutinised in the following section, emphasising both their strengths and limitations.

2.7. Research Methodology: Strategies, Techniques and Procedures

The term research methodology is employed in a number of ways in scientific literature, but here it is used in reference to a package of research strategies, techniques and procedures chosen for the 3 research stages. Given there is a plethora of quantitative and qualitative methods available, the researcher briefly demonstrates in Box 1 a few dismissed options, only to illustrate the reasoning underlying the methodological decision-making for ruling out potentially viable methods. Then, the chosen strategies and their respective techniques and procedures to collect and analyse data deployed in the 3 stages of this research are dissected.

Box 1: Examples of Dismissed Strategies

- Survey: involves analysis of variables that are already known and that can be quantitatively measured (Neuman, 2013). After conducting the systematic literature review, a new area of interest emerged: the one of studying 'hacking' as a potential driver of sociotechnical system change. At that moment, the researcher has assessed surveys as a possibility to understand the phenomenon. However, since this has shown to be a nascent, open-ended and context-dependent area of interest, the researcher could not identify variables that could be generalized or that had to be tested. Similarly, the 3rd research question could not be investigated through surveys either, given this was an untapped research area. A qualitative approach was best suited for developing a new concept and to explore the dominant characteristics of a phenomenon that has not been yet captured by existing theories.
- Grounded Theory: the researcher recognises in hindsight that the methodological approach of the 2nd stage of this research resembles grounded theory. However, it is even better represented by Phenomenon-Driven Research (described subsequently in this section) – with which Grounded Theory has much in common. Both are essentially inductive, exploring real-life situations, and using observations and interviews as common mechanisms to collect data (Glaser and Strauss, 1967; Strauss and Corbin, 1990). However, Grounded Theory often presents an objectivist perspective, towards which the researcher was sceptical. Objectivism considers that, as in natural sciences, there are realities to be revealed. Grounded Theory then uncovers what is believed to be 'there', to be 'real'. Even when grounded theorists are constructivist, they view their research outcomes as representing one of multiple realities. Alternatively, Phenomenon-Driven Research is more receptive towards subjectivity, revealing 'hidden' meaning through human experience of the phenomenon, instead of providing causal explanation. Furthermore, it is more descriptive than Grounded Theory – and this was particularly important for the 2nd stage of research, since it was unpacking a rather unexplored phenomenon.

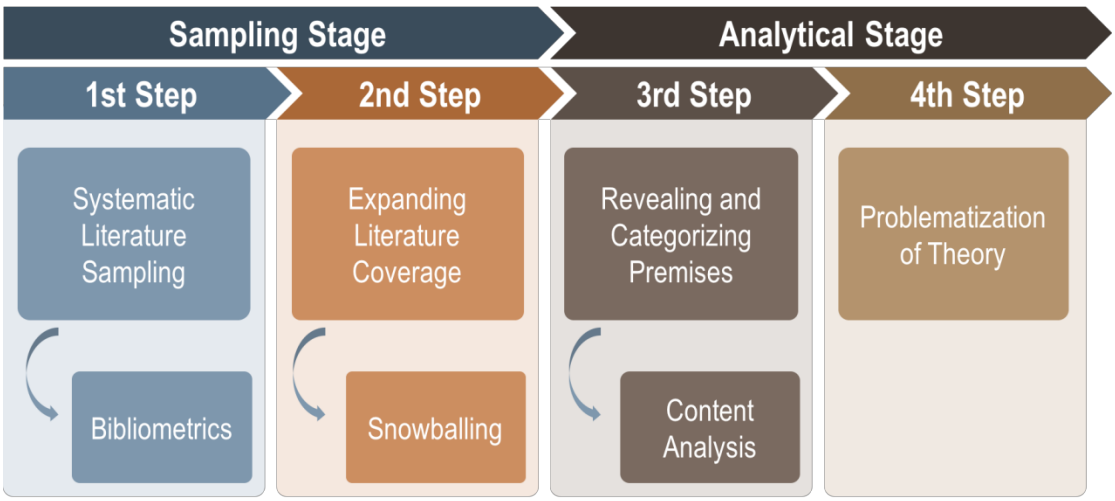
2.7.1. 1st Stage: Systematic Literature Review[4]

- **Overview**

Systematic reviews are used as key mechanisms to promote diversity of knowledge in a certain domain (Easterby-Smith, Thorpe and Jackson, 2015). If conducted diligently, the process of inclusion or exclusion of theoretical contributions is not implicitly biased as in conventional approaches that may underrepresent certain perspectives (Tranfield, Denyer and Smart, 2003). I adopted a replicable and transparent process for inclusion or exclusion of references in the review, which consequently provided audit trails to question the employed criteria and the identified conclusions (Pittaway *et al.*, 2004).

This literature review aimed at investigating the theoretical foundations of sociotechnical systems change for sustainability. It did so by revealing the main foundations, which influence boundaries and prospects for future theoretical development. As illustrated in Figure 4, this literature review consisted of a combination of structured and semi-structured approaches for data collection and analysis.

Figure 4: Methodological Steps for Literature Review



Source: Savaget et al (2019)

I started with a bibliometric analysis, guiding the initial sampling of papers. This initial sample was subsequently complemented by semi-structured snowballing to expand the literature and compose the final sample. I thereafter conducted a content analysis to reveal and

[4] This section has been adapted from one of my publications (see Savaget et al. 2019). The initial draft of the paper was solely written by me. The published version counted with the valuable comments and edits of my co-authors Martin Geissdoerfer, Ali Kharrazi and Steve Evans, as well as from anonymous peer-reviewers.

categorise foundations underlying theoretical developments. Finally, this analysis allowed me to problematize the prevailing theoretical foundations and identify areas for future contribution.

It is important to stress that bibliometrics was the only quantitative method employed in this PhD research. This was used to provide a big picture of the area of interest, hence informing what (i.e. the sample) was going to be qualitatively analysed. This means that the quantitative and qualitative analytical procedures were not used in parallel: they were sequential. Quantitative data was analysed quantitatively and the outcomes of this process were used to guide the following steps, which were exclusively qualitative.

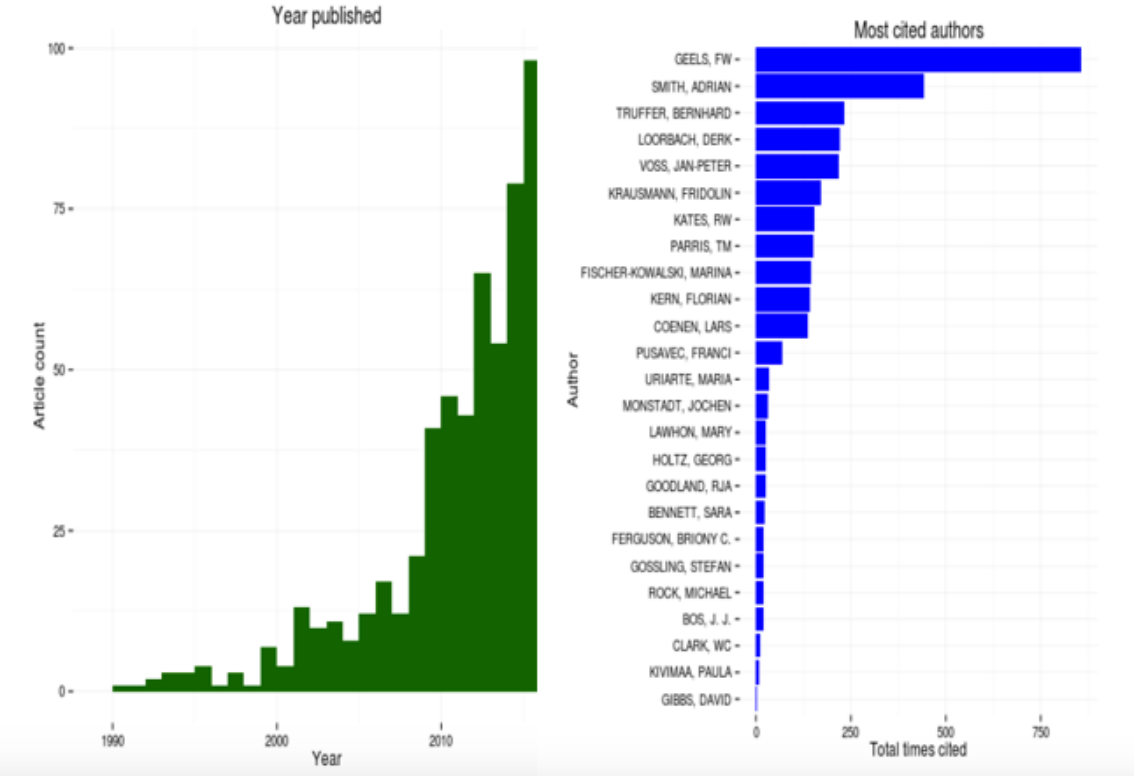
- **Data Collection**

The process started by collecting and analysing bibliometric data to inform the initial sampling of papers for the review. Bibliometric analysis scrutinises published data, measuring text content and bibliographic information such as authorship, affiliation, citations, and keywords (Bellis, 2009). It can be used to describe, evaluate and monitor the state of a field over time. I employed it to identify the most cited journals, scholars, and keywords to choose a sample capable of informing about these prevailing theoretical foundations. As I aimed to obtain a comprehensive historical perspective of the literature, at this stage, I did not filter my data collection by date, geography or discipline.

Data was collected from the Web of Science database in January 2016, following recommendations of Webster and Watson (2002). As literature recognises that incremental and standalone changes in sociotechnical systems will not be sufficient to address sustainability challenges, my first focus was on theories covering wide-scale sociotechnical change. I then searched for the strings “sociotechnical transition” OR “strategic niche management” OR “sustainability transitions”. I also checked for an alternative, hyphenated spelling of the word sociotechnical (i.e. socio-technical). The resulting dataset of 565 records was then analysed through statistical and networks approaches with the software Hammer (Knutas *et al*. 2015).

As illustrated in Figure 5, the field has grown steeply between the period of 2008 and 2016, reaching more than 6-fold the number of publications on this research topic. There is also a great disparity in numbers of citations, suggesting that, despite the growing number of publications, a few authors are much more influential than others.

Figure 5: Bibliometric Results – Evolution of the Field and Most Cited Authors



Source: Savaget et al (2019)

Based on its analysis, the top ten most cited papers were selected for further review. Since I was interested in revealing ontological and normative foundations of theory (detailed in Chapter 3), number of citations was a good initial metric for sampling: the more cited, the higher the likelihood of reflecting pervasive perspectives among scholars. In order to supplement the sample with more recent and emerging research, the five most cited papers published between 2014 and 2016 in the most influential journals were also included into the review. Finally, to better expose future research motivations and expectations, a report discussing the Mission Statement of the Sustainability Transitions Research Network (STRN, 2010), a leading research group in the field was also included in the review. Table 2 depicts the author name, year, and source of the initial 16 documents for the literature review.

Table 2: Initial Sample for Literature Review

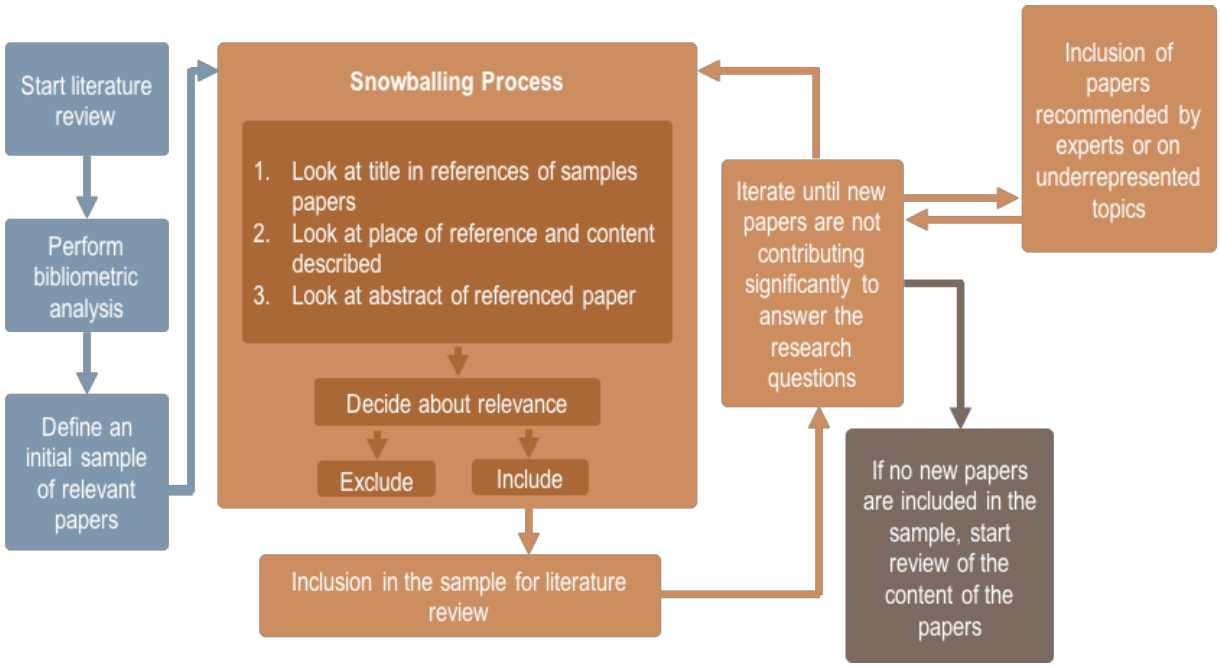
Source	Source
(Kemp et al, 1998)	Technology Analysis and Strategic Management
(Geels and Schot, 2007)	Research Policy
(Schot and Geels, 2008)	Technology Analysis and Strategic Management
(Smith et al, 2010)	Research Policy
(Kemp, 1994)	Futures

(Geels, 2010)	Research Policy
(Markard et al, 2012)	Research Policy
(Shove and Walker, 2010)	Research Policy
(Kates and Parris, 2003)	PNAS
(Smith and Raven, 2012)	Research Policy
(Sushandoyo and Magnusson, 2014)	Journal of Cleaner Production
(Pincetl *et al.*, 2014)	Landscape and Urban Planning
(Wittmayer and Schäpke, 2014)	Sustain Sci
(Shaw et al. , 2014)	Global Environmental Change
(De Haan *et al.*, 2014)	Technological Forecasting and Social Change
(STRN, 2010)	A mission statement and research agenda for the Sustainability Transitions Research Network

Source: Savaget et al (2019)

To gather comprehensive data on theories influencing this research terrain, snowballing technique was adopted (Wohlin, 2014) to cover an extensive range of additional literature – following the approach portrayed by Geissdoerfer et al (2017). The snowballing process is illustrated in Figure 6, where blue indicates the definition of the initial sample, light brown the beginning of the iterative snowballing process, and dark brown the end of data collection. I examined the relevance of these papers for inclusion/exclusion by analysing their titles, abstracts and contents. Relevant papers are defined as the ones capable of contributing with novel insights on similarities, differences or relationship types between the studied concepts. If a new paper was included in the sample, its references were also examined for new inputs – these iterations would continue until no new and significant insight relevant to the research questions was found. Furthermore, the sample was complemented by articles either recommended by experts or resulting from specific searches on topics that were relevant but still underrepresented in the sample. This process resulted in a final sample of 208 documents.

Figure 6: Snowballing Process



Source: adapted from Savaget et al (2019)

- **Data Analysis**

Most academic endeavours are focused either on extending the coverage of literature or filling gaps that have been neglected by previous research (Alvesson and Sandberg, 2011) rather than challenging embedded foundations of existing theories. Since this research aims at revealing theoretical foundations, it follows the approach introduced by Whetten (1989) who assumes that the most relevant theoretical features lie on knowledge on *Why, What* and *How*.

What and *How* describe approaches to understand a phenomenon, while *Why* explains the motivations leading to such conceptual developments. Together "they provide the essential ingredients of a simple theory: description and explanation" (Whetten, 1989, p. 491). *When*, *Who* and *Where* are categories covering temporal or contextual factors, responsible for setting the boundaries for theoretical generalisability. In what jurisdiction are these predictions valid? In what timeframe is this phenomenon applicable? What agents are accountable for (or influenced by) this event? These kinds of questions only limit the propositions, set the boundaries for contributions, and expose the pervasiveness of a phenomenon (Whetten, 1989).

In this research, I was focused on the foundations (*Why*, *How* and *Why*) of theories of sociotechnical system change, and not on contextual characteristics (*Where*, *Who* and *When*). I conducted content analysis with the assistance of the software Nvivo. This process allowed me to analyse written communication through thematic interpretation of the 208 articles in the final sample by attentively reading them to code relevant extracts (Weber, 1990).

I coded the data with the support of the previously established categories (*What*, *Why*, *How)*. Subcategories then arose throughout the process, allowing me to compile, group and summarise data according to their specificities and draw their interconnections (i.e. the subcategories described in the column "What does it include" of Table 7, in Chapter 3). As a result, this process provided a condensed description of the 15 most relevant foundations of this field of research. By reflecting upon them, it was possible to identify different research avenues to contribute to theoretical development.

- **Limitations**

The methodological approach has the following limitations. First, there is an intrinsic limitation of findings that derive from the 'obvious' search strings used for the literature review – which, as described in a previous section, was mitigated through the inclusion of more data entries through snowballing and recommendations from experts.

Second, since data was initially collected from the Web of Science database and subsequently expanded through snowballing, relevant publications not covered by the database are not included in the initial sample. Since snowballing only addresses publications cited by, and therefore published before, the publications in the sample, research areas emerging after my initial sample collection were not included, unless recommended by experts or identified as an underrepresented topic. The same limitation also applies to publications at the margins of the research field that have not been sufficiently cited.

Third, the content analysis was conducted in a structured and systematic fashion but involves intrinsic subjectivity in defining relevant extracts through codification.

2.7.2. 2nd Stage: Phenomenon-Driven Research

- **Overview**

The strategy employed in the second stage is Phenomenon-Driven Research (Schwarz and Stensaker, 2014). It adopts a constructivist and relativist approach towards knowledge, in which a new phenomenon is a starting point to build knowledge (von Krogh, Rossi-Lamastra and Haefliger, 2012). The aim of the researcher is to describe as accurately as possible the investigated phenomenon, by refraining from pre-established frameworks and focusing instead on the perspectives of people involved (Schwarz and Stensaker, 2014).

new phenomenon (a novel or alternative observation of a well-known phenomenon) is a starting point in the process of discovery and in building knowl- edge.

This research thus moves from the observation of the empirical world to the construction of theory – assuming the world as socially constructed, subjective and value-laden, and exploring meaning by unearthing unnoticed and overlooked human experiences of phenomena (i.e. 'Hacking'). Rather than making inferences, it describes and interprets the phenomenon to develop new and alternative theoretical contributions based on observed trends. The focus lies on exploring the whole and revealing complex and unexplored phenomena, instead of validating or testing its parts for generalisability or providing causal explanation of the investigated experiences (Schwarz and Stensaker, 2014).

As outlined by Table 3, this Phenomenon-Driven Research was performed through a combination of procedures and techniques for collection and analysis of qualitative data, described in further details in the following sections.

Table 3: Research Design – 2nd Research Stage

Strategy	Phenomenon-Driven Research
Justification	Lack of plausible theory
Data Collection	- Exploratory Interviews - Participant observation - Secondary data
Data Analysis	- Content analysis of qualitative data through textual coding - Construction and description of relevant definitions and characteristics

- **Data Collection**

My data collection technique consisted of purposive sampling, intentionally looking for those who have had experiences relating to the investigated phenomenon. I aimed at interviewing both experts and self-declared Hackers to diversify my sample and, as a result, enhance the likelihood of generating novel contributions to this rather under-researched area. I have thus started by identifying individuals using the term 'Hack' in different fields (e.g., cybersecurity, culture, diplomacy, and healthcare) and snowballed after initially contacting 2 academics, 1 employee of a large company, 1 employee of a small company, 1 journalist and 1

policymaker. I stopped adding participants to the sample when I observed that responses became repetitive (i.e. reached saturation).

The sample was then composed by:

- ✓ 6 academics from the University of Cambridge specialised on cybersecurity, 4 of whom also consider themselves Hackers of computer systems (interviewed in-person);
- ✓ 1 cybersecurity expert from Microsoft Research (interviewed in-person),
- ✓ 5 self-declared Hackers based on distinct geographical locations, working on domains other than computer systems (interviewed over Skype).

Twelve interviews were conducted individually – in order to reduce power plays biasing data collection – between October and December 2016[5]. Interviews were conducted in an exploratory and semi-structured fashion (Robson, 2002). Each interview lasted between 60 and 100 minutes and the identities of interviewees are protected by a confidentiality agreement[6]. They are anonymously identified in Chapter 4, which presents the results of this research stage, with randomly assigned numbers (i.e., X1, X2…X12).

The interviews combined a pre-determined set of 16 open-ended questions capable of prompting discussions on definitions, connotations, determinants, applications, contextual characteristics, and prospects of 'Hacking', while concomitantly leaving scope to explore novel themes arising throughout the interviews. They were conducted as informally as possible, in a "conscious attempt by the researcher to find our more information about the setting of the person" (Bailey, 1996, p. 72). Participant observation was used as a complementary technique, allowing the researchers to perceive reality from the viewpoint of someone observing from within rather than from an external viewpoint (Yin, 2003). These occurred during 2 Hackathons – sprint-like events collaborating on specific (often software-related) projects – and 1 meeting of cybersecurity experts.

- **Data Analysis**

[5] Table 26, in the Appendix A, scrutinises important characteristics of the recorded data (e.g. location, date, description of the interviewee, etc). Boxes 10 and 11 in Appendix B illustrate the open-ended questions used to initiate these interviews.

[6] The researcher conducted a self-assessment of ethics and good practice, which was subsequently validated by the Divisional Representative of the Institute for Manufacturing, who considered this research low-risk. Only after receiving approval to proceed, the researcher conducted the interviews. All interviewees signed a confidentiality agreement.

As illustrated in Figure 7, I adopted a stepwise approach to process and analyse data. I started by fully transcribing[7] the interviews and analysing their content through qualitative coding, with the assistance of Nvivo[8] software. Due to the nascent nature of this research, I adopted an exploratory approach, coding data without the support of previously established nodes and categories, by attentively reading documents to identify and group extracts relevant to address the research question of the 2nd stage (i.e., to derive a definition and most relevant characteristics).

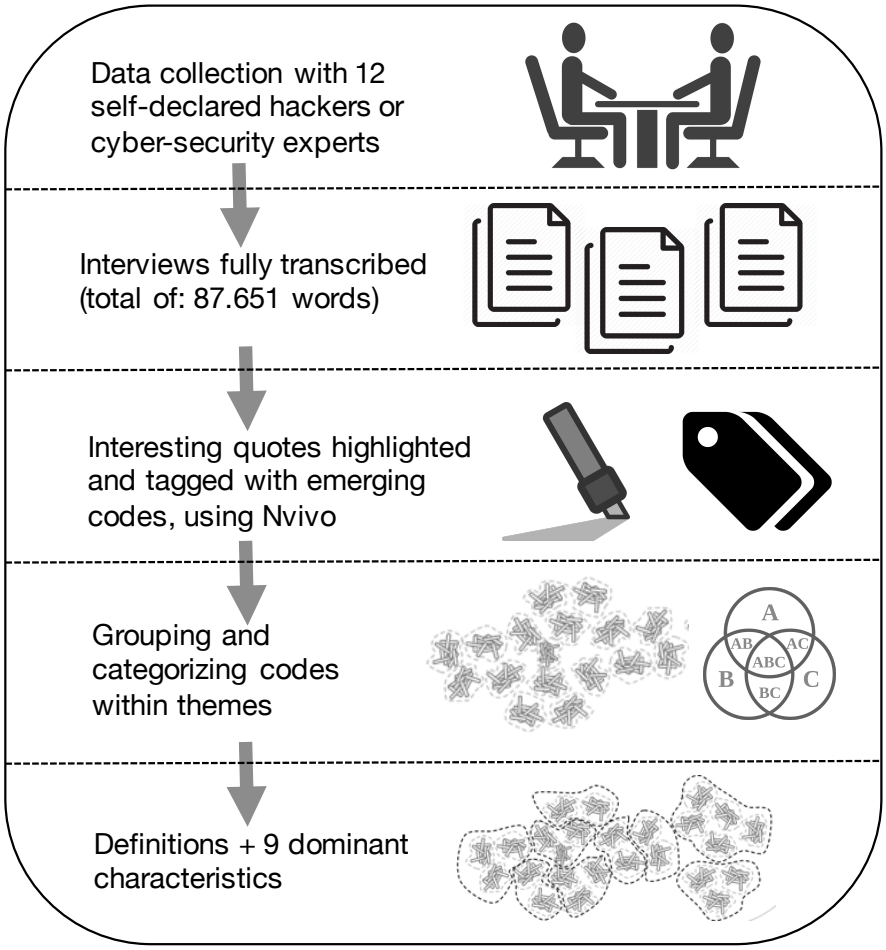
I first highlighted interesting quotes and tagged them with emerging codes. Interesting quotes are the ones that provide insightful observations on the investigated topic and/or occupied a central role in the narratives of the interviewees. This process, therefore, occurred without a preceding conceptualisation, letting the text speak for itself (Strauss and Corbin, 1990). As a result, this process provided a condensed description of patterns across participants, revealing their common and different perspectives. These codes were then grouped into categories, forming the basis for developing new theoretical constructs (Weber, 1990).

I finally compiled extracts for each relevant category and contrasted their contents to the observations arising both from secondary sources recommended by the interviewees and from participant observation; thus unpacking novel insights that were related back to the existing literature to address the research question.

[7] Some of these interviews were transcribed by myself. Others by a professional transcription service based in India.

[8] See: https://www.qsrinternational.com/ [Accessed 10 October 2015]

Figure 7: Data Analysis - 2nd Research Stage



- **Limitations**

This research stage has the following limitations. First, I focused on exploring multiple perspectives composing the 'whole', instead of validating or testing its parts for generalisability (Yin, 2003). Second, Phenomenon-Driven Research is essentially descriptive and, as a result, this strategy lacks the capacity of inferring causality. Furthermore, the content analysis, despite being conducted in a structured and systematic fashion, incurs in subjectivity when identifying relevant extracts and the best codes that define them.

2.7.3. 3rd Stage: Case Study and Action Research

- **Overview of Case Study**

This strategy has greater potential when the research question revolves around the understanding of complex social phenomenon, addressing questions of 'why', 'what' and 'how' while simultaneously gaining a rich understanding of contexts (i.e. 'where' and 'when') (Yin,

2003). Case Study is an inductivist and constructivist strategy that allows building theory based on inferences from observed phenomena (Eisenhardt, 1989; Eisenhardt and Graebner, 2007). It involves "an empirical investigation of a particular contemporary phenomenon within its real life context" (Robson, 2002, p. 178). It is thus critical to consider the context of the enacted research, since the boundaries between the researched phenomenon and the context within which it is being studied can be blurred (Yin, 2003).

Case study traditionally involves an array of sources of evidence that can be used in combination for data collection (Yin, 2003). Table 4 provides examples of how data can be collected within each, besides indicating their respective strengths and weaknesses.

Table 4: Sources of Evidence

Source of Evidence	Examples	Strengths	Weaknesses
Documentation	Letters, e-mails, notes, agendas, meeting minutes, proposals, formal studies of the same case, new clippings	* Stable – can be reviewed repeatedly * Unobtrusive – not created as a result of the case study * Exact – contains exact names, references and details * Broad coverage – long span of time, many events and settings	* Retrievability – can be difficult to find * Biased selectivity, if collection is incomplete * Reporting bias – reflects (unknown) bias of author * Access – may be deliberately withheld
Archival records	Public use files (e.g. census data), client service records, survey data	* {same as those for documentation} * Precise and usually quantitative	* {same as those for documentation} * Accessibility due to privacy reasons
Interviews	Structured, semi-structured, unstructured	* Targeted – focuses directly on case study topics * Insightful – provides perceived causal inferences and explanations	* Bias due to poorly articulated questions * Response bias * Inaccuracies due to poor recall * Reflexivity – interviewee gives what interviewer wants to hear

Direct observation	Casual observation, protocol-driven observation (e.g. assess the occurrence of certain behaviours)	* Reality – covers events in real time * Contextual – covers context of 'case'	* Time-consuming * Selectivity – broad coverage difficult without a team of observers * Reflexivity – event may proceed differently because it is being observed * Cost – hours needed by human observers
Participant observation	Non-passive observer (e.g., serving as key decision-maker)	* {same as those for direct observation} * Insightful into interpersonal behaviour and motives	* {same as those for documentation} * Bias due to participant-observer's manipulation of events
Physical artefacts	Technological device, work of art, instrument	* Insightful into cultural features * Insightful into technical operations	* Selectivity * Availability

Source: adapted from Yin (2003)

Attempting to triangulate multiple sources of evidence is often recommended to increase the likelihood of identifying data inputs that are not credible and of interpreting data accurately. Furthermore, an approach that compares data entries of multiple cases can reveal characteristics that may either be peculiar of a case or pervasive across cases, besides contextual aspects factoring in the occurrence of the investigated phenomenon (Yin, 2003).

- **Overview of Action Research**

The term 'Action Research' has been interchangeably interpreted by qualitative studies. Saunders et al (2009), nonetheless, emphasise some common themes across them. First, differently from Case Study, Action Research goes beyond research *about action*: it is also research *in action*. In other words, it is a process of collaborative engagement with the ones who, in all research strategies described in this Chapter (i.e. case study, survey, and grounded theory), are solely designated as subjects, as informants (Stringer, 2007).

Second, this strategy implies a commitment of the researcher over a matter of genuine concern to the one who is providing empirical data (Eden and Huxham, 1996). The implications of the research may, therefore, go beyond theoretical development, by nurturing 'real-world' change within the scope of what was agreed between the researcher and the researched agent. Due to an active involvement with problem-solving, Action Research is particularly useful for

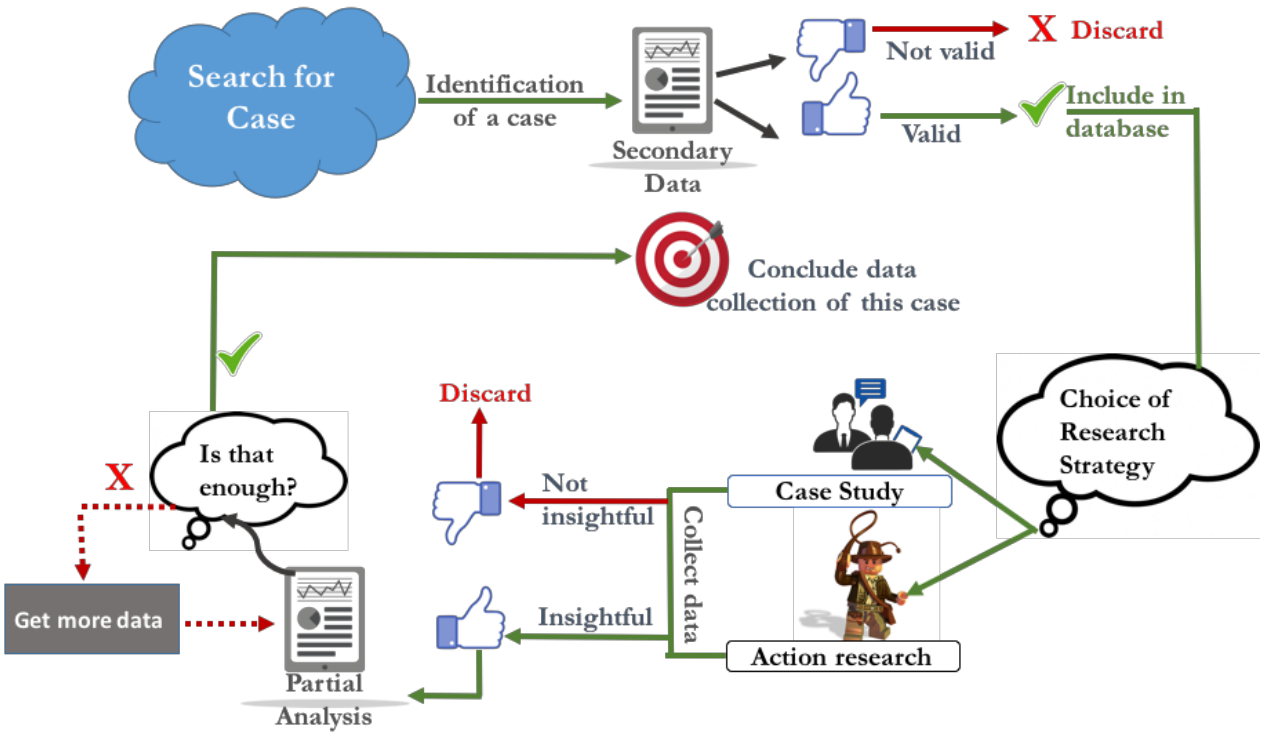
'how' questions: the researcher is devoted to diagnosing, planning, taking action and then evaluating (Saunders, Lewis and Thornhill, 2009).

Besides tacit knowledge that can be 'learned-by-doing' (instead of merely 'learned-by-observing'), Action Research involves similar codified sources of evidence to Case Study (described in Table 4). The reasons to opt for the former are connected to the possibility of gaining valuable insights that are only possible when actively engaging with the problem, and to the potential of being granted access to a richer dataset.

- **Data Collection**

Data collection followed the process illustrated in Figure 8.

Figure 8: Overview of Data Collection Process – 3rd Research Stage



First, cases that could be potentially insightful to address the research question were identified, mostly through searches online or recommendation by academics and practitioners who were exposed to partial results of the 2nd research stage. When a case was identified, I analysed secondary data (i.e. archival records and documents available online) as a first filter. If the case did not meet the definition of Sustainability Hacking, as defined in the end of the 2nd research stage, it would be discarded. If it met the definition, or if secondary data did not suffice to confirm its validity, it would be included in the preliminary database.

The case would then be contacted and an initial interview would be conducted. Differently from the interviews conducted for the 2nd stage, the ones for the 3rd stage did not have a pre-established set of questions. Some questions were jotted down as aspects that needed clarification, after carefully reading the documents/records available online, thus providing a clear idea about potential directions that could be explored for each case. These were, nonetheless, only a starting point for conversation[9]. Since 'Sustainability Hacking' was a very nascent research domain, the researcher was interested in exploring novel insights, deepening into aspects that surfaced throughout the interviews. Interviews were, therefore, unstructured, in-depth and informal (Yin, 2003). Although the researcher guided the discussions, interviewees were also given the opportunity to talk freely and deviate from the original question. Participant and direct observation occurred when, during an initial interview, the agent mentioned the possibility of joining work meetings with stakeholders and/or going to the places where their Sustainability Hack has been implemented. In these circumstances, the researcher would adopt a more passive and responsive approach, letting the agents conduct the processes and focusing on taking notes and, if allowed, photographs.

Data was then collected through a variety of sources of evidence, as described in Table 4. When a mutually-beneficial opportunity for Action Research was identified, the researcher would consider its viability. Opportunities were mutually-beneficial when: 1) the researcher could benefit with novel insights and improved access to datasets and the interviewed individual/organisation could benefit from analytical skills that the researcher possesses (e.g. writing reports and academic papers); or 2) both parties could collaborate to tap into a pool of tangible resources for applied research (e.g. applying for grants for joint projects). Viability refers exclusively to time constraints of the PhD. In fact, many opportunities for engagement through Action Research were identified but could not be viably pursued. Action Research was pursued only with 1 of the 19 cases included in the sample, as scrutinised in Table 5.

[9] See Box 12 in Appendix B for an example

Table 5: Data Collected – 3rd Research Stage

Case	Name	Methodological Strategy	Description of engagement	Sources of evidence		Recorded and transcribed interviews/ meetings (min)	Description of direct/participant observation and archives/documents	Interviewees
A	Cola Life	Action Research	1) Building an intervention model that could be used to scale-up the Sustainability Hack beyond Zambia, without needing the presence and active engagement of ColaLife. The researcher and his supervisor have then applied and received an award from IBM to write a playbook, based on this experience. This playbook, combined with the support of ColaLife and other members of the network, is meant to assist agents in other low-income regions to uptake a similar intervention. This engagement is detailed in subsequent sections of this thesis.	Interviews	Archival records	Recorded: 2118,85	Meetings with stakeholders and field visits to rural and peri-urban areas	Keepers Zambia Foundation staff Pharmanova Ministry of Health Zambian Regulatory Agency Centre for Infectious Disease Research Centre in Zambia
			2) Publishing a paper in a medical journal, which could be used for advocacy with governments and intergovernmental organisations.	Documentation	Direct observation	Transcribed: 1550,12	Access to statistics (and raw data) of the projects; base-line, mid-line and end-line reports for funding agencies; presentations given by founders; blog posts and reports to wide audiences; articles published by the media	Medical Stores Limited Wholesalers and large retailers Public health officials Community members Community-based retailers International organisations
			3) The researcher has helped with more specific analytical tasks while getting data in Zambia, such as processing and analysing quantitative data, used to inform ColaLife's next steps.		Participant observation			
B	Operação Serenata de Amor (OSA)	Case study	Passive observer	Interviews	Archival records	Recorded: 454,98	Discussions of over 500 collaborators through GitHub[4] and Telegram Messenger[5]	Founders and active members
				Documentation	Direct observation	Transcribed: 454,98	Open-source materials made available by the participants involved through GitHub and Medium[6]	
C	Women on Waves	Case study	Passive observer	Interviews	Archival records	Recorded: 322,94	Visit to office to see how they operate and the technologies used	Founder 3 members of staff/volunteers performing different roles
				Documentation	Direct observation	Transcribed: 258,94		
D	Guarani-Kaiowá	Case study	Passive observer	Interviews	Archival records	Recorded: 154,67	Visit to a tribe to see how they live and interact and to the office of a governmental agency to see how they work	Tribe leader Staff member of governmental agency
				Documentation	Direct observation	Transcribed: 154,67		

E	Shoot the Shit	Case study	Passive observer	Interviews Archival records Documentation Direct observation Participant observation	Recorded: 88,20 Transcribed: 88,20	Workshop organised and conducted by Shoot the Shit. I observed for 3 days, and gave a talk in the end of the workshop.	Staff members of the organisation
F	Vigie Aqui	Case study	Passive observer	Interviews Archival records Documentation	Recorded: 54,52 Transcribed: 54,52	Materials available online (e.g. articles published by the media and websites)	Staff members of the organisation
G	Sugata Mitra	Case study	Passive observer	Interviews Archival records Documentation	Recorded: 86,07 Transcribed: 86,07	Materials available online (e.g. articles published by the media and websites)	Sugata Mitra
H	Social Finance	Case study	Passive observer	Interviews Archival records Documentation	Recorded: 34,21 Transcribed: 34,21	Materials available online (e.g. articles published by the media, and websites)	Staff member of the organisation
I	Goats for Water	Case study	The researcher, his supervisor and the founder of this case applied for a grant from the British Government, i.e. DICE, in October 2018. The proposal aimed at creating a highly scalable business model for the organisation, which included workshops, research with primary data in Pakistan, and writing a report on the findings.	Interviews Archival records Documentation	Recorded: 83,42 Transcribed: 83,42	Materials available online (e.g. articles published by the media, websites and videos)	Founder Staff member
J	Elango	Case study	Passive observer	Interviews Archival records Documentation Direct observation	Recorded: 254,02 Transcribed: 183,35	Visit to the village and observation of how locals live, work and interact Materials available online (e.g. articles published by the media, websites and videos)	Elango Academic expert in the area
K	Deity Tiles	Case study	Passive observer	Interviews Archival records Documentation	Recorded: 85,13 Transcribed: 65,02	Materials available online (e.g. articles published by the media, websites and videos)	Academic expert
L	Ugly Indian	Case study	Passive observer	Interviews Archival records Documentation	Recorded: 29,26 Transcribed: 29,26	Materials available online (e.g. articles published by the media, websites and videos)	Volunteer

M	Dharma Rao	Case study	Passive observer	Interviews Archival records Documentation Direct observation	Recorded: 47,04 Transcribed: 47,04	Visit to a village to see how they use the technology and how they interact with Dharma Rao	Dharma Rao Community Members
N	Kalpana Srivastava	Case study	Passive observer	Interviews Archival records Documentation	Recorded: 182,79 Transcribed: 87,54	Materials available online (e.g. articles published by the media, websites and videos), and an academic article	Kalpana Srivastava Academic expert
O	Mod Skool	Case study	Passive observer	Interviews Archival records Documentation	Recorded: 68,25 Transcribed: 68,25	Materials available online (e.g. articles published by the media, websites and videos), and interactions on Facebook and blogs	Volunteer and idealizer
P	Field Ready	Case study	Passive observer	Interviews Archival records Documentation Direct observation	Recorded: 120,88 Transcribed: 120,88	Visit to their office to see how they operate and the technologies they use Materials available online (e.g. articles published by the media, websites and videos)	Staff member
Q	Sikka	Case study	Passive observer	Interviews Archival records Documentation Direct observation	Recorded: 122,48 Transcribed: 122,48	Visit to their office to see how they operate and the technologies they use Materials available online (e.g. articles published by the media and websites)	Staff Members
R	Honey Bee Network, Gian, SRISTI and Palle Srujana	Case study	Passive observer	Interviews Archival records Documentation Direct observation	Recorded: 920,12 Transcribed: 353,85	Visit to some villages to see how they interact and foster grassroots innovations and the impacts in livelihoods Materials available online (e.g. articles published by the media, websites and videos), and published academic articles	Founder Staff members Grassroots innovators
S	Four Thieves Vinegar	Case study	Passive observer	Interviews Archival records Documentation	Recorded: 94,39 Transcribed: 94,39	Materials available online (e.g. articles published by the media, websites and videos)	Founder
Total	**19 cases**				Recorded: 5322,22 **(~89hours)** Transcribed: 3937,19 **(~66 hours)**		

It is important to highlight that cases are described in details in Chapter 5 – the aim here is solely presenting how data was collected. Primary data collection for the 3rd stage of this research occurred from January 2017 until July 2018[10], including fieldwork in Brazil, Zambia, the United Kingdom, Netherlands, India, Nepal, Pakistan and the United States, either in-person or over Skype[11].

After collecting data, the case was partially analysed and, if gaps were identified and not filled by secondary data, the researcher opted to collect more primary data. The techniques for further data collection took into account the subjective trade-offs between 'exploring novel insights' *vs* 'targeting what was still unclear'. When, after collecting data, the researcher identified a case was not a Sustainability Hack, it was discarded from the sample. This has happened with 6 cases that had data collected but the researcher realised they did not fit the definition established in the end of the 2nd stage.

Finally, if the case was a Sustainability Hack and gaps were not identified, data collection for that specific case would be concluded. The researcher could then opt to find and collect data from other cases, or to conclude data collection and move on to focus exclusively on analysis, depending on time constraints for the conclusion of the PhD. The researcher has concluded this research step with a vast amount of data: a total of 19 cases compose the final sample of the 3rd research stage, counting with approximately 89 hours of recorded interviews, besides archives, documents, and noted observations.

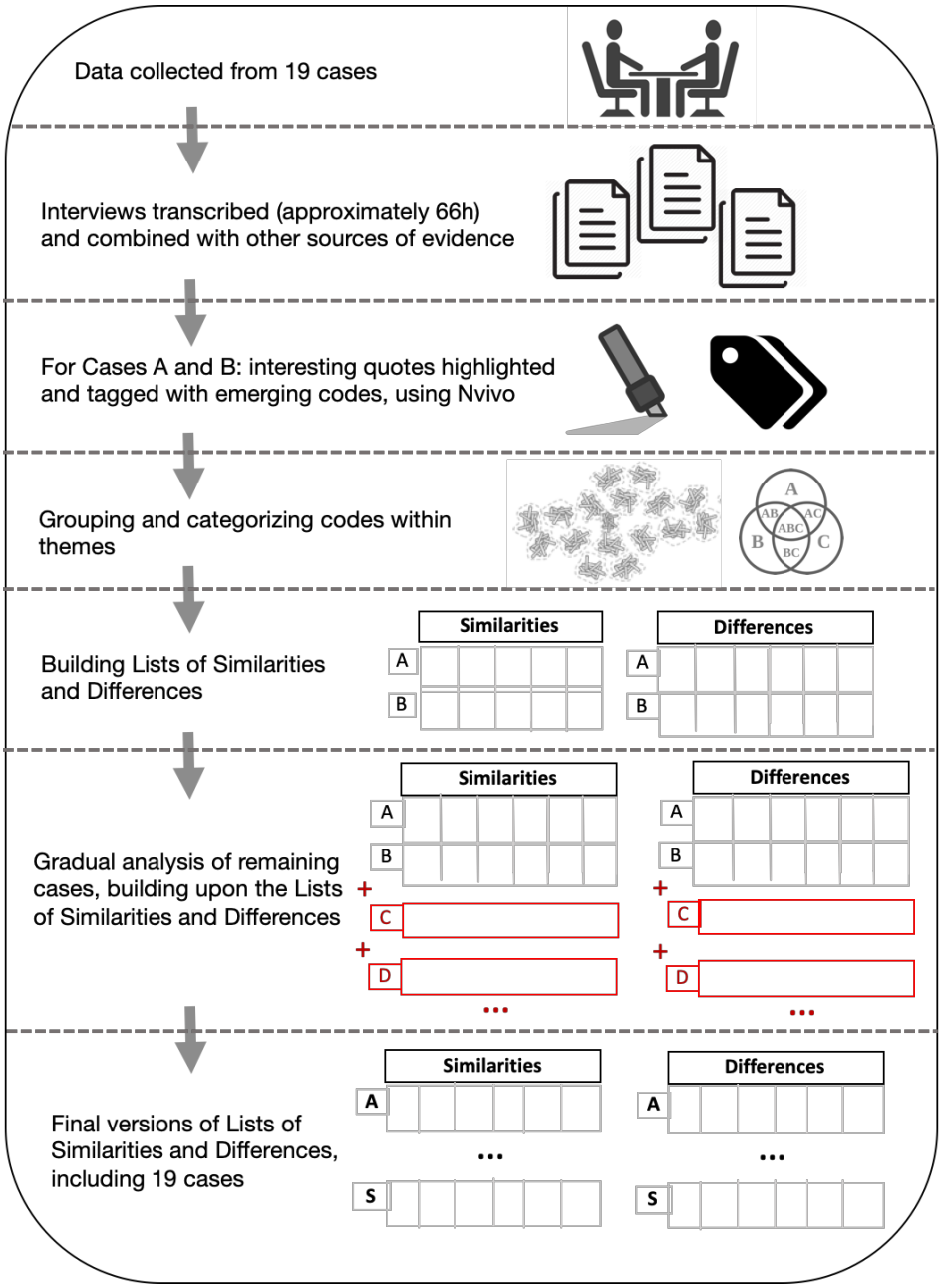
- **Data Analysis**

Figure 9 illustrates the stepwise approach adopted for data analysis in the 3rd stage. The intent of this section is of outlining the procedures for data analysis, since Chapter 5 walks the reader through the analysis of the 19 cases.

[10] The researcher conducted a self-assessment of ethics and good practice, which was subsequently validated by the Divisional Representative, who considered this research low-risk. Only after receiving approval to proceed, the researcher conducted the interviews. The interviewees were verbally informed of the possibility of opting for confidentiality. All of them opted for no-confidentiality.

[11] Appendix A supplements this section with important characteristics of the recorded data (e.g. location, dates, categorization of interviewees, acronyms, recorded time for each stakeholder, etc). Appendix B illustrates the open-ended questions used to initiate interviews.

Figure 9: Stepwise Approach for Data Analysis – 3rd Research Stage



I started by transcribing[12] relevant interviews and combining them with my noted observations and archival records/documents for the 19 cases within the sample. I have then analysed the contents of Cases A and B through open, exploratory coding, with the assistance of Nvivo software. I attentively read the documents to identify and group extracts that seemed relevant to address the research question of the 3rd stage. Codes have thus emerged throughout the process, without the support of previously established nodes/categories. This process provided a condensed description of critical variables both for cases A and B.

[12] Some of these interviews were transcribed by myself. Others by a professional transcription service based in India.

As detailed in Chapter 5, the results of the analysis of Cases A and B were contrasted to pinpoint their similarities and differences. They were also overlapped with the dominant characteristics of System Hacking, identified in the end of the 2nd research stage. The researcher then compiled the preliminary Lists of Similarities and Differences, which were used as a starting point for the analysis of the remaining cases. Case C was subsequently analysed, also with the assistance of Nvivo software, but this time with closed codes (i.e. investigating exclusively the similarities and differences identified from the analysis of Cases A and B). A similar analysis was then gradually conducted with the remaining cases, one-by-one, but this time by attentively reading and searching for the information that addressed each category of the Lists. I then reached the final result: the complete List of Similarities and Differences across cases, shedding light on a phenomenon that has not yet been covered by the literature, and from which 5 Archetypes of Sustainability Hacking also emerged as frames of reference for future studies.

- **Limitations**

This research stage has the following limitations. First, given its inductive and exploratory nature, I was focused on unpacking the most notable similarities and differences across cases, not on validating results or testing them for generalisability (Yin, 2003).

Second, since the phenomenon of 'Sustainability Hacking' has never been previously studied, data collection was particularly challenging. Finding cases depended on online searches and recommendations from academics and practitioners who were exposed to the results of the 2nd stage. For this reason, data collection has an unintended selection bias that the researcher recognises as an important limitation. The absence of a typology of potential cases to guide case selection constrain both the breadth and the generalisability of the findings.

Third, the researcher attempted to contact all identified cases, but some were unresponsive. For an unknown reason, the Sustainability Hacks motivated by social goals were more responsive and easier to find than the ones motivated by improved environmental performance. Investigating more environmental cases could have unpacked other novel insights or contradicted the ones observed in my sample and portrayed in Chapter 5.

Fourth, it is important to recognise that the involvement my supervisor and I had with Case A, through Action Research, implies in greater analytical bias. Differently from the other cases, the researcher was biased not only by his world views, cultural experiences and upbringing, but also by the nature of his involvement with the investigated organisation. The same applies, to a lesser extent, to Case I, since the researcher and his supervisor unsuccessfully attempted to

support the organisation through Action Research and ended up employing Case Study method as the most viable alternative.

Lastly, the analysis, despite being conducted in a structured and systematic way, inevitably incurs in subjectivity in the process of identifying, extracting and coding content.

2.8. Summary and Final Remarks of the Chapter

This Chapter has laid the methodological foundations of this research. Table 6 provides a final overview of the most notable characteristics of the research design of this thesis. The following 3 Chapters present, respectively, the results of the 3 stages of this research, while simultaneously walking the reader through the analytical processes from which the most notable observations of this PhD research have surfaced.

Table 6: Summary of Research Design

Stages	**1st Stage**	**2nd Stage**	**3rd Stage**
Philosophical Stance	Pragmatic (tending to interpretivism)		
Research Questions	What are the theoretical foundations of sociotechnical system change for sustainability?	What the heck is 'hacking'? What are its dominant characteristics?	What are the dominant similarities and differences of Sustainability Hacking in the real-world?
Approaches	Abductive	Inductive	Inductive
Arrangements	Mixed-methods, primarily qualitative	Multi-methods, only qualitative	Multi-methods, only qualitative
Strategies	Systematic literature review	Phenomenon-Driven	Case Study and Action Research
Data Collection	Initial search in the Web of Knowledge database with pre-defined strings, combined with bibliometric analysis, to reach an initial sample. From this, a snowballing technique was implemented to reach the final sample of 208 documents	A combination of exploratory interviews with 12 self-declared hackers and cybersecurity experts; participant observation; and secondary data available online	Data collection of 19 cases (approximately 89 hours of recorded interviews). Sources of evidence include exploratory interviews, archival records, documentation, direct observation and participant observation
Data Analysis	Coding data with the support of the previously established categories (*What*, *Why*, *How)*, allowing subcategories to arise throughout the process	Transcribing interviews and analysing their content through textual coding. These were openly coded, grouped and categorized within themes for the	Transcribing interviews and combining with other sources of evidence for content analysis through textual coding. Cases A and B were openly coded and

		construction and description of relevant definitions and characteristics	emerging features were grouped and categorized. After contrasting these cases, the Lists of Similarities and Differences were created. The analysis of the remaining cases was gradually performed by building upon these Lists
Outcomes	A condensed description of the 15 most relevant foundations of this field of research, and the reflection of different research avenues	Definition of System Hacking + 9 dominant characteristics	List of Similarities, List of Differences, and Archetypes of Sustainability Hacking

3. Literature Review

"From all tools of mankind, the most amazing is, without a doubt, the book. The others are extensions of our bodies. The microscope and the telescope are extensions of our sight; the telephone is an extension of our voice; we also have the plough and the sword, extensions of our arm. But the book is something else: the book is an extension of our memory and our imagination".
(Jorge Luis Borges, Borges Oral, p.13)[13]

3.1. Introduction to the Chapter[14]

Sustainability can be framed as the integration of social inclusiveness, environmental protection and economic progress for the benefit of current and future generations (Brundtland, 1987; Elkington, 1999). There is growing concern to transition towards more sustainable directions. Issues include, for example, biodiversity loss; water, air, and soil pollution; climate change; unemployment and poor working conditions; poverty trap and social vulnerability; widening inequalities; and financial volatility (Seiffert and Loch, 2005; e.g. Jackson, 2009; Markard, Raven and Truffer, 2012; Sachs, 2015).

Standalone, incremental improvements are not sufficient to address current, let alone future sustainability challenges (Evans et al., 2009). These challenges will require deep changes of sociotechnical systems. This term refers to co-evolving social and technical aspects, which are analysed according to arbitrarily defined boundaries – such as organizations, sectors or nations (Geels, 2004; Savaget and Acero, 2017).

Theories on innovation systems; sustainable innovations; system thinking and design; and sustainability transitions, among others, have attempted to describe potential changes capable of shifting development towards more sustainable directions.

System thinking and design contributed greatly to a holistic understanding of system change, including ways to make its parts work together, while dealing with multiple and often unpredictable sources of instability, discontinuity and resistance to change (Senge, 1990; e.g. Meadows, 2002). Studies on innovation systems, more specifically, influenced the understanding of co-evolutionary dynamics of sociotechnical change, including the connections

[13] My translation, from Spanish to English.
[14] This section is an adapted and improved version of one of my articles (see Savaget et al, 2019). The initial draft of the paper was solely written by me. The published version counted with the valuable comments and edits of my co-authors Martin Geissdoerfer, Ali Kharrazi and Steve Evans, as well as from anonymous peer-reviewers.

between knowledge and technologies, institutions, actors and networks (e.g. Freeman, 1991; Malerba, 2002).

Along these lines, several studies have been dedicated to studying how to steer sociotechnical system change to address pressing sustainability challenges. Sustainable innovations literature, for example, describes the generation and diffusion of innovative products, services, processes and business models contributing to improved social and environmental performance (Seyfang & Smith 2007; Esty & Winston 2009). Sustainability transitions theory, alternatively, focuses on advancing the understanding of highly institutionalised processes that constrain sustainable innovations in their attempts of leapfrogging the prevailing unsustainable alternatives – thereby constraining path-breaking and wide-scale changes (e.g. Geels, 2002; Smith, Stirling and Berkhout, 2005).

Despite their different approaches, all these contributions emphasise that unsustainable characteristics of prevailing sociotechnical systems are not easily changed, as they are part of mutually-reinforcing dynamics, encompassing for example technologies, policies and social behaviours. Literature has responded to these challenges by investigating the intensities and causalities of these developments; hence, contributing towards a better understanding of the multiple and co-existing possibilities to purposefully drive sustainable changes.

Knowledge on how to analyse and describe sociotechnical system change has gained academic prominence as means of shifting progress towards meeting the most pressing sustainability challenges of our time (Clark and Crutzen, 2005; Kates, Parris and Leiserowitz, 2005; Leach, Scoones and Stirling, 2007). However, there has been no systematic effort to reveal the ontological and normative foundations grounding theoretical development in this field. According to Stirling (2009, p. 4), normativities consist of evaluative frameworks for judgement, carrying different institutional, political, and cultural commitments. Each of these commitments concerns, for example, how we may better understand the world; the manners in which we should act in (or on) Nature; and the ways in which we ought to relate to one another and structure society. Ontologies, on the other hand, consist of how we think 'things are' rather than how we think 'things should be' (Savaget and Acero, 2017)

Since I could not identify any systematic effort to reveal the ontological and normative foundations of literature in this field, this chapter focuses on the following research question: *What are the theoretical foundations of sociotechnical system change for sustainability?* By 'foundations', I mean the fundamental, taken-for-granted assumptions on how sociotechnical system change occurs, what is seen as viable and desirable, and how it can be best steered towards reaching more socially desirable outcomes. This question was addressed through a systematic literature review, as described in Chapter 2.

3.2. Structure of the Chapter

The research question presented in Section 3.1 was addressed through a systematic literature review, whose deployed methods for sampling documents and analysing data were detailed in Chapter 2. This chapter portrays the results of this review. It starts by outlining the identified research areas, their main contents and references. This is followed by narratives resulting from the textual coding of the documents of the sample, summarising, respectively, the *Why*, *What* and *How* embedded in the literature on sociotechnical system change for sustainability. After exposing their main sources of agreement and tension, I then derive and discuss the dominant ontological and normative foundations at the core of the literature. Besides providing a better understanding of the state-of-the-art of literature, this process has opened up scope for reflecting upon its shortcomings and for questioning novel research avenues that may contribute to furthering development in the field. Finally, this chapter connects the results of the systematic literature review with the investigation of Hacking, described with greater details in Chapter 4.

3.3. Outline of the Research Areas

The methods employed for collecting, processing and analysing data have been scrutinised in Chapter 2. This chapter focuses solely on presenting and discussing the results arising from that process. In total, 208 prominent documents on sociotechnical system change for sustainability were collected and analysed. The first output of the content analysis was the categorization of the sample into research areas, whose contents were then dissected and contrasted. The 6 main research areas are categorised in Figure 10, and the content of each category and respective publications are illustrated in Table 7.

Figure 10: The main research areas of this study

Table 7 pinpoints the most notable themes explored by each research area, as well as their main references. This overview provides a glimpse of the breadth and scope of the literature on sociotechnical system change for sustainability.

Table 7: Content and references for the six main research areas

Category	What does it include?	References
1.Governance of Innovation Systems	Systematic stimulation of innovation and its link to macroeconomic performance	(Amsden 2002; Carlsson et al. 2002; Chang 2002; Freeman & Louçã 2001; Freeman & Perez 1988; Freeman & Soete 2000; Lanahan & Feldman 2015; Lundvall et al. 2009; Martin et al. 2012; Mazzucato 2013; Schumpeter 1997)
	Public governance frameworks of science, technology, and innovation systems	(Cooke et al. 1997; Doloreux & Parto 2005; Freeman 1995; Furman et al. 2002; Frank W. Geels 2004; Lundvall et al. 2002; Malerba 2004; Malerba 2002)
	Institutional theories influencing Innovation Systems	(Hodgson 2005; North 1990; Kukk et al. 2016; Coriat & Weinstein 2002; Markard et al. 2016)
	Concepts focusing on the peculiarities of innovation-driven development in low and middle-income regions	(Abramovitz 1986; Fagerberg 1994; Gerschenkron 1962; Viotti 2002)
2. Innovation Management and Entrepreneurship	Resources, competences, dynamic capabilities, routines, learning of companies, bricolage, diy, maker culture and business venturing	(Dosi et al. 2000; Leonard-Barton 1992; Meyer & Utterback 1993; Nelson & Winter 1982; Penrose 2013; Teece et al. 2008; Baker et al. 2003; Brass et al. 1997; Ciborra 2004; Dreborg 1996)
	Invention, innovation, R&D management and new product introduction	(Clark & Fujimoto 1991; Roussel et al. 1991; Arrow 1972; Jewkes et al. 1969; Schmookler 1966; Abernathy & Utterback 1978)
	Multifunctional and systemic approaches of innovation and technological management	(Goffin & Mitchell 2010; Gregory 1995; Phaal et al. 2001; Tidd 2001; Van de Ven et al. 1999)
	Concepts clarifying or distinguishing innovation in processes, products, services, and business models	(Barras 1986; Chesbrough 2010; Eisenhardt & Tabrizi 1995; Ettlie & Reza 1992; Gallouj & Weinstein 1997; Hipp & Grupp 2005; Utterback & Abernathy 1975; Zott et al. 2011; Tennant 2015; Brennan & Tennant 2018; Yang et al. 2014; Geissdoerfer et al. 2016)
	Collaborative frameworks for generation, diffusion and adoption of innovation, such as open innovation, triple helix, user innovation and human-centred design	(Chesbrough 2003; Leydesdorff 2000; Mortara & Minshall 2011; Roijakkers et al. 2018; Ahn et al. 2014; Minshall et al. 2010; Pisano & Verganti 2008; Von Hippel 2001; Giacomin, 2014)
3. Sustainable Development	(Chesbrough 2003; Leydesdorff 2+B11000; Mortara & Minshall 2011; Roijakkers et al. 2018; Ahn et al. 2014; Minshall et al. 2010; Pisano & Verganti 2008; Von Hippel 2001; Giacomin,	(Grey 1993; Morton 2007; White 1967)
	Theories on growth and environment trade-offs, e.g., degrowth, growth limits, steady-state, and growth-fetish	(Daly 1991; Daly & Townsend 1993; Hamilton 2004; Jackson 2009; Kallis 2011; Meadows et al. 1972)
	International sustainable governance discussion on environmental, social, and economic dimensions	(Brundtland 1987; Clark & Crutzen 2005; Elkington 1999; Kates et al. 2005; Middleton & O'Keefe 1993; O'Riordan 1993; Sachs 2015)
	Different perceptions of what is to be sustained, what is to be developed and what is attainable	(Fowke & Prasad 1996; Kates et al. 2005; Leach et al. 2007; National Research Council 1999; UNCED 1992; United Nations 2015; Williams & Millington 2004; Stirling 2014)
	Vulnerability, resilience and complexity of social-environmental systems	(Kharrazi et al. 2016; Rockström et al. 2009; Turner et al. 2003; Derissen et al. 2011; Meroni & Milano 2015)
	Sustainable corporate strategy, e.g., sustainable industries, CSR, shared value, bottom of the pyramid, and circular economy	(Cohen 1997; Cohen 2006; Crane et al. 2014; Evans et al. 2009; Jänicke & Jacob 2006; Mcwilliams 2016; Porter & Kramer 2011; Prahalad 2004; Prahalad & Hart 2002; Webster 2015)
	Sustainability-driven innovation, e.g., eco-innovation and social innovation	(Basu et al. 2013; Ekins 2011; Esty & Winston 2009; George et al. 2012; Graddy-Reed & Feldman n.d.; Hart 2000; Hart & Milstein 2003; Jordan & Lenschow 2008; Kemp 1994; Kemp & Pearson 2007; Lafferty & Hovden 2002; Nakata & Weidner 2012; OECD 2011; Prahalad et al. 2012; Radjou et al. 2012; Schiederig et al. 2012; Seyfang & Smith 2007; Birtchnell 2011; Prabhu & Jain 2015; Gupta 2016; Smith et al. 2014; Bhatti 2012; Zeschky et al. 2011)
4. Public Understanding of Science, Technology and Society	Social construction of knowledge	(Jasanoff 2009; Latour & Woolgar 1986; MacKerron & Berkhout 2009; Miller 2005; Millstone 2007; Pestre 2008)
	Plurality and democratic accountability in policy-appraisal and mechanisms for appraising different dimensions of uncertainty	(Beck 1999; Ezrahi 1990; Funtowicz & Ravetz 1990; Funtowicz & Ravetz 1995; Jasanoff & Kim 2009; Jasanoff 2010; Leach et al. 2005; Smith & Stirling 2007; Stirling 2003; Stirling 2007; Stirling 2009; Wynne 1992)
5. System Thinking and Design	Ontologies of knowledge-about-system and epistemologies of system thinking and complex system theory	(Cabrera 2006; Capra 1983; Forrester 1961; Kauffman 1995; Meadows 2008; Mingers & White 2009; Senge 1990; Thaler & Sunstein, 2009)
	System design for sustainability	(Blizzard & Klotz 2012; Ceschin & Gaziulusoy 2016; Charnley et al. 2011; Gaziulusoy & Brezet 2015; Seiffert & Loch 2005; Dorst 2011; Manzini 2015)
6. Wide-scale Changes of Sociotechnical Systems	Technological paradigms and revolutions, dominant design, sociotechnical regimes and their transformation/lock-ins	(Arthur 1989; Bijker 1995; Dosi 1982; Kuhn 1996; Mckelvey 2002; Nelson & Winter 1982; Perez 2002; Stegmaier et al. 2014; Van de Poel 2000; Von tunzelmann et al. 2008)
	System innovation, sociotechnical governance, transition and strategic niche management, and complexity governance	(Borrás & Edler 2015; Ekins 2011; Elzen et al. 2004; Kemp et al. 1998; Kivimaa & Kern 2016; Mokyr 1990; Rotmans et al. 2001; Schot & Geels 2008; Smith & Raven 2012; Sushandoyo & Magnusson 2014; Teisman et al. 2010)
	The roles performed by different agents, such as companies, governments and civil society in sustainability transitions	(Berkhout et al. 2004; Coenen et al. 2012; De Haan et al. 2014; Farla et al. 2012; Geels & Schot 2007; Jørgensen 2012; Kemp 1994; Loorbach 2007; Penna & Geels 2012; Rip 2006; Shove & Walker 2010; Smith et al. 2005; Smith et al. 2010; Smith & Stirling 2007; STRN 2010; Turnheim et al. 2015; Wittmayer & Schäpke 2014; Geels 2002; Geels 2005; Geels 2010)
	Mechanisms to assess and influence transitions, e.g. backcasting, forecasting, roadmapping and scenario building	(McDowall 2012; Eames & McDowall 2010; De Jouvenel 2000; Dreborg 1996; Durance & Godet 2010; Holmberg & Robert 2000; Pincetl et al. 2014; Rip & Schot 1996)

The second output was then to build a narrative, based on my textual coding, that summarises the *Why*, *What* and *How* embedded and widely diffused into literature – as described in the following subsections. It is important to stress that I was particularly focused on exposing the main sources of agreement and tension within literature, in order to open up room to synthesise the theoretical foundations of literature on sociotechnical system change.

3.4. Why?

The covered literature reveals two main underlying motivations. The first refers to the understanding of sustainability goals. The second consists of understandings of why sociotechnical systems should be addressed to influence such goals.

3.4.1. Why sustainability?

It is widely agreed in the literature that Sustainability is a balanced integration of economic performance, social inclusiveness and environmental resilience, to the benefit of current and future generations (Brundtland, 1987; Elkington, 1999). Detrimental impacts of many technological trajectories upon natural resources have raised questions about whether present prosperity trends can be expanded – or even maintained – in the future (Clark and Crutzen, 2005). This term is the basis for discussions on alternative directions of sociotechnical progress and on shared responsibilities both in defining societal goals and on how to better pursue them (Leach *et al*. 2007).

Sustainability concerns have entered both into the agendas of policymakers and industry managers since the second half of the 20th century. Although the term has been since interpreted very differently, its diffusion is attributed to environmental discussions. Since the 1960s, science has identified a series of global-scale environmental risks, such as the ozone depletion, climate change, biodiversity loss, and the alteration of the nitrogen cycle. These risks have resulted from extensive anthropogenic activities and fuelled by rapid technological developments beyond "the wildest Neolithic dreams" (Grey, 1993, p. 464). Furthermore, these emerging sustainability risks challenge our former understandings of development patterns as purely positive and question our ability to sufficiently account for the scarcity of environmental resources (Cohen, 1997).

The identified threats initiated international discussions on the complex and dynamically interconnected nature of the environment, society and the economy (Kates, Parris and Leiserowitz, 2005). These discussions started to systematically challenge prevailing economic frameworks and instead envisioned new frameworks integrating the social, economic and

environmental dimensions as continuously and cumulatively affecting one another (Mckelvey, 2002).

It is consensual that sustainable development initiatives should be planned and coordinated on a local level because requirements and opportunities vary among regional contexts. The definition of sustainable development is, therefore, deliberatively vague (O'Riordan, 1993). This vagueness accommodates a variety of understandings and expectations for progress and allows for heterogeneous responses to the diversity and complexity of challenges faced by humans around the world (Kates, Parris and Leiserowitz, 2005).

The verb *sustain* means to maintain certain features of an instance over time. The meaning of the noun *development* can vary depending on values, interests and disciplinary lenses (National Research Council, 1999). The term can be interpreted in different ways and justify commitments based on various motivations, from targeting inflation to controlling pandemics. Tensions within the literature lie mostly on what to prioritise in decision-making. Given that resources are limited and problems are complex, addressing sustainability requires comparing and deciding what co-existing goals will be prioritised; what responsibilities will be assigned to each stakeholder; and what means can be deployed to reach the goals.

However, the nature of goals set by different narratives of sustainable development clearly relies on their dominant interests, which are essentially plural (Clark and Crutzen, 2005). Instead of merely setting common goals, the literature on public understanding of science and technology emphasises that sustainability widens the scope for multiple expectations on what is to be developed, what is to be sustained, for how long, and for the benefit of whom (S. Jasanoff, 2010). It also illustrates the extent of our ignorance whereby policy interventions are gradually seen as path-dependent and adaptable experiments. This in effect paves a path from cognitive predicaments (e.g., uncertainty and incommensurability), to challenges associated with agency behaviour and intentionality upon the wide range of responses to sustainability challenges (Stirling, 2014).

3.4.2. Why sociotechnical systems?

In the sample, there were many sources of agreement. Several studies on sociotechnical change for sustainability refer to environmental threats (e.g., climate change, biodiversity loss, and water scarcity), and suggest that relevant solutions cannot be achieved only through the incremental development of clean technologies. In this avenue, social, economic or political aspects, such as unsustainable consumption, financial crises, and public budget overruns, are sometimes seen as resulting factors of technological lock-ins and path-dependency (Smith,

Stirling and Berkhout, 2005; Markard, Raven and Truffer, 2012). They thus indicate the need for substantive transitions, with deep structural changes in sociotechnical systems (Berkhout, Stirling and Smith, 2004; Smith, Voss and Grin, 2010).

There are, nonetheless, profound sources of tension in the perceptions of the role of science, technology and innovation among scholars and policy makers, given the following four reasons.

Firstly, there are discussions on the way past technological trajectories led to unintended consequences. Since the industrial revolution, new technological paradigms have been emerging, which have changed human behaviour and wellbeing, consumption preferences, industrial infrastructure, and political frameworks (Evans *et al.*, 2009). The literature also recognises that companies are increasingly under pressure to create innovations capable of capturing new opportunities to drive profits for shareholders and ensuring longevity (Hart and Milstein, 2003). However, the benefits of technological development have not reached all stakeholders equally while the environment has been degraded considerably and is compromising the long-term life-support systems for human existence (Sachs, 2015).

Secondly, progress in science, technology and innovation provided the knowledge base and tools to assess unintended consequences, to appraise desired futures and to reveal potential alternatives. Technical knowledge and technological tools have been critical to inform decisions aimed at shifting sociotechnical progress towards more sustainable directions (Beck, 1999).

Thirdly, innovations are increasingly the main source of hope in finding alternative development models. Changing the existing unsustainable paradigms requires efforts from different agents to generate and diffuse products, processes, services, technologies, business models and policies capable of simultaneously benefitting the economy, the environment, and the society (Kemp, Schot and Hoogma, 1998; Hart and Milstein, 2003; Jordan and Lenschow, 2008). As there are various sources of stimuli to the generation and diffusion of sustainable innovations, it becomes critical to understand how innovation management (and governance) can steer innovative performance towards more sustainable directions. However, while many implemented efforts have emphasised technical solutions, rather than social and political mobilisation (Clark and Crutzen, 2005), others claim instead that a successful transition towards sustainability could be achieved with existing technologies (National Research Council, 1999). Therefore, they believe that capabilities, social learning, and political willpower promoting viable and technologically feasible alternatives should be prioritised.

Fourthly, the scope of analysis has broadened from technical to sociotechnical or societal systems in the literature. Technical systems revolve around artefacts, and indirectly recognise the role of social dimensions in the generation and diffusion of technologies. Differently,

sociotechnical systems are composed by several technologies entrenched with social, political and economic dimensions (De Haan *et al.*, 2014).

3.5. What?

In the following, I describe factors, variables and concepts widely used to describe sociotechnical system change, before presenting what system changes qualify as sustainable.

3.5.1. What is a sociotechnical system?

It is very consensual within literature that innovations are not isolated events: they should be seen in the light of co-evolving systems (Freeman and Soete, 2000). The most important property of system thinking is that a system is more than the sum of its parts, and these parts are interconnected into complex structures (Seiffert and Loch, 2005; Meadows, 2008). The basis of system thinking is thus seeing "wholes": investigating entire systems within a boundary, understanding their components, functions, and interconnections (Senge, 1990).

It is widely accepted that systems are characterised by feedback loops, self-organisation, and hierarchies. Feedback loops are closed chains of causal connections that can be either sources of (in)stability, (dis)continuity or resistance to change. Self-organisation describes the ability of systems for self-structuring to learn, diversify, and become more complex over time. However, self-organisation also tends to create resilience towards radical changes, as systems tend to keep coherence in their functions. Systems often involve hierarchies too, with arrangements between systems, subsystems and their components. The trade-off between autonomy and coordination in hierarchical systems is seen as rather complicated, potentially constraining or fostering subsystems. It is also important to highlight that, as resilience, self-organisation, and hierarchy are the main reasons dynamic systems work so coherently, intervening in these properties can drastically influence the system's ability to function (Meadows, 2008; Blizzard and Klotz, 2012).

The literature presents some sources of tension, in what regards distinct analytical characteristics and the proposition of different pathways. This includes, for example, regime transformation (Van de Poel, 2000), technological revolutions (Perez, 2002), system innovation (Elzen, Geels and Green, 2004) and sociotechnical transitions to sustainability (Geels and Schot, 2007). However, despite conceptual specificities, these perspectives share the understanding that systems are changed through interconnected changes within self-reinforcing domains of technology, the economy, institutions, behaviour, and cultural systems (Rotmans, Kemp and van Asselt, 2001).

Furthermore, using a sociotechnical system as an unit of analysis draws from several converging scholarly contributions, including dominant design (Utterback and Abernathy, 1975), technological paradigms (Dosi, 1982), and technological regimes (Nelson and Winter, 1982).

A dominant design is what provides a reference outlook for engineers, designers and technologists, signalling the basis for further progress (Utterback and Abernathy, 1975). These outlooks enable continuous technological development in certain sociotechnical clusters. They are composed by beliefs, expectations and knowledge bases that illustrate certain opportunities, while simultaneously hindering the development of other potentially viable alternatives (Kemp, Schot and Hoogma, 1998).

It is widely accepted in the literature that sociotechnical evolution reflects a process of ongoing reproduction that incorporates cumulative, gradual, and self-reinforced characteristics (Kemp, 1994; Shove and Walker, 2010). This idea was further elaborated in the concept of technological paradigms (Dosi, 1982), which describes core technological frameworks that guide innovative activities of industries. With a similar yet broader scope, the concept of technological regimes was initially framed by Nelson and Winter (1982) and has highly influenced studies on sociotechnical system change. Similar to "dominant design", this concept recognises the stable and incremental nature of problem-solving, also introducing boundaries for the expected direction of technological progress (Kemp, 1994). However, when new technological trajectories emerge, agents start exploring different solutions. This is done through negotiations and coalition building (Geels and Schot, 2007), eventually reaching a dominant interpretation based upon goals, strategies, heuristics, and tacit and codified knowledge, to cite just a few (Bijker, 1995).

The term regime has also been widely used in sustainability transitions theory because it does not exclusively focus on paradigms or systems. It also incorporates the idea of 'rules' from institutional theories (North, 1990; Hodgson, 2005). A technological regime encompasses sets of rules – for example, from the market, heuristics of engineering communities, user requirements, laws, and policy framings. These guide the innovative activities that companies are likely to undertake, the solutions that will be prioritised and the strategies of a vast array actors (Kemp, Schot and Hoogma, 1998). The concept of regime has helped academics in the field to understand why some radical technological alternatives are not explored, especially when requiring substantial contextual changes, and why most innovative efforts are aimed at incremental changes instead of regime transformation.

This notion of regimes was broadened by scholars analysing contributions of a diverse set of stakeholders to technological progress (Bijker, 1995). The resulting concept of

sociotechnical regimes combines the dynamics of variation, selection and retention, which is highly accepted within the sample.

Variation refers to expectations, visions and cognitive guidance for intentional and deliberate innovative efforts. Selection occurs due to the context, which incorporates not only markets, but also regulations, social behaviour, industrial structures, knowledge, and cultural influences. Dominant technologies and infrastructures thus act as selection pressures through articulated standards and arrangements imposed on sociotechnical features. Guiding principles and cognitive processes favour incremental developments over paradigm shifts, and dominant consumer preferences stabilise market institutions, supply and demand, prices, and user behaviour (Nelson and Winter, 1982; Geels, 2002). Retention provides and reinforces the rules to maintain working solutions, stabilising technological trajectories through, for example, cognitive routines of engineers (Nelson and Winter, 1982), regulations and standards, adaptation of social lifestyles, and infrastructure and competencies (Geels and Schot, 2007). The more a technology is adopted, the more the user familiarises itself with it; this stimulates further improvements and entrenchment into the economic system (Smith and Raven, 2012).

Academics also agree that sociotechnical regimes are neither fully deterministic nor completely behavioural. Agents are capable of interpreting, applying and negotiating rules they do not fully control (Geels, 2010). By applying the concept of sociotechnical regimes, it is then possible to realise that the prevailing unsustainable technologies and social habits can be interpreted as embedded and self-reinforcing systems, opening up scope to questions of 'how' to steer change towards more socially desired directions.

3.5.2. What is sustainable?

The analysis of sociotechnical systems often implies the ultimate idea that there are mutually reinforcing and highly institutionalised processes in sociotechnical regimes. This makes it difficult for sustainable innovations to succeed against the existing unsustainable alternatives, consequently constraining radical structural changes. These investigations are often methodologically based on historical analysis and case studies.

The conceptual responses to sustainability challenges represent great sources of tension. They can range from confrontational to pacifying approaches. Confrontational concepts tend to be anchored on the prioritisation of "sustaining" instead of "developing", mostly emphasising trade-offs between the economy and the environment. These approaches lay different emphasis on the extent of confrontation or resistance to be employed, and encompass notions like Steady-State (Daly and Townsend, 1993), Degrowth (Kallis, 2011), and Prosperity Without Growth (Jackson, 2009). Alternatively, pacifying approaches aim at harmonising divergences and

exploring win-win situations. Different value opportunities are uncovered that promote soothing bridges for apparent trade-offs and to nurture reflexivity about desired directions and potential futures (Hart and Milstein, 2003; Evans *et al.*, 2009).

Yet, despite diversity, the emphasis lies on some major areas of agreement. A literature review conducted by the Board on Sustainable Development of the United States National Research Council (National Research Council, 1999) found major categories that are still very up-to-date. Under the heading of "what is to be sustained" they found 3 categories: life support systems, nature, and communities. A substantial part of the literature highlights sustaining life-support systems, by analysing natural resources as necessary conditions to the survival of humankind. In contrast, a minority would rather defend nature's value for its intrinsic qualities, instead of what it provides to humans. A third strand in the literature also covers the importance of sustaining livelihoods, cultural diversity and threatened communities (Kates and Parris, 2003; Clark and Crutzen, 2005).

According to the same study, there are also three areas of agreement about "what is to be developed": economy, people and society. The first aggregates much of the traditional literature on economic development, focusing on wealth, desired consumption, productive sectors and employment. The shift to human development falls under the second category, describing inequality, education, equal opportunities and other better quantifiable targets, such as life expectancy and infant mortality rates. The Board also identified goals centred on broader concepts of life in society, with a focus on community ties, national security, institutional change, social capital, and well-being (Kates and Parris, 2003).

Furthermore, authors tend to prioritise specific sociotechnical systems, sectors or even sets of infrastructures such as transportation or agricultural systems. In a literature review conducted by Markard et al (2012) on sustainability transitions, between 1990 and 2011, the energy sector and its technologies represented by far the most dominant topic, amounting for 36% of all papers, followed by studies covering transportation (8%), water and sanitation (7%), and food (3%). Besides, the analyses of sociotechnical systems depend on system boundaries that are essentially arbitrary but often institutionalised. The definition of such boundaries varies according to goals, challenges, actors, networks, geographical location, generalisability, and analytical feasibility. A great part of the art of analysing and designing systems therefore lies on setting appropriate boundaries for each purpose. However, as described by Meadows (2008), we are too attached to our accustomed boundaries, such as, national, ethnic, or income boundaries. These conventional boundaries have, in fact, greatly influenced the literature. That is the case, for example, in literature on 'National Innovation Systems' (e.g. Freeman, 1995) and 'Sectoral Innovation Systems' (e.g. Malerba, 2002).

Another source of agreement is the importance of analysing structures, agents, and processes that reproduce or cause breakthroughs in sociotechnical systems. Some unsustainable sociotechnical systems are more embedded than others, as they enjoy larger economic significance, supportive infrastructures, political legitimacy, and institutional support than the relevant alternatives (Smith and Stirling, 2007). For this reason, several authors also emphasise the importance of nurturing innovative niches. These are particularly relevant because sustainable innovations, even more than the traditional ones, can be referred to as 'hopeful monstrosities' (Mokyr, 1990, p. 291). They can be hopeful, as they might contribute to a desired future while they can also be monstrous because they might perform crudely in their early stages (Kemp, Schot and Hoogma, 1998).

This is, in fact, widely described as a pivotal problem for sustainable innovations with a radical impact potential, as they can get stuck while aiming at trespassing a metaphorical 'valley of death' between generation and wide diffusion (Schot and Geels, 2008). Therefore, as sociotechnical regimes benefit from accumulated privileges that act as a form of protection of unsustainable alternatives, radical innovations often struggle to emerge to the market and compete with incumbent alternatives. Niches can nonetheless shield sustainable innovations, holding at bay certain selection pressures from the regime in order to protect desired alternatives (Geels and Schot, 2007; Smith and Raven, 2012).

3.6. How?

A pervasive challenge is to understand connections between variables, delineating correlation or introducing causality influencing sociotechnical system change for sustainability. The most notable ones refer to understanding how sustainability can be fully pursued, as well as the extent to which sociotechnical change is (and can be) susceptive to deliberation.

3.6.1. How to steer sociotechnical system change?

It is highly consensual that the capacity of generating and diffusing innovations depends on the agency and coordination of different players, such as companies, governments, civil society or even collaborative networks (Minshall *et al.*, 2010). The literature thus tends to investigate the scope of the performance of each agent in influencing innovative performances and consequently sociotechnical system change.

Innovation management of companies, for example, covers multifunctional components and interactions between strategic choices, corporate culture, human resources, and operations (Tidd, 2001). Companies are central change agents, which are integrated into networks with

other actors, such as governments, civil society, and other users of their products and services. They are thus influenced by other actors and by institutional arrangements in ways that can either constrain or enable innovations to arise and diffuse (Lundvall *et al.*, 2009).

However, when the unit of analysis shifts from an innovation or from the innovating agent to a sociotechnical system, the understanding of "how" leads to many new questions. These questions include for example: How to define the boundaries of a system and what systems should be prioritised? How to steer (or adapt to) ongoing systems change? How to operationalise change and who should be involved? How to coordinate many agents? How should each agent behave? How are they accountable for the desired change?

In fact, by emphasising sociotechnical systems as units of analysis, the literature embarks on a more open-ended journey than when analysing innovative performance, opening up room for interpretive tensions. The analytical focus lies "on processes such as learning, radical innovation, experimentation, searches for new paths, participatory approaches, multi-actor interactions, selection processes, reactions, and network evolution" (STRN, 2010, p. 5)**.** Since sociotechnical systems are very complex, and do not have owners, the idea of managing or governing sociotechnical systems is often framed as reflexive, evolutionary, and adaptive processes (Smith and Stirling, 2007; Voß, Smith and Grin, 2009), maintaining the objective of developing instrumental models to steer ongoing change (Smith, Voss and Grin, 2010; Markard, Raven and Truffer, 2012). These ideas received great contributions, for example, from complex systems theory (e.g. Kauffman, 1995), innovation governance (e.g. Smith, Stirling and Berkhout, 2005), resource-based approaches of management (Teece, Pisano and Shuen, 2008; e.g. Penrose, 2013), and some streams of innovation studies – e.g., innovation systems (e.g. Freeman, 1995; Perez, 2012) and technological regimes (e.g. Nelson and Winter, 1982). Furthermore, the idea of distributed governance arises as the means of covering different societal actors, their distinct patterns of governance, and their resulting interplay of activities. This also leads to a better understanding of the conflicts inherent to sociotechnical change, the influence of politics of knowledge, and the different forms that power affects decision-making (S. Jasanoff, 2010; STRN, 2010).

3.6.2. How to change sociotechnical systems towards sustainability?

A major source of agreement within the literature consists of fostering the adoption of sustainable solutions to replace or reshape current sociotechnical systems to achieve environmentally, socially and economically desirable outcomes (Schot and Geels, 2008; Sushandoyo and Magnusson, 2014; Kivimaa and Kern, 2016). These concepts either focus on innovation or system change. The ones focussing on innovations or innovative agents

emphasise sustainable processes, products, services or business models, capable of replacing unsustainable alternatives. This includes, for example, concepts of eco-innovation (Hart, 2000; Kemp and Pearson, 2007; e.g. Esty and Winston, 2009; OECD, 2011), innovation for the bottom of the pyramid (Prahalad and Hart, 2002; Prahalad, 2004; e.g. Prahalad, Di Benedetto and Nakata, 2012), grassroots innovation (e.g. Seyfang and Smith, 2007; Gupta, 2016), and frugal or inclusive innovation (George, Mcgahan and Prabhu, 2012; Radjou, Prabhu and Ahuja, 2012; e.g. R. Basu, Banerjee and Sweeny, 2013).

Concepts focussing on wide-scale system change focus on the directionality, intensities, extents, and reasoning behind these changes. Since they are subjective and depend on multiple ontologies of "what the world is" and "what the world will likely be", as well as normative perceptions of "what the world should be" (Geels, 2010), many studies emphasise democratic and deliberative governance as important for promoting greater appreciation of plurality and human intentionality upon the multiple (and often contending) viable pathways for sociotechnical progress (Leach, Scoones and Stirling, 2007). Human-centred design (HCD, henceforth), for example, is presented as an alternative to assess this plurality. This differs from conventional approaches that heavily rely on the limited understanding of the organisations or individuals leading the change. This form of design uses "techniques which communicate, interact, empathize and stimulate the people involved, obtaining an understanding of their needs, desires and experiences" and "leads to products, systems and services which are physically, perceptually, cognitively and emotionally intuitive" (Giacomin, 2014, p. 610). It is particularly described as preferable to top-down design when addressing sustainability issues, allowing the design of products, services or systems with a focus on the users or beneficiaries (Giacomin, 2014).

Literature converges in the description of the importance of influencing selection pressures of sociotechnical regimes, as well as the coordination of resources to better adapt, react, or anticipate to such pressures. Selection pressures include political, social and economic developments, and pressures that "bubble up from below, from innovative niches that are not yet so established as to constitute a regime" (Smith, Stirling and Berkhout, 2005, p. 1495). The Multi-Level Perspective, for example, describes the importance of destabilising undesirable sociotechnical features, while building up momentum for niche-innovations (Geels, 2002; Geels and Schot, 2007; Smith, Voss and Grin, 2010).

It also seems consensual that the ability of influencing sociotechnical change towards sustainability is also diffused among a vast array of actors. Most concepts covering wide-scale changes, like Strategic Niche Management (Schot and Geels, 2008; Smith and Raven, 2012; Sushandoyo and Magnusson, 2014), Transition Management (Rotmans, Kemp and van Asselt,

2001; Loorbach, 2010; McDowall, 2012), or the Multi-level Perspective of Sustainability Transitions (Geels, 2002, 2010; Smith, Voss and Grin, 2010), argue that different agents can assume more dominant roles to influence, manage or govern transitions, including governments and policy-makers, companies, non-governmental organisations, and entrepreneurs. However, all of them also make explicit that deliberate intents of transitioning to more sustainable directions are not purviews of single actors. Instead, they are collective endeavours requiring a certain degree of coordinated action (Kemp, Schot and Hoogma, 1998; Geels, 2005).

A challenge and source of tension is, therefore, to bring these concepts to action, providing practical guidelines on the activities and roles that can be performed by different actors. Many strategies, instruments and tools have emerged to address these challenges. The literature on Sustainability Transitions, for example, indicates clusters of activities capable of unsettling regimes and translating sustainable alternatives from the fringe to the mainstream (STRN, 2010). Among these strategies and instruments are: backcasting (Dreborg, 1996; Holmberg and Robert, 2000) and scenario-building (De Jouvenel, 2000; Durance and Godet, 2010), as well as conceptual frameworks such as Constructive Technology Assessment (Rip and Schot, 1996), Transition Arena's (Loorbach, 2010), Complexity Governance (Teisman, van Buuren and Gerrits, 2010), and Strategic Niche Management (Kemp, Schot and Hoogma, 1998; Schot and Geels, 2008; Sushandoyo and Magnusson, 2014).

3.6.3. Breadth, scope and limitations of change drivers

The literature indicates the relevance of promoting deep, structural sociotechnical changes, since incremental changes will not suffice to tackle some of the most pressing societal challenges (Evans *et al.*, 2009; Markard, Raven and Truffer, 2012). Undesired characteristics of complex systems, however, are not easily changed. Systems present feedback loops (i.e., closed chains of causal connections that can act as sources of (in)stability, (dis)continuity and resistance to change), and are formed by the coevolution between technologies, industrial structures, policies, social behaviour, ecology, markets, civil society, and many other factors (Smith, Voss and Grin, 2010). Furthermore, complex systems are also characterized by self-organization – i.e., the ability to diversify, working more coherently, becoming more complex over time, and more resilient towards radical changes (Arthur, 1989; Farla *et al.*, 2012).

As a response to these challenges, scholars have discussed different opportunities to steer change in sociotechnical systems. As summarised in Table 8, the literature review has identified a variety of change drivers, i.e., forms of purposefully changing a sociotechnical system towards individual or societal goals (e.g., profit of companies, societal welfare, environmental resilience). Notable change drivers were selected to illustrate different forms of driving

sociotechnical system change. The selection aimed at diversifying the following key characteristics: heuristics (i.e., how to solve problems), speed (i.e., timeframe of impact), resources (i.e., tangible and intangible resources employed), agency (i.e., who is responsible or accountable for changing systems) and ownership (i.e., who owns and directly benefits from the outcomes).

Table 8: Selection of change drivers of sociotechnical systems

	Change Drivers	Definition	Key characteristics	Key references
1	**System transition/ innovation**	Wide-scale transformations in how society functions	Heuristics: coordinated change, often through adaptive governance	(Smith et al. 2005; Shove & Walker 2010; Geels & Schot 2007; Markard et al. 2012)
			Speed: long-term	
			Resources: multiple stakeholders and employing vast tangible and intangible resources	
			Agency: distributed among multiple stakeholders, with a particular emphasis on policymakers	
			Ownership: no one owns outcomes. Focus lies on shifting directionality of progress towards meeting societal expectations	
2	**Invention**	A novelty introduced to the world	Heuristics: tackling existing problems – or emulating new needs – by creating unprecedented solutions	(Arrow 1972; Jewkes et al. 1969; Schmookler 1966)
			Speed: both creating and registering inventions is lengthy	
			Resources: often requires sophisticated resources, but not necessarily	
			Agency: anyone, i.e., organisations or individuals who can invent and register intellectual property	
			Ownership: the ones who register intellectual property rights	
3	**Innovation**	The process of generating and diffusing a new process, product, service or business model	Heuristics: generation, adaptation, imitation, absorption and commercialization of novelties. Change happens, consequently, through the marketplace.	(Schumpeter 1997; Abernathy & Utterback 1978; Freeman & Soete 2000)
			Speed: varies, especially according to sectors and technological intensity, but aims at being as fast as possible to gain/maintain competitive advantage	
			Resources: often requires sophisticated resources (e.g., R&D), but not necessarily.	
			Agency: Agency lies mostly on companies, since they are the ones commercializing, but several other agents influence the propensity of a company, sector or region of innovating	
			Ownership: companies own outcomes and profit from them	
4	**Disruptive innovation/ technology**	Market-based solutions, initially catering low-end or non-consumers, potentially allowing the disruptive company to move upward the market and displace incumbents	Heuristics: similar to 3, but with a focus on initially solving problems of underserved markets before reaching more sophisticated segments	(Christensen et al. 2015; Christensen 2013; Markides 2006; Bower & Christensen 1995)
			Speed: aims at being as fast as possible to gain competitive advantage and displace incumbents	
			Resources: in initial stages, sophisticated resources are not needed, but they tend to be required when moving upward the market	
			Agency: same as 3	
			Ownership: same as 3	

5	**Frugal innovation/ technology**	Good-enough and affordable products or services, meeting the needs of resource-constrained consumers	Heuristics: similar to 3, but focused on solutions to resource-constrained consumers	(Basu et al. 2013; Bhatti 2012; Zeschky et al. 2011)
			Speed: tends to be quicker than other innovations, since solutions tend to be as simple as possible	
			Resources: simple, cheap, and, preferably, widely accessible resources	
			Agency: same as 3	
			Ownership: same as 3, but with a particular emphasis on the benefits for the poor, who get access to products adapted for them	
6	**Grassroots innovation/ technology**	Innovative products created by who lacks formal education and is disenfranchised from formal support systems	Heuristics: similar to 3, but focused on solutions from and for the poor, often through informal commercial relationships	(Gupta 2016; Seyfang & Smith 2007; Smith et al. 2014)
			Speed: same as 5	
			Resources: same as 5	
			Agency: same as 3	
			Ownership: same as 3, but with a particular emphasis on the benefits for the marginalised innovator	
7	**Bricolage/ DIY/Maker culture**	Making do with the means and resources available at hand	Heuristics: improvisation and tinkering to address local problems	(Ciborra 2004; Baker et al. 2003; Brass et al. 1997; Dreborg 1996)
			Speed: relatively fast, since solutions can be sub-optimal	
			Resources: the ones widely available and relatively cheap	
			Agency: DIY and Maker Culture have a especial focus on civil society or entrepreneurs, whereas Bricolage focuses on companies	
			Ownership: the ones leading the change, but there is no formal restriction for replicability	
8	**Jugaad**	Overcoming constraints by improvising new products and technologies with limited resources	Heuristics: commercialising an improvised solution that overcome tangible and intangible constraints	(Radjou et al. 2012; Prabhu & Jain 2015; Birtchnell 2011)
			Speed: same as 4	
			Resources: same as 4	
			Agency: has a especial focus on small-scale entrepreneurship	
			Ownership: the ones selling locally-adapted and cheap solutions	
9	**System design**	Process of purposefully conceiving and planning what system changes are desired and how they can be pursued	Heuristics: causing discontinuity in what is mainstream in systems, by conceiving and planning how to make things to serve a goal	(Manzini 2015; Blizzard & Klotz 2012; Dorst 2011; Ceschin & Gaziulusoy 2016)
			Speed: since the concept is very open-ended, speed varies according to the goal. It does not have immediate results, but are faster than transitions	
			Resources: depends on the goal, but tends to focus on resourceful and creative solutions, and engagement of multiple stakeholders	
			Agency: a especial focus on influential agents, such as large organisations and policymakers	
			Ownership: society at large, but distribution of benefits can be unequal	

These change drivers range from wide-scale transformations of sociotechnical systems to the micro-level analysis of innovative agents or specific innovations. The former sheds light on enablers (and constrains) within the regime, directionality and causality of positive change, diffused agency, and the unbounded nature of sociotechnical change (Nelson and Winter, 1982; Geels and Schot, 2007). Some prominent concepts include, for example, 'system transitions' and 'system innovation'. The focus of both lies on how to steer societal functions – such as transportation, communication, housing, and feeding – towards more desired directions (Smith, Stirling and Berkhout, 2005; Jørgensen, 2012). The main difference between them is that 'system innovation' focuses on the emergence, diffusion and replacement of technologies, whereas 'transitions' reflects interactions of emerging niches, regimes, and exogenous features influencing technical change (Markard, Raven and Truffer, 2012).

Yet, these approaches often fail to provide practical guidance on how to change systems, and on how to move away from the statement that everything is coevolving (Malerba, 2006). As goals for system change are essentially open-ended (Rip, 2006; Stirling, 2014), recommendations mostly lie on long-term governance, in which goals are "negotiated and defined through the interaction of different parties in spaces for societal learning" (Wittmayer and Schäpke, 2014, p. 486). Recommendations mostly consist of rather vague prescriptive statements, such as the importance of incorporating diversity, assessing expectations, or fostering coordinated action. While these statements might be arguably correct, they do not provide practical guidance on how to effectively act upon components, interdependencies and connections of systems.

Micro-level approaches, alternatively, often emphasise the generation and diffusion of products, processes, services or business models, capable of replacing the incumbent alternatives in the marketplace and, hence, influencing sociotechnical system change. An 'innovation', in comparison to an invention, does not need to be new to the world, but it involves commercialization (Schumpeter, 1997). It refers to the entire process ranging from the generation of ideas to the diffusion of products, services, processes and business models (e.g. Abernathy and Utterback, 1978; Poole and Van de Ven, 1989; Freeman and Soete, 2000). That includes, for example, absorption, imitation, and deployment of technologies (Abramovitz, 1986; Cohen and Levinthal, 1990), as well as the process of learning and enhancing dynamic capabilities (Teece, Pisano and Shuen, 2008). While inventors can be individuals or different kinds of organizations, innovators are companies, since commercialization is a central feature of innovative endeavours (Coriat and Weinstein, 2002).

Since innovations are at the core of micro-level approaches, many concepts emerged to qualify them, focusing on how the processes occurred, their impact, the resources used, who

generated, and who benefited from them. ‘Disruptive’ is an example of a concept qualifying an innovation process. As defined by Bower and Christensen (1995), the term refers to the process of displacing incumbent companies by initially targeting low-end or non-consumers and progressively moving upward in the market through the development of more sophisticated solutions. Its rationale is based on dynamic thinking of competitive behaviour. The term ‘disruption’ has also been widely used by academics and practitioners with an alternative connotation: the one of system reconfiguration, similar to the idea of ‘radical innovation’, ‘breakthroughs’ or ‘technological revolution’ (Perez, 2002), whose focus lies on the impact of the innovation instead of the process of moving upward in the market.

‘Frugal innovation’ is an example focused on the intended beneficiaries of an innovation. It is a resourceful process aimed at developing affordable, appropriate, adaptable, and accessible services and products, usually targeting the bottom of the pyramid in emerging markets (R. Basu, Banerjee and Sweeny, 2013). The focus here is, therefore, to develop good-enough solutions meeting the needs of resource-constrained consumers. In contrast to ‘frugal’, ‘grassroots innovation’ emphasises solutions created by the marginalised (Seyfang and Smith, 2007; Gupta, 2016). The bottom of the pyramid is, therefore, not portrayed exclusively as underserved consumers, they are the ones generating innovations by experimenting and deploying resources available at hand, in order to tackle individual or community problems. Similarly, the concept of ‘jugaad’ – i.e. a colloquial Hindi word that has been extensively applied as a managerial technique – has been broadly defined as a resourceful and improvised approach to overcome constraints (Radjou, Prabhu and Ahuja, 2012). Jugaad refers specifically to flexible and inclusive approaches to innovation and entrepreneurship, which emerged out of India, but which is particularly advantageous to analyse innovative behaviour in emerging economies.

There are other concepts in which change agents also occupy a central role, but whose focus does not lie on innovations. Operations research has described micro-level change drivers, based on an understanding of how companies cope with ‘systems of problems’ (Ackoff, 1974). ‘Bricolage’ is an example: it is a construct initially developed in anthropology (Lévi-Strauss, 1962) which has been extensively used in managerial literatures – such as, operations studies (e.g. Ciborra, 2004), organizational competences (e.g. Baker, Miner and Eesley, 2003) and technological entrepreneurship (e.g. Garud and Karnøe, 2003). It is often referred to as making do with the means and resources available at hand. It is also used as reference to systematic, although not necessarily formalized, processes of improvising and experimenting to solve problems by drawing on procedural (know-how) and declarative (know what) organizational memory (Moorman and Miner, 1998).

Other concepts share similarities to bricolage, but are not necessarily connected to for-profit entrepreneurship. That is the case of the 'maker culture' and the 'do-it-yourself' (DIY) ethic (Brass, Searle and Poklewski Koziell, 1997). These encompass both the creation of new devices and the tinkering with existing ones. They are often used as an anti-consumerism ethos, promoting the idea that anyone is capable of performing tasks autonomously, instead of constantly purchasing or hiring specialists. The focus lies on using and learning practical skills and design techniques, which are often available through open-source mechanisms.

Despite their immense contributions, approaches focused on change agents often fail to recognise the existence of a wide array of possibilities to change systems, in especially the ones that do not necessarily involve commercialization. This is due to the fact that innovations are at the core of most approaches and they inevitably revolve around the commercialization of products or services, with companies occupying a protagonist role. Concepts that are not necessarily revolving around commercialization, such as bricolage, tend to be very specific in scope – i.e., the heuristics of improvising and are mostly referring exclusively to physical materials or organisational processes.

Furthermore, connecting micro-level and wide-scale analytical lenses seem to be a bottleneck in the literature on sociotechnical system change. System design often combines both lenses to introduce different forms of thinking and problem-solving strategies capable of causing discontinuities to what is mainstream within systems. To design, as described by Simon (1996, p. 111), is "to devise courses of action aimed at changing existing situations into preferred ones". Manzini (2015) adds that design is a process, which involves purposefully conceiving and planning how to make things to serve a goal, including how to act on the physical world, address human needs, and generate the built environment. However, system design is mostly focused on the following levels: product; product-service; spatial-social; and sociotechnical (Ceschin and Gaziulusoy, 2016). As a result, it also orbits either around innovations and their cascading impacts on system change, or on coordinated governance for system design. In other words, they keep the same analytical lenses and, hence, the same shortcomings of other established approaches.

3.7. The Core Foundations of Theories on Sociotechnical System Change

This section discusses the dominant ontological and normative foundations of theories on sociotechnical systems change for sustainability.

Fifteen foundations were identified, which are summarized in Table 9. Among them, two describe the underlying motivations that are justifying the research questions and the selection

of variables that scholars have been investigating (i.e., the *Why*?), which are essentially normative; six describing factors widely considered as part of the explanation of the phenomena (i.e., the *What*?); and seven that describe connections, causality patterns, and possibilities of steering sociotechnical progress towards sustainable outcomes (i.e. the *How*?). Together, these three dimensions constitute the foundations of sociotechnical system change for sustainability. It is important to stress that foundations are essentially intertwined; refuting one of them might lead to changes in others.

Table 9: The foundations of sociotechnical system change for sustainability

Category	What does it include?
Why?	Sustainability should have flexibility in its interpretation to justify different interests and adapt to different contexts
	Democratic accountability is critical to assess expectations and deliberate over the multiple understandings and aspirations for progress
What?	There are multiple interpretations of what is to be sustained and what is to be developed. There are multiple goals and pathways for development, but only a subset will be fully pursued. Knowledge is also socially constructed and politics of power influence why some systems or certain sustainability goals tend to be prioritised
	When the unit of analysis lies on sociotechnical systems, the analysis involves a wide range of actors, and no agent has full accountability nor ownership of sociotechnical systems
	Sociotechnical systems are composed by a variety of co-evolving components, functions and interconnections, and are characterised by feedback loops, self-organisation, and hierarchies
	Boundaries are arbitrary for analysis
	Institutions shape solutions that will be prioritised, the strategies of a vast array of actors, and the heuristics of problem-solving
	System change happens through a combination of variation, selection, and retention. Analysis revolves around the generation and diffusion of innovations capable of replacing predominant and unsustainable alternatives
How?	Diversity and plurality are critical, both to open up and to close down appraisal over multiple alternatives
	Incremental changes will not suffice. Wide-scale changes of sociotechnical systems should be at the core of sustainability ambitions
	Long-term governance, with stakeholder engagement, is the standard approach to deal with wide-scale system-level changes
	Governance or management has dimensions that can be controlled (e.g. internal aspects of management or governance), others that can only be influenced (e.g. knowledge base), and exogenous features they react upon (e.g. demography)
	Although boundaries of systems are analytically flexible, agency tends to follow conventional boundaries
	Cooperation is critical, but priorities are defined by each agent
	Mostly seeking win-win situations for the economy, environment, and society

A foundation in the literature is the interpretive flexibility of sustainability discourses. This is connected to the diversity of interpretations of both the terms ‘sustainable’ and ‘development’. However, only a small subset of options is assumed to be currently investigated and decision-making seems to be shaped by power relations. Knowledge is also seen as socially constructed, thus affecting the prioritisations of certain systems and goals over other alternatives. These foundations are connected to the observation that development goals and steering mechanisms of sociotechnical systems are socially negotiated through plural appraisals and deliberations and that action is coordinated among a vast array of agents continuously adapting to changes in their respective contexts.

Another underlying motivation consists of the investigation of wide-scale changes of sociotechnical systems towards more sustainable outcomes. Sustainable innovations alone may influence sociotechnical systems and cooperation seems to be critical for realising opportunities and improving results. Nevertheless, each agent may have different priorities and the analytical foci often lie too narrowly on their efforts in promoting win-win situations for themselves and for their stakeholders.

Their impacts are therefore uncertain, may be socially exclusory, and entail unintended consequences. Many studies discuss the importance of using sociotechnical systems as a unit of analysis, rather than single solutions or actors. This meso-level oriented analytical lens allows the examination of a wide range of components and connections of the system, including several actors integrated in webs of sociotechnical change. In this picture, several agents influence sociotechnical systems, but none are fully responsible, nor accountable for the desired change. This may justify why most studies set long-term governance objectives, through the coordination of multiple stakeholders, as the standard approach to deal with wide-scale system-level change.

When deepening the analysis of systems, it is revealed that sociotechnical systems are composed by a variety of co-evolving components, functions, and interconnections. These systems are characterised by feedback loops, hierarchies, and self-organising patterns. These characteristics attribute complexity both to the investigation and the potential steering efforts of sociotechnical systems. They present embedded characteristics and lock-ins into certain technological trajectories, but their components, functions and interconnections may be unpredictable.

As a result, actors who try to manage or govern sociotechnical system change may simultaneously face internal levers (e.g. aspects of a company or a public body upon which they have agency); leverage points to influence or nudge (Thaler and Sunstein, 2009) systemic change (e.g. knowledge base, political framings, social behaviour, and industrial structures);

and exogenous aspects that restrain their scope for action and upon which they can only react (e.g. environmental or demographic shocks).

The other implication of setting meso-oriented analytical lenses is that systems are arbitrarily bounded when analysed, in order to fully examine characteristics and evaluate possibilities of steering ongoing changes. They are often framed according to goals, interests and viabilities to appraise and act upon. However, the scope for action of some agents often lie within pre-established ones. Taking a federal government as example: agency lies on the national borders. Similarly, a company has its agency limited by a conventional boundary, since it is an organizational entity, legally defined by ownership and composed by an interconnected pool of resources.

Furthermore, system change happens through a combination of variation, selection and retention. Although most studies focus on variation, it seems clear that evolutionary dynamics of sociotechnical change derive from the interplay of these three features. The characteristics and components of sociotechnical systems shape solutions that have higher potential of succeeding, the strategies of each agent, and the heuristics to solve problems and adapt to ongoing change.

3.8. Shortcomings and Opportunities for Contribution

The previous section scrutinized the dominant foundations guiding theoretical development in the field to date. By deconstructing theory to pinpoint its foundations, it becomes possible to take more informed decisions on how to contribute to further theoretical development.

Contributing with a new normativity can change the motivations of research in the field, while an ontology, without necessarily challenging the motivations underlying their investigation, offers new lenses for interpreting phenomena. A new ontology is more academically defensible than a new normativity, since the latter is essentially argumentative, resonating more with values, interests and institutional commitments of a wide range of scholars. For example, when Hardin (1968, p. 1247) implied that "social injustice is preferable to environmental ruin", he was raising a new normativity, based on his widely diffused ontology of the 'tragedy of the commons'. If his normativity, instead of the renowned triple bottom line (Elkington, 1999), had become widely diffused and accepted by scholars, theory would have had developed very differently in Sustainability studies.

Based on reflections upon the 15 foundations revealed in this Chapter, this section introduces and illustrates 3 possibilities for future contributions. These include: 1) how to fill existing gaps without questioning the foundations; 2) how to rebut the foundations by

questioning their validity; and 3) how to build theory by creating new foundations that can either substitute or complement currently existing foundations.

3.8.1. Gap filling

Opportunities for gap filling mostly derive from questions on contextual influences (i.e. *Where*, *Who* and *When*). They tend to be ontological contributions, incrementally adding to the existing theoretical understandings and without challenging the existing theoretical foundations.

For example, one of the foundations described in Section 3.7 is the existence of 'multiple interpretations of what is to be sustained and what is to be developed'. There are several potential questions that can arise for *Where, Who* and *When*, such as the ones below:

- *Who*: how different are the interpretations of businesspeople and policymakers?
- *Where*: how do these interpretations differ across low, middle, and high-income countries?
- *When*: are these interpretations changing since the publication of the Brundtland (1987) report?

These kinds of questions aim at better qualifying the circumstances, contingencies, and contexts in which the theoretical foundations are manifested, hence contributing to filling gaps within theory.

3.8.2. Refuting existing foundations

It is possible to refute the foundations listed in Section 3.7, as exemplified in Boxes 2, 3 and 4. This process is essentially deductive, raising hypothesis on the validity of an ontology or the desirability of a normativity. Since *Why* foundations are more argumentative, there is scope both for normative and ontological rebuttals, whereas *What* and *How* are likely ontological.

Box 2

Why foundation: 'sustainability should have flexibility in its interpretation, justifying different interests and adapting to different contexts'

Examples of Rebuttals: is interpretive flexibility desirable? Should we prioritise specific goals, such as eradicating hunger, instead of open-ended goals? Are academics converging towards similar understandings, independently of contexts? Are academics progressively interpreting sustainability exclusively as environmental performance?

Box 3

What foundation: 'when the unit of analysis lies on sociotechnical systems, the analysis involves a wide range of actors, and no agent has full accountability nor ownership of sociotechnical systems'

Examples of Rebuttals: are some agents entitled to having full accountability and ownership of sociotechnical systems? Are multiple agents, in fact, involved in sociotechnical systems change, or is change mostly led by a single one?

Box 4

How foundation: 'mostly seeking win-win situations for the economy, environment, and society'.

Example of Rebuttals: are the solutions really a win-win in all three dimensions, or is that just an encouraging, pacifist discourse that has become institutionalised? What are the trade-offs that have been largely ignored under such false pretences?

3.8.3. Creating new foundations

New foundations can either substitute, or complement the ones listed on Section 3.7. As discussed by Whetten (1989), potentially radical contributions often arise from novel interpretations of *Why*, *What* and *How*, reframing interests, goals, motivations, or the analytical principles and lenses used to investigate empirical phenomena.

As exemplified in Boxes 5 and 6, new contributions can arise when analysing the implications and resulting complications of existing foundations; hence leading to the proposal of alternative research avenues.

Box 5

Existing foundation: 'analysis revolves around the generation and diffusion of innovations capable of replacing predominant and unsustainable alternatives'
Implication: analytical focus lies on the generation and diffusion of products, processes, services or business models, which are capable of replacing the predominant unsustainable alternatives in the marketplace.
Complication: as innovations inevitably revolve around commercialization, roles of a diverse set of interconnected agents (e.g. companies, governments, and individuals) are investigated accordingly. As a consequence, analysis of sociotechnical system change tends to be market-centred.
Alternative investigation: what steps can individuals and organizations take at the micro-level that may not materialize through the marketplace, but which may be capable of changing sociotechnical systems?

Box 6

Existing foundation: 'long-term governance, with stakeholder engagement, is the standard approach to deal with wide-scale system-level changes'.
Implication: a wide range of possibilities needs to be assessed, various agents coordinated, and multiple actions planned and adapted to changing contexts.
Complication: the speed and scope for tackling complex sociotechnical problems are limited by agency failures, resulting from the coordination of multiple agents for deliberation.
Alternative investigation: what purposeful actions conducted by self-entitled agents can be pursued to leverage wide-scale system change 'here and now'?

Furthermore, the process of creating new foundations often involves overlapping the existing ones to novel empirical insights. For example, Bitcoin bypasses sovereignty and traditional boundaries of governance. It is not an innovative product, service or business model

generated and diffused by companies; its social, environmental and economic outcomes are contested; and it is derived from a purposeful (and anonymous) action happening 'here and now' which may deeply change sociotechnical systems. It strays deeply from some foundations presented in this work. Hence, by analysing this phenomenon in contrast to the dominant foundations, novel and potentially disruptive contributions can arise, complementing or even substituting the existing ones.

3.9. The Opportunities Pursued by this Research

After the systematic examination of the literature, this research has purposely focused on deviating from the foundations listed in Boxes 5 and 6 of the Section 3.8.3. Previous sections of this Chapter have indicated that literature on sociotechnical system change is rather focused on market-based solutions or on change drivers based on the coordination of multiple agents and expectations. It shies away from questions such as: 'how can an individual take agency of deep sociotechnical changes?', 'how can systems be transformed, here and now?' and 'how can agents circumvent traditional heuristics for systemic change?'

By asking these questions, I had the idea of examining the literature on 'Hacks' in complex computational systems as potential sources of inspiration. While the term 'Hack' originally referred to a heavy blow to make furniture with an axe (Raymond, 1996), its connotations have expanded considerably in the last decades to describe decentralized and self-entitled forms of bypassing traditional heuristics and agency expectations for systemic change. As described by Levy (2010, p. 3), Hackers have no need "to justify the impulse, when confronted with a closed door with an unbearably intriguing noise behind it, to open the door uninvited. And then, if there was no one to physically bar access to whatever was making that intriguing noise, to touch the machine, start flicking switches and noting responses, and eventually loosen a screw, unhook a template, jiggle some diodes, and tweak a few connections".

When reviewing published documents on Hacking, I observed that most uses of the term in the academic arena are related to cybersecurity, information forensics, and risk management. The term was also sparsely used in other scientific areas – such as biohacking, referring to intrusive approaches towards biological systems (e.g. Banks, Pim and Thomas, 2003); and feminist hackerspaces, stimulating a culture of collaborative workspaces to support women's creative pursuits (e.g. Fox, Ulgado and Rosner, 2015). Seemingly, the word has gained much more traction in colloquial arenas than in academic research.

A search in these arenas, such as blogs and online forums, revealed that people who break into, subvert the functions, or circumvent the rules of systems are often called Hackers,

independently if the system is computational or not. For example, Paul Buchheit, a renowned computer programmer (creator and lead developer of Gmail), entrepreneur (founder of FriendFeed) and angel investor (partner at Y Combinator), described in a blog post[15] that: "Hacking is most commonly associated with computers, and people who break into or otherwise subvert computer systems are often called Hackers. Although this terminology is occasionally disputed, I think it is essentially correct - these Hackers are discovering the actual rules of the computer systems (e.g., buffer overflows), and using them to circumvent the intended rules of the system (typically access controls) … Hacking is not limited to computers though. Wherever there are systems, there is the potential for Hacking, and there are systems everywhere."

Hacking does not have to be, therefore, limited to computers: it can be applied to other kinds of systems and to pursue a wide array of goals. However, the word 'Hack' lacks conceptual clarity. In particular, little is known about its potential of changing complex systems and its connection to sociotechnical system change has not yet been explored.

Therefore, the intent of pursuing alternative research avenues, following the systematic literature review, has led to the empirical investigation of the meanings and potential applications of Hacking as a change driver of sociotechnical systems, which is scrutinised in the following Chapter.

3.10. Summary and Final Remarks of the Chapter

- What was found and how?

This chapter has exposed and discussed 15 foundations that shape how we understand sociotechnical system change for sustainability. These foundations influence both what system change is perceived as desirable and as attainable; as well as how to navigate between all the coexisting pathways, trade-offs, and complexities of the three dimensions of sustainability. By identifying the theoretical foundations, I illustrate the most up-to-date theoretical developments and concomitantly pinpoint a few opportunities for future contributions that improve, refute or complement them.

This was conducted through a systematic literature review of 208 documents, following a methodological process scrutinised in Chapter 2. This approach was selected due to its ability of being comprehensive, while simultaneously avoiding vested bias in the selection of the sample of documents. The criteria for sampling were made explicit, providing an audit trail,

[15] https://paulbuchheit.blogspot.co.uk/2009/10/applied-philosophy-aka-Hacking.html

and analysis was diligently conducted by coding text. This systematic review has provided the compilation, grouping and summarization of data according to dominant ontological and normative characteristics. This has then resulted in the condensed description of the most relevant foundations of the field of research, followed by the reflection on potential avenues for future contributions.

- What next?

Chapter 4 consists of the conceptual development of the idea introduced in the end of this chapter, borrowed from complex computational systems, i.e. Hacking. It explores the term by empirically investigating its meanings and potential applications as a driver of sociotechnical system change. Data was gathered through exploratory interviews with 12 self-declared Hackers and cybersecurity experts. Based on the main connotations and dominant characteristics of System Hacking, potential theoretical contributions and implications of System Hacking are explored further, including the one of addressing socio-environmental problems. The Chapter ends with a Triage Checklist for Sustainability Hacking, which is then used as a starting point to investigate situations where this change driver has been motivated by Sustainability ambitions.

4. What the Heck is Hacking?

"On a wall of a bar in Madrid, there is a sign that says: 'No singing'. On a wall of the airport of Rio de Janeiro, there is a sign that says: 'No playing with luggage carts'. Ergo: there are still people who sing, there are still people who play".
(Eduardo Galeano, Las Palavras Andantes, p.61)[16]

4.1. Introduction to the Chapter

Industrialists and policymakers alike put great effort both on the generation and diffusion of innovations and on long-term, coordinated governance, involving multiple agents and expectations. The speed and scope for tackling complex sociotechnical problems are, nonetheless, limited by agency failures, resulting from the need of coordinating multiple agents for deliberation. As a result, initiatives are designed and planned with care, but are often either sluggishly operationalised or are not brought to fruition (Savaget *et al.*, 2019). Likewise, academic concepts on change drivers – such as innovation (e.g. Freeman and Soete, 2000), bricolage (e.g. Ciborra, 2004) and disruption (e.g. Christensen, 2013) – are either focused exclusively on market-centred changes, or fail to address situations where information is limited, resources are scarce, stakes are high, and decision-making is urgent.

These observations have arisen from the intentional process of reviewing the literature on sociotechnical system change for sustainability, scrutinised in the previous Chapter. After revealing the ontological and normative foundations guiding theoretical development in the field, the following questions were raised: 'how can an individual take agency of deep sociotechnical changes?'; 'how can systems be transformed, here and now?' and 'how can agents circumvent traditional heuristics for systemic change?'.

These questions have led to the idea of examining literature on 'Hacks' in complex computational systems as potential sources of inspiration. The term has gained traction, especially in colloquial arenas, to describe system change that includes, but is not limited to computational systems. However, the definition of this term lacks clarity and its potential applications to understand sociotechnical system change has not yet been explored.

[16] My translation, from Spanish to English.

This Chapter focuses on portraying the results of the second research stage. The overarching questions here are "what is the definition of 'Hacking'?" and "what are its dominant characteristics?". These were answered through the analysis of qualitative data collected through the exploratory interviews with 12 self-declared Hackers and cybersecurity experts, following the methods thoroughly detailed in Chapter 2.

4.2. Structure of the Chapter

The inductive methods employed for collecting, processing and analysing data have been detailed in Chapter 2. This chapter focuses solely on presenting and discussing the results arising from the interviews with 12 self-declared Hackers and cybersecurity experts. Section 4.3 outlines the connotations of the term 'Hacking', and derives the definitions of 'Material Hacking' and 'System Hacking', then describing the reasons why this research focuses on the latter. Section 4.4 describes the 9 dominant characteristics of System Hacking, and Section 4.5 contrasts this concept with a selection of change drivers reviewed in Chapter 3. Section 4.6 discusses the implications of the findings for literature on sociotechnical system change for sustainability. Section 4.7 justifies the focus of the following steps of this research on System Hacking addressing pressing socio-environmental challenges (i.e. 'Sustainability Hacking'), also introducing the starting point used for data collection (i.e. the 'Triage Checklist for Sustainability Hacking'). Finally, Section 4.8 concludes this Chapter, by summarizing its main findings and briefly introducing the next steps of this research.

4.3. Definitions of Hacking[17]

The analysis indicates that the term 'Hacking' has been notably appropriated by creative computer programmers, who tend to eschew mainstream values and working habits and embrace instead a culture of "*tearing apart anything of a status quo*" (X11). Its use spilled-over from computer systems to other domains and it has been used mostly in colloquial, non-academic arenas, referring to different forms of employing "*skill and ingenuity to achieve a result which has a certain aesthetic appeal in terms of surprisingness*" (X1). This includes, as illustrated by X2 and X11, "*lifehacks*" (i.e., shortcuts, methods, or tricks to increase productivity), "*political hacks*" (i.e., party-political machinations), or a "*creative prank*".

[17] Earlier drafts of Sections 4.3 – 4.6 counted with the valuable comments from Ali Kharrazi and Frank Tietze, besides from my supervisor Steve Evans.

Despite its diverse connotations, the interviews revealed that 'Hacking' tends to convey the idea of "*circumventing limitations*" (X6); "*circumventing rather than directly approaching problems*" (X12); and exploiting vulnerabilities, "*legal ambiguities or loopholes*" (X8). The term 'Hack' has also taken pejorative connotations, referring to nefariously breaking laws, compromising cybersecurity, and or unethical behaviour. This includes, for example, 'black-hat Hackers' or 'Crackers' (i.e., coders violating computer security with malicious intents), and 'Hack-writers' (i.e., someone churning out words to produce low-quality, rushed articles). However, the interviewees would often discern that "*Crackers have a criminal motive while Hackers do not*" (X4) and express frustration at the media portrayal of Hackers as criminals. Thus, while Crackers may have dishonourable motives, similar to Hackers, "*they are finding ingenious ways of bypassing limitations*" (X2).

Through the interviews I also derived the existence of 2 forms of Hacks, hereby called 'Material' and 'System' Hacking. To borrow the evolutionary language (e.g., Freeman, 1991) described in Chapter 3, while Material Hacking refers to a specific kind of technological 'variation' capable of influencing sociotechnical system change, System Hacking is about working around 'selective pressures' constraining the delivery of desired functions. They have been defined as follows:

- ✓ *Material Hacking: to repurpose a physical material*

'Repurposing' here means to change products or technologies to perform functions different from the originally intended ones. That requires "*lateral thinking*" (X2), by "*identifying, addressing and solving a problem using skill, ingenuity and usually limited resources*" (X1). It is creative problem-solving through practical, simplified, and unexpected solutions tackling what computational language books refer to as "*accidental complexity*" (X3). This includes improvising technology to deliver new value, e.g., "*boiling an egg in a coffee machine*" (X3), or creating value by combining distinct technological functions, e.g., "*solar-powered roof tiles*" (X2). In this context, every material is potentially 'hackable', so long as they deliver unexpected functions. As described by X11: "*one can Hack almost anything*".

- ✓ *System Hacking: to pursue an unconventional solution to a systemic problem*

'Unconventional' here means deviating from formal and informal institutions, i.e., the "rules of the game in a society" (North, 1990). Systemic problems are complex and deeply-rooted and the rules of the game often limit the scope of potential responses. As described by X2, despite having "*lots of complex issues to deal with, our evolved responses are still quite primal*", mostly lying on acting against perceived systemic causes of problems. For example,

the mainstream response to an impeding law would be its removal. Likewise, if lack of infrastructure is a bottleneck of an underdeveloped healthcare system, the conventional response would be to invest in infrastructure. Unconventional solutions are, instead, rather pragmatic actions diverging from the rules of the game to deliver good-enough functions. In other words, while system Hackers are not aiming at changing the rules of the game, they are not coping with them either: they are simply ignoring, bypassing, or transgressing them to pursue alternative routes.

The latter, i.e., System Hacking, has greater potential of configuring a novel contribution, while also being capable of shedding light on phenomena that have been largely ignored by academia and contributing to theories on institutional and sociotechnical system change. Material Hacking, on the other hand, shares more similarities with existing theories on grassroots, frugal or jugaad innovation, and bricolage, which were described in Chapter 3. For that reason, in this research I opted to dig deeper only on System Hacking, exposing its dominant characteristics, as presented in the following section.

4.4. The Dominant Characteristics of System Hacking

The content analysis of the 12 interviews, following the process described in 2.7.2, revealed 9 dominant characteristics of System Hacking. These are summarized in Table 10 and subsequently explained, by deploying a detailed textual narrative for each characteristic. They are also illustrated through a sequence of figures[18] employing the metaphor of 'aliens' as Hackers and the 'abduction of humans' as their desired goals, in order to represent these characteristics and their connections within a visual storyline.

Table 10: Characteristics of System Hacking

	Characteristics	***Description***
1	External	does not have ownership nor accountability of the system
2	Practicality	pursues good-enough outcomes
3	Resourcefulness	manipulates resources available at hand, often repurposing their use
4	Urgency	seeks immediate outcomes

[18] Contribution of the drawing artist Paulo Marcelo Óz, who I hired to help with these illustrations.

5	Self-entitlement	neither asks for permission, nor has to have permission granted by an authority
6	In Beta	involves experimentation, exploration, tinkering, learn-by-doing and often certain degree of playfulness
7	Democratized Agency	in principle, everyone can hack, although it involves certain personal characteristics, such as ingeniousness and curiosity
8	Arbitrary Boundaries	are not necessarily restricted by jurisdictions or other conventional boundaries
9	Distributed Ownership	outcomes are openly available and can be redistributed or modified

- External

Hacks are system interventions carried out by external agents. Being external does not mean they are formally or informally barred from active participation: it means, instead, that they are disenfranchised, often invisible and at the fringe of the system. Hacking is thus a form of democratizing access to system change. Since they are not believed to be the ones responsible for managing a system, they are not expected to take action. Therefore, Hacks may evoke an impression of surprise.

Hackers feel empowered for taking agency beyond what is socially expected from them. X2 describes that a Hacker, when confronted by others, will likely claim: "*to be honest, I was only looking for stuff*". That reflects their belief in more decentralized power structures, as resulting from their mistrust in authority, in traditional heuristics, conventional boundaries, and deep-rooted privileges. Accordingly, as highlighted by X4, the Hacker ethics is that "*all information should be free, authority mistrusted, decentralisation promoted…and Hackers should be judged by Hacking, not bogus criteria such as degrees, age, race, sex or position*".

Besides, by acting as an outsider, they can contribute with unprecedented and unconventional forms of addressing a problem (see Figure 11). As described by X11, Hacks "*do not come from people that have been faced with the problem every day because they are sort of numb to it*". X5 adds that "*there are complex and entrenched [system] problems, whose responses need a new look, a new conception, and that is why people who are outside the system can bring different ideas and approaches*". As a consequence, they are more likely to adopt a posture of "*disregard for limitations*" (X6) to find alternative solutions.

Figure 11: External

- Practicality

Rick Hickey, creator of Clojure, a programming language, highlighted a deep-rooted belief of the Hacking culture: "*overcoming complexity is not work, it is waste*"[19]. Instead of attempting at removing, minimizing or managing complexity, Hackers weave through inherently complex systems. They then adopt an adaptable, agile and rather practical approach towards system change, going against the rules of the game in the pursuit of a good-enough outcome which may not be optimal. In other words, robust and comprehensive solutions require a high level of time-consuming coordination of people and resources; an approach that Hackers may consider wasteful.

In contrast to mainstream approaches, "*the Hacking mentality would tend to favour just getting things done* (X9)". This mentality emphasizes the inherent coding trade-offs between investing time and effort for a comprehensive modification versus only "*solving the immediate problem*" which may in turn result in the "*accumulation of future problems*" (X9). However, the long-term future does not necessarily matter to many Hackers and they favour doing something than potentially ending up with nothing.

Hacks can present very different "*degrees of elegance*" (X1). At the least sophisticated end of the spectrum is what many refer to as a "*kludge*" or as an "*aesthetically inelegant or crude Hack*" (X1). A "*kludge...is a skilful solution, which is nonetheless crude, it is something pulled together*" (X1), going for the "*low-hanging fruit*" (X2). On the opposite side of the spectrum is

[19] http://ryanverner.com/post/46265984864/code-complexity-accepting-the-intrinsic-and

"*a neat Hack, meaning, it is a rather elegant way of achieving [an objective]*" (X9). It is often a simple, cheap and fast way of addressing a problem especially if decisions are urgent, information is limited, and resources are scarce.

Interestingly, gaining elegance does not mean adding intricacy. Simplicity on its own is often a good sign for a Hack. Elegance may also depend on the desire for recognition and respect from peers and from society. In this light, "*a kludge does not get you respect*" (X1). Independently of their different degrees of elegance, when compared to conventional approaches of governing systems, Hacks are always 'good-enough' solutions (see Figure 12).

Figure 12: Practicality

- Resourcefulness

Hackers tend to perceive limited resources as a trigger to come up with "*non-obvious*" (X4) heuristics and to benefit from them in "*non-intuitive ways*" (X4). The term 'Hacking' conjures a connotation of "*solving a problem using intelligence, observation, and ingenuity with limited resources. There is no manual*" (X1) for Hacking and the Hacker "*does not really rely or depend on other people to tell him what to do*" (X7).

This resourcefulness (see Figure 13) implies using what is available at hand in what Hackers perceive as their working space: "*If you need to go somewhere else and get a screwdriver and come back, it is not a Hack any more, it is a pain*" (X6). Computers, the internet, and, more specifically, the development of programming have opened up unprecedented scope for Hacking, since a great deal of system changes can be done with very little tangible and intangible resources. Accordingly, when describing what was needed to Hack, X9 highlighted:

"*Computers. That is about it, really. A screen, a keyboard. That is the nice thing about programming*".

Figure 13: Resourcefulness

- Urgency

Hacking aims at immediate results when opposed to more conventional ways of addressing complex problems: it is "*something that allows you to see some kind of result within a very, very short amount of time*" (X7). In this vein, Hackers may see traditional management and design approaches as sluggish, believing their focus lies at obtaining too much information and following very procedural methods. As described by X10, "*Hack is a quick solution for a complex problem, whereas a design is definitely something that takes time... and observation and research and surveys and interviews over time*".

Some would see 'Hacks' as having "*a beginning and an end, as a time-bounded thing*" (X4), as "*a discrete action*" (X2). Others would refer to Hacks instead as "*milestones of open-ended processes*" (X10). As described by X4: "*I am not sure if anything is ever actually accomplished or is it an ongoing process and so there is always another Hack... and as I said they can escalate and escalate and escalate*". X2 also highlighted the blurred nature of time needed for Hacking: "*a short series of commands…may take quite a short space of time, but to actually develop the Hack may take months to get code review working out to bypass the problem*".

It is, therefore, important to stress that the timeframe of Hacks is not absolute: it is relative to the timeframe demanded by what they perceive as hierarchical approaches. A speedy action

is self-imposed by Hackers themselves, while opposing to socially expected heuristics. For example, when asked to describe time requirements, X12 prompted the following provocation: "*what would happen if you apply [Hacking] to diplomacy? Because the way they build stuff takes forever*". This exemplifies how Hackers adopt instead a rather informal and fast-paced attitude towards problem-solving, given their angst for authorities and hierarchical structures.

Besides their urgency for taking action and for obtaining immediate results (see Figure 14), the cascading, long-term impact is unknown; and this is not a matter particularly distressing them. As described by X3: "*if you are having an immediate impact, you never know the result in long term*".

Figure 14: Urgency

- Self-Entitlement

Hacking is often used in the media to refer to "*gaining unauthorised access*" (X2) through a "*manipulative streak*" (X1) "*associated with anti-social behaviour*" (X4). The self-entitlement of Hackers, nonetheless, goes much beyond that description. Hackers mistrust authority, valuing decentralized agency of systems. Being 'anti-social', in this case, does not imply performing criminal activities, or disrespecting law enforcement. It means that Hackers defy social norms and power structures, by counteracting expectations of how things are meant (or told) to be done.

In this avenue, the line between transgressing laws and bypassing social norms without infringing them is thin. That also justifies why many Hackers make a deliberate choice for anonymity. The decision for anonymity, according to X1, depends on the trade-off between retribution and acclamation: "*if there is fear of retribution, there is an incentive to remain*

anonymous. But if you don't fear retribution sufficiently enough, then you may take a view that the acclamation outweighs the retribution". Opposing anonymity in all circumstances, the so-called 'ethical Hackers' movement considers that "*nothing should be in secret*" (X3). In their case, Hacks are conducted openly and publicly, even if their exposure opens up possibilities for being legally charged or causes "*fear of being coerced in anyway*" (X3) by picking fights with powerful enemies.

Self-entitlement is, thus, an essential trait of Hackers (see Figure 15). This trait might derive from "*an intense curiosity, a desire to understand things*" (X1), or a disgruntlement with the status quo. On the latter, X5 described: "*We cannot accept the fact that this is the process, a process that makes people unhappy, but that is how things work. We just cannot accept*". Therefore, Hackers do not ask for permission, neither need to have permission granted by an authority. In X6's words: "*Hacks don't have to go to a review board to be approved*".

Figure 15: Self-Entitlement

- <u>In Beta</u>

Hackers are intrigued by how systems function and their approach is essentially experimental and exploratory, involving an "*element of surprise, ingenuity and skill*" (X1) and resembling "*a treasure hunting activity*" (X8). Hacking thus involves learning through tinkering, "*trial and error*" (X8), and by employing "*creativity and informality to get into the flow*" (X9) of the system to change it from within. As "*inquisitive people wanting to learn*" (X1), many Hackers would describe their main motivation as having fun by pursuing system change. As described by X1, "*playfulness goes along with curiosity and modifying the*

environment in ways which are not necessarily utilitarian". X2 went further, emphasizing that there are Hackers who "*want to see the world burn … but a lot of the time, it is just people who have that playful problem solving ability*". In fact, most of the interviewees referred to Hacking as solving puzzles, describing how they often feel challenged to "*find their way into complex puzzles*" (X9), including, for example, the ones which have been deliberately "*designed to keep them out*" (X9).

Furthermore, the 'Hacker culture' also propels them to excel, since they interact in online communities based on recognition of Hacks accomplished; not on academic degrees, wealth or other conventional status criteria. X2 highlighted "*it is just a game for a lot of them and there is also some sort of status, so if they are better at it than their colleagues they can get to the top of the pile*". Their learning and exploratory processes are also rather messy and collaborative. As described by X9, the exploration tends to be non-linear and ideas can be implemented piecemeal and whereby "*you might implement a bit and then discuss it with some other people and you change it a bit and you might throw it all away and start again. It is pretty chaotic*".

Finally, it seems clear that Hackers feel challenged due to their own inquisitive nature, to cultural characteristics, as well as to the complex and intriguing nature of the problems they are addressing through experimentation (see Figure 16). Problems can vary in terms of complexity: "*the problem could be trivial, it could be profoundly difficult but, nonetheless, it is problem solving, by and large, not invariably*" (X1). Even if the problem is profoundly difficult, they experiment with it in a semi-autonomous way: "*there are problems that can be solved by one person or a very small team of people. So Hacking is not a solitary activity*" (X6). That is only possible because Hackers are not addressing problems by coping with formal and informal rules of the game, they explore by diverging from them instead – and the latter might require less resources and coordination than the former.

Figure 16: In Beta

- Democratized Agency

Differently from actions that can only be taken by pre-determined agents – such as policymaking, whose responsibility lies with governments, or launching a new product in the market, which is inevitably led by companies – Hacking is an activity that has open and democratized access. A Hacker "*could be anybody, even a 6-year-old child*" (X9), since Hacking is "*not an expert thing like brain surgery*" (X9). While some interviewees emphasize that "*all they have to do is be playful and creative*" (X9), others describe that Hacking "*is more a mind-set than a skillset*" (X2). Hacking is also seen as an activity of an individual or group of autonomously organised individuals. These are "*often organic teams; they are just sort of formed obviously [between people who] work or want to work on the same thing. They are seldom structured, top-down teams*" (X9). As a result, Hacking is not seen as conducted in a formalized environment, since employees often "*feel they have to abide by the guidelines*" (X4). For these reasons, most interviewees often do not conceive Hacking as occurring as part of the operations of formal organizations.

Moreover, it is not consensual if a "Hacker" is a person who has already Hacked, or a person who still Hacks. When asked about this, X6 highlighted the ambiguity by drawing a comparison with other skilled activities: "*if you become a Blacksmith, do you ever stop being a Blacksmith even if you are now also an Accountant*"?

Hacking, therefore, does not pose great barriers to start: anyone, in principle, can Hack (see Figure 17). Accordingly, X2 highlighted that "*one of the most obvious properties of Hackers is their autodidactic characteristic*", that "*Hackers do not read manuals: they want to get started*

straight in". Hacking involve skills "*which are not necessarily particularly advanced*" (X6) either, and they can be enhanced by "*talking to other people and learning and escalating from one bit to another bit, through a kind of gradual process*" (X4). Some personality traits are inevitably present though, such as creativity, curiosity, and ingeniousness. Hackers also present a certain sassiness when comparing to people "*who are hindered by the fear to do something wrong or just to try*" (X3).

Figure 17: Democratized Agency

- Arbitrary Boundaries

Hackers can intervene in any kind of system. Per definition (e.g. Meadows 2008), systems do not have intrinsic boundaries: they depend on how components are observed and interrelated to form a unified whole. A system's configuration is thus defined by the observer, who deliberately decides what will be taken into consideration and what will be excluded from the observation. Boundaries of systems are, thus, essentially arbitrary when analysed. However, the scope for action of some agents often lie within pre-established ones. For example, the perceived agency of a federal government lies on conventional national borders. Likewise, a company has its agency limited by a conventional boundary: an organizational entity, legally defined by ownership, and composed by interconnected tangible and intangible resources.

In contrast, Hackers have full flexibility to define the system they will exert agency upon. Since they are seen as external agents, they are not constrained to adopt a conventional boundary (see Figure 18). They can, instead, frame their observation in the way that – to the best of their knowledge – allows them to reach a desired result. This might be the reason why

the public perception of Hackers, according to X6, is one of individuals "*pushing the boundaries*". They are not pushing though; they are, consciously or not, leveraging their flexibility of deliberately framing the system they wish to act upon.

Figure 18: Arbitrary Boundaries

- Distributed Ownership

The Hacking culture emphasizes a 'membership culture', which fosters collective effort and recognizes (and often praises) contributors. In this vein, the main motivation for non-malicious Hacking "*is not money*" (X10): "*ownership is not important for them; they are motivated by trying to solve a puzzle*" (X9). The activity is not seen as "*a career or as a job*" (X11) either. Hackers are, instead, motivated by the "*approbation of peers and the sheer satisfaction in solving a problem, which may well lead on to career opportunities*" (X1). Since Hackers feel incentivized without needing to hold onto property, it creates a culture with few constraints to entry, in which people can tap into latent complementarities to explore systemic change. Hacks can thus be modified and might evolve to fit changing needs. Likewise, new Hacks can arise by building upon previous contributions.

In what concerns ownership, Hacking resembles the Open Source movement. As highlighted by X4: "*Hacking has something similar to what you see in academic communities in terms of open source, open data, and open access where they produce things for the common good*". Hacking can be viewed as a successful form of "*gift-economies*" (Malinowski, 1922), as opposed to the "*tragedy of the commons*" (Hardin, 1968). In the latter, individual users act with self-interest and behave against the common good. In the former, however, recognition

within a 'tribe' prevails over material rewards in which exchange is not based on trading or selling.

Furthermore, there is, within the wide Hacker community, a social pressure against forking projects. Removing a contributor's credit "*is absolutely not done*" (X2) while building upon previous contributions, cooperation, but not permission, may be sought. This does not mean, however, a total absence of responsibility towards their acts. As described by X4: "*there is some sense of responsibility…. if people are going to do stupid things it comes down to the responsibility of the person who is using it in that stupid way*".

While the community recognizes and values Hacks from others, Hackers do not hold possession of their contributions (see Figure 19). Besides recognition and praise from others, and the motivation of solving problems, Hackers can indirectly benefit by getting job offers, improving networks, and other forms of immaterial rewards. Moreover, lack of formalized possession does not mean that there is no 'sense of ownership' of Hacks. For example, a common title given to self-run, open-source projects is "*Benevolent Dictator for Life (BDFL)*"[20] – originated in reference to Guido van Rossum, who created the Python programming language. Hackers make daily decisions of improvements and have full freedom to promote changes, but founders retain a final say in case of strong disputes within the community about future developments, thus avoiding sub-groups forking the project to impose their own ways.

Figure 19: Distributed Ownership

[20] Available at: http2s://www.theatlantic.com/technology/archive/2014/01/on-the-reign-of-benevolent-dictators-for-life-in-software/283139/ [Accessed 11 November 2016]

4.5. Contrast to Other Change Drivers

The concept of System Hacking, as defined and characterised in sections 4.3 and 4.4, appears as a novel, yet barely understood driver for sociotechnical system change. In this section, I briefly contrast it to the sample of 9 change drivers presented in the literature review to illustrate its originality and relevance for theoretical development.

Table 11 compares System Hacking to each of these change drivers, pinpointing and justifying similarities and differences in regard to the 5 key characteristics deployed in the Table 8 of the literature review – i.e., heuristics, speed, resources, agency and ownership. Subsequently, I discuss how these change drivers differ from System Hacking in regard to the 9 dominant characteristics described in the section 4.4.

Table 11: Contrast of System Hacking to other change drivers

	Change Drivers	Heuristics	Speed	Resources	Agency	Ownership
1	**System Hacking**	Practical, experimental and unconventional solutions, defying rules of the game and causing discontinuity in what is mainstream in systems	Immediate	As few as possible, used creatively	Any self-entitled, external agent that does not have responsibility nor accountability for their desired system change	No one owns a 'system Hack', and it benefits the ones targeted by Hackers
2	**System transition/ innovation**	Different focuses on coordinated change, often through adaptive governance	Different refers to long-term change	Different requires a vast pool of tangible and intangible resources	Different refers to distributed agency among multiple stakeholders	Similar since no one owns outcomes
3	**Invention**	Different focuses on creating novelties	Different it often takes long time	Different it often requires sophisticated resources	Similar Anyone can invent or hack. However, there is an expectation that inventors will be formally recognized (i.e. IPR) whereas recognition for Hacks happens informally	Different inventors are owners of their inventions so long as they have registered IPR
4	**Innovation**	Different focuses on changes happening through the marketplace, typically motivated by profit	Different it is not an immediate action, it often requires time from generation to diffusion	Different often requires sophisticated resources	Different agency lies mostly on companies/ entrepreneurs	Different companies/entrepreneurs own the outcomes and profit from them, others benefit indirectly
5	**Disruptive innovation/ technology**	Different same reasons as 4	Different although it aims at being as fast as possible to gain competitive advantage, it takes longer than system Hacks due to the reasons described in 4	Different although it does not involve sophisticated resources, it unlikely deploys exclusively resources available at hand	Different same reasons as 4	Different same reasons as 4
6	**Frugal innovation/ technology**	Different same reasons as 4	Different although it tends to be quicker than most innovations, it takes longer than Hacks due to the reasons described in 4	Similar since it also deploys simple, cheap and preferably widely available resources	Different same reasons as 4	Different companies/entrepreneurs own the outcomes, but it must also benefit disenfranchised consumers
7	**Grassroots innovation/ technology**	Different same reasons as 4	Different same reasons as 6	Similar same reasons as 6	Different same reasons as 4	Different the disenfranchised innovator owns, also benefiting disenfranchised consumers
8	**Bricolage/ DIY/Maker culture**	Similar they also involve practicality and experimental solutions, but, differently from system Hacks, it does not have to be unconventional	Similar since they also have a sense of urgency and solutions can be sub-optimal	Similar the ones widely available and relatively cheap	Different since agents do not have to be external. They focus on solving their own problems	Different given the ones leading the change own the outcomes
9	**Jugaad**	Different since it focuses on commercialising improvised solutions, typically motivated by profit	Different same reasons as 6	Similar same reasons as 6	Different given it has a especial focus on small-scale entrepreneurship	Different same as 6
10	**System design**	Similar since it also aims at causing discontinuity in what is mainstream in systems. However, it does not have to be unconventional , neither practical	Different as the concept is open-ended, speed varies according to the ambitions, whereas system Hacks must be immediate	Similar given it focuses on resourceful and creative solutions. However, differently from system Hacks, it also tends to involve multiple stakeholders	Different since it has a especial focus on influential agents, such as large organisations and policymakers	Similar same reasons as 2

Both System Transition/Innovation and System Hacking might represent discontinuities in sociotechnical systems. However, System Transition/Innovation are focused on analysing and steering variation, selection and retention of innovations, which can then influence sociotechnical system change in the long-run. System Hacking, instead, is a problem-solving approach, in which problems are immediately addressed through unconventional solutions that defy the rules of the game. System Innovation/Transition also do not necessarily display the 9 dominant characteristics of System Hacking.

System Hacking is in contrast to Invention as it may not necessarily be something novel to the world and, therefore, cannot be safeguarded by intellectual property rights. System Hacking contrasts to Innovation (i.e. process, product, service, and business models), since it does not have to be led by companies, neither to impact the marketplace. Furthermore, neither Innovation nor Invention necessarily have to meet the 9 characteristics of System Hacking.

Similar to System Hacking, Disruption evokes an idea of 'Practicality', since companies enter the market by commercializing something that is just good-enough for low-end or non-consumers. However, Disruption occurs through changes happening within markets. While there may be some overlaps between System Hacking and Disruption on the dimension of 'Practicality', Disruption does not present similarities with the other 8 characteristics of System Hacking. Furthermore, System Hacking also differs from the ideas of radical innovation, breakthrough or technological revolution[21]. It is, instead, about unconventional solutions, which do not have to cause massive changes in the system, and that do not aim at changing the rules of the game.

Besides having a very different definition and being employed to analyse different phenomena, the concepts of Bricolage, DIY/Maker Culture, Jugaad, Frugal Innovation and Grassroots Innovation only overlap with System Hacking on a few characteristics, most especially with 'Practicality', 'Self-entitlement', 'Resourcefulness', 'Democratized Agency' and 'In Beta'. Furthermore, they focus on physical materials or organisational processes, not open-ended systems. For this reason, they resemble the idea of Material Hacking, but not System Hacking.

Although System Designers are deliberately taking action to steer system change, the focus here lies on planning processes. System Design can share a few characteristics of System Hacking. Designers prioritise 'Practicality' to test hypotheses and, hence, better plan future actions. However, System Design is about planning components and interactions within a given

[21] As described in the Literature Review, the term Disruption has been extensively used with a different connotation of the one framed by Christensen (2013): referring, instead to radical innovation, breakthrough or technological revolution.

boundary. Its solutions mostly lie on how to best tackle or cope with system problems by following or changing the rules of the game. It does not share most of the characteristics identified for System Hacking either.

It is therefore possible to observe that System Hacking has little in common with other change drivers; and, as a result, the concept has great potential of unpacking insightful observations of phenomena that have not yet been explored by the existing literature. Next section briefly describes what I consider as the most relevant implications of this novel concept for theories on sociotechnical system change.

4.6. Implications for Sociotechnical System Change for Sustainability

This section discusses some of the main implications of the concept of System Hacking for theoretical development; thereby connecting to the opportunities that were explored in the following stage of this PhD research.

4.6.1. Defying undesired institutions

Institutions are the formal and informal rules of the game in a society (North, 1990), shaping the activities that will likely be undertaken, the solutions to be prioritised, and the strategies of a vast array of actors (Ostrom, 2000). Since rules motivate individuals and organisations to act in a certain manner, they contribute to their own perpetuation. Institutions thus represent sources of stability, coherence and continuity of systems, while simultaneously shaping public expectations of what changes are viable and heuristics of how change should occur (Savaget and Acero, 2017).

Despite the variety of change drivers discussed in the literature, the analytical focus mostly lies either on solutions in accordance to rules or changes to rules. Little is known, however, about solutions that are purposefully attempting at ignoring, bypassing or even transgressing the rules of the game. The concept of System Hacking proposed in this Chapter can contribute to institutional theory by indicating possibilities of working around undesired rules to reach good-enough and immediate solutions.

4.6.2. Identifying other change drivers for systemic change

Recommendations for wide-scale system change often lie on long-term, adaptive governance, through the coordination and interaction of multiple parties. These analytical lenses face difficulties of shying away from vague prescriptive statements – e.g., incorporating

diversity, assessing expectations and fostering coordinated action. They, therefore, lack recommendations on how different agents can act upon systemic components and connections.

Micro-level approaches are focused instead on changes happening through the marketplace and on their cascading impacts on the functions of the sociotechnical system. There is little scope to discussing mechanisms of changing systemic components or connections realized through actions that do not involve commercialization.

By shedding light on System Hacks, such changes which have been neglected by theories can be addressed and subsequently, the multiple and coexisting drivers of sociotechnical system change can be better understood. In other words, it becomes possible to analyse actions, happening 'here and now', which are directly promoting new or enhanced systemic functions by defying the rules of the game.

4.6.3. Reflecting upon legitimacy and agency

The literature emphasises that attempts of changing sociotechnical systems frequently cloak tensions between interested parties and different understandings of nature and institutional patronage (Leach, Scoones and Stirling, 2007). In other words, such changes often do not question who is changing the system, for what reason, for whose benefits, and through what means (Jasanoff, 2009). Whereas, democratic deliberation seems to be the most accountable approach to appraise and pursue sociotechnical change, the coexistence of multiple, and often contending viable pathways for system change are largely ignored by traditional mechanisms of decision-making. These favour a technocratic or entrepreneurial elite who may deny deliberative and inclusive agency (Savaget and Acero, 2017).

System Hackers, on the other hand, are self-entitled agents that are intentionally defying social norms, counteracting expectations of how things are meant to be done. Decisions taken by System Hackers, or by a technocratic elite, can equally be labelled as "democratic" – although with different interpretations. While democratic governments follow rules that are, in principle, formulated and enforced by an elected government, System Hacking is democratised in terms of access. That is, in principle, 1) everybody can Hack, 2) Hacking does not pose great barriers to entry, and 3) it does not involve ownership. The phenomenon of System Hacking thus opens up scope for questioning agency and legitimacy over the multiple co-existing possibilities of changing a system.

4.6.4. Tackling pressing sustainability problems

Some sustainability problems are extremely urgent, compromising the ability of current generations to meet their basic needs and leading to the trespassing of environmental resilience

to a point beyond return. Solutions following the rules of the game tend to require a high level of coordination, hence increasing the possibilities of things going wrong, initiatives not being taken ahead, or of presenting sluggish action when tackling urgent problems (Sull and Eisenhardt, 2015). That is one of the reasons leading to lengthy decision-making towards some of the most pressing sustainability problems, in which decisions are urgent, information is limited, stakes are high, and resources are scarce. In this avenue, System Hacking has great potential due to the following reasons.

First, since it defies the rules of the game, System Hacks can address sustainability problems that are highly engrained and difficult to be tackled by mainstream solutions. In contrast to influential agents, System Hackers do not have ownership nor accountability of the system and are not restricted by arbitrary boundaries. Consequently, they can pursue the changes they may find correct and worthy of pursuit. They are, therefore, less constrained by formal and informal rules responsible for the persistence of an undesirable status quo.

Second, given our bounded rationality and limited ability in coordination and implementation, by considering a wide range of possibilities for deliberation, the number of initiatives that can either go wrong or that will not be taken ahead also increase (Sull and Eisenhardt, 2015). By focusing on good-enough outcomes, System Hackers can also experiment to address pressing problems. Yet sub-optimally, they can focus on alleviating problems or breaking systemic inertia towards deeper system change.

Third, since everybody can Hack using the resources available at hand, System Hacks are less impacted by coercive power relationships or the scarcity of resources. The opportunity of changing systems thus becomes more accessible to people who are often disenfranchised from power structures.

Finally, since System Hacks cannot be owned, cannot be protected by intellectual property rights, and deploys only resources that are widely available, System Hacking does not have great barriers to entry. As a consequence, it has great possibilities of being successfully and quickly replicated or adapted to different contexts.

4.7. Opportunities Further Pursued

The major focus of the following step of this research was on the issue raised by 4.6.4: to understand System Hacking addressing pressing socioenvironmental challenges, henceforth called ‘Sustainability Hacking’. The subsequent contribution of this thesis was to analyse ‘real world’ cases of Sustainability Hacks through inductive and qualitative approaches. That led to collecting and analysing data of 19 cases, whose results are scrutinised in the following Chapter.

The starting point for contrasting data of real-world cases of Sustainability Hacking portrayed in the following Chapter was the Triage Checklist for Sustainability Hacking (see Table 12), which contains the definition and the dominant characteristics of the concept as developed in this Chapter.

Table 12: Triage Checklist for Sustainability Hacking

Triage Checklist of Sustainability Hacking									
Definition	**Dominant Characteristics**								
	External	Urgency	Practicality	Resourceful	In Beta	Democratized Agency	Arbitrary Boundaries	Self Entitlement	Distributed Ownership
to pursue an unconventional solution to a systemic socioenvironmental problem	*does not have ownership nor accountability of the system*	*seeks immediate outcomes*	*pursues good-enough outcomes*	*manipulates resources available at hand, often repurposing their use*	*involves experimentation, exploration, tinkering, learn-by-doing and often certain degree of playfulness*	*in principle, everyone can hack, although it involves certain personal characteristics, such as ingeniousness and curiosity*	*are not necessarily restricted by jurisdictions or other conventional boundaries*	*neither asks for permission, nor has to have permission granted by an authority*	*outcomes are openly available and can be redistributed or modified*

4.8. Summary and Final Remarks of the Chapter

- What was found and how?

This chapter explores a largely ignored change driver of sociotechnical systems. From the exploratory interviews with cybersecurity experts and self-declared Hackers, I propose System Hacking as a novel concept, defined as unconventional solutions to systemic problems, deviating from the rules of the game.

Following the definition of the concept, I identified and scrutinized the 9 dominant characteristics of System Hacking, namely: External; Urgency; Practicality; Resourcefulness; Self-Entitlement; In Beta; Democratized Agency; Arbitrary Boundaries; and Distributed Ownership. I then contrasted this concept to other prominent change drivers of sociotechnical systems to highlight its potential to contribute to theoretical development. System Hacking seems particularly advantageous to address situations in which information is limited, resources are scarce, stakes are high, and decision-making is urgent.

The findings of this Chapter derived from an exploratory, Phenomenon-Driven approach undertaken both for data collection and analysis, which allowed me to unpack empirical insights with greater breadth. Due to the novelty of the topic and to the nature of qualitative research (described in detail in Chapter 2), relevant characteristics of System Hacking may have unintendedly passed undetected. Yet, everything reported here was diligently analysed and backed up with data from the interviews.

- What next?

Chapter 5 investigates real-world cases of Sustainability Hacking. It portrays the analysis of 19 cases that have addressed multiple sustainability problems, were conducted by different agents, were spread across several national jurisdictions, and have deployed different heuristics to hack a system. The chapter walks the reader through the stepwise process deployed to analyse and contrast data, while presenting the main findings and how they were gradually identified and validated. Besides outlining the cases and providing an in-depth description of some of them, the analysis scrutinises the similarities and differences across the 19 cases and reveals 5 Archetypes of Sustainability Hacking that can guide future research.

5. Sustainability Hacking in the Real World

"The Directorium Inquisitorum, published by the Holy Inquisition in the fourteenth century, diffused the rules of the suffering. The most important of them ordered: Torture the accused who hesitates in his responses".
(Eduardo Galeano, El Hijo de Los Dias, 126)[22]

5.1. Introduction to the Chapter

The previous chapter first developed the concept of System Hacking, which derived from the analysis of interviews with self-declared Hackers and cybersecurity experts. Borrowing the understanding of Hacking from computational systems, and based on the interview data, I developed an analytical lens to investigate understudied phenomena of sociotechnical systems. This concept was then contrasted to the existing literature, pinpointing possibilities for further contributions to theories on change drivers of sociotechnical systems.

These observations led me to question if the heuristics of System Hacking could be applied to address pressing sustainability problems – and, if so, how? Since this analytical lens is unprecedented, its empirical application had to be tested. The conceptual development of the previous chapter has, as a result, urged me to investigate cases of Sustainability Hacking in the 'real world'.

According to Eduardo Galeano[23], an Uruguayan novelist: "Scientists say that human beings are made of atoms, but a little bird told me that we are also made of stories". Chapter 4 provided an initial set of 'atoms', i.e. the 'Triage Checklist for Sustainability Hacking', containing fragments that helped classifying a phenomenon as a Sustainability Hack. I did not have, however, the stories of Sustainability Hacking.

[22] My translation, from Spanish to English
[23] Video of Eduardo Galeano introducing the book "Children of the Days" in 2012. Available at: https://www.youtube.com/watch?v=wOsOaa5f9Jg [Accessed 05 December 2018]

At that moment, I started an exploratory journey in search for stories, the *wholes*. I used qualitative methods – described in Chapter 2 – to learn from individuals and organisations that addressed what they perceived as a sustainability problem through an unconventional solution (i.e. diverging from what was identified as the expected heuristics and rules of the game).

This search was exploratory, without using inputs from the analytical lens provided in the previous chapter except for the definition of Sustainability Hacking. Otherwise, I could risk falling into what the Nigerian novelist Chimamanda Ngozi Adichie described in her TED talk as "the danger of a single story"[24]. During her childhood in Lagos, she read mainly British books and could not conceive literature without white protagonists who ate apples and talked about the weather. These stories might not be wrong as such, but they are, at the very least, incomplete or imprecise in representing a greater part of the world's population. The same principle applies to the stories I was looking at: I first needed to understand them without biasing myself with the conjectures from Chapter 4. Only after doing that, I became well positioned to understand if the 'fruit was indeed an apple', if the 'protagonists were in fact white', and to pinpoint 'what fruits and races' were not addressed by the framework from the previous chapter.

5.2. Structure of the Chapter

Data was collected from 19 cases, as portrayed in Section 5.3. From these, Cases A and B were analysed in-depth, by using exploratory and open-coding to prevent the bias of *finding the conclusions I was looking for.* The analysis, therefore, started from the *stories* and investigated their *atoms*, i.e. the most notable fragments composing them. These results are presented in Section 5.4.

I then depict the Triage Checklist for Sustainability Hacking to identify what fragments across these 2 cases were encapsulated by the concept of System Hacking and which ones were not. In Section 5.5, I was not only testing if the Checklist – that arose from the analysis of interviews with self-declared Hackers and cybersecurity experts – was robust to analyse 'real-world' cases of Sustainability Hacking, but also to identify variables across cases A and B that have not yet been captured in order to build a robust analytical framework of Similarities and Differences of Sustainability Hacking. This analysis resulted in a preliminary version of the

[24] TED Talk "The Danger of a Single Story" from Chimamanda Ngozi Adichie in 2009. Available at: https://www.ted.com/talks/chimamanda_adichie_the_danger_of_a_single_story [Accessed 05 December 2018]

Lists of Similarities and Differences: tables that were built upon through the gradual inclusion of the remaining cases.

The 17 remaining cases were analysed through closed-coding, using the similarities and differences from these Lists. Cases were investigated one-by-one, and then contrasted to the partial results. Towards the end of this process, all cases were analysed according to the variables of the Lists of Similarities and Differences. Section 5.6 presents how I conducted this process with Case C, illustrating and walking the reader through the stepwise analytical process that was reproduced for all the remaining cases. Section 5.7 portrays the final analysis, for all the 19 cases within the sample. Section 5.8 presents the 5 archetypes of Sustainability Hacking, which arose from the analysis of the final List of Differences. This chapter is concluded in Section 5.8 with a reflection of the results and methods of this cross-case analysis, also outlining the connection with the following Chapter.

5.3. Overview of Cases

This section provides a brief overview of the 19 cases of Sustainability Hacking, by outlining important characteristics used throughout data collection to diversify the scope of the sample. Diversification was critical because, to the best of my knowledge, academics have never formally used the idea of 'Hacking' before in order to both understand sociotechnical system change and to address a wide range of pressing sustainability problems.

The sample of cases was purposefully diversified in terms of agents (i.e. 'who'?), locations (i.e. 'where'?), sustainability problems (i.e. 'what'?), the expected heuristics (i.e. 'how' the problem tends to be addressed) and the Hacks pursued to address the problem (i.e. the unconventional solution). These features are briefly described in Table 13 for all cases. The methods employed for data collection and analysis will not be presented in this section, since they have been scrutinized in Chapter 2.

Table 13: Overview of the Sample of Cases

Case	Name	Agent	Location	Sustainability Problem	Expected Heuristics	The Hack
#A	**ColaLife**	NGO	Zambia (in the process of scaling up to other Sub-Saharan regions)	Lack of access to medicines in remote regions (i.e. the Last Mile)	Improving public infrastructure and governance	Emulating Coca-Cola's value chains to make medicines available in multiple outlets of the private sector
#B	**Operação Serenata de Amor**	Open, non-formalised civil society group (a company has then spinned off)	Solution in Brazil (interviewees in multiple countries)	Corruption and lack of political participation	Enhancing inspection and oversight by the responsible public authorities	Open-source AI-technologies to empower civic auditing of public administration and report suspicious expenses
#C	**Women on Waves**	NGO	Based in the Netherlands (solution implemented in over 100 countries)	Women deprived from abortion rights and healthcare problems deriving from illegal abortions	Changing the legislations of countries where abortion is illegal	Women from countries where abortion is illegal go onboard of an dutch ship that sails to international waters to provide them safe and legal abortions
#D	**Guarani-Kaiowá**	Indigenous tribe	Brazil	Eviction of indigenous communities of their lands	Negotiation with authorities and politicians, intermediated by FUNAI (National Foundation of the Indigenous)	Open letter announcing mass suicide
#E	**Shoot the Shit**	Company	Brazil	Lack of information on routes of buses	Provision of information by bus companies and public transportation authorities	Collaborative posters at bus stops to be filled by users
#F	**Vigie Aqui**	Company	Brazil	Lack of recognition of politicians investigated for corruption	Prevent prosecuted politicians to run for elections, and/or disseminate information of their wrongdoings through the media	Browser plug-in that highlights names of investigated politicians every time they appear, informing what they are being prosecuted for and verdicts
#G	**Sugata Mitra**	Individual	India (scaled to multiple countries)	Vulneravle children cannot access the means to improve their educational outlook	Provide access to schooling	Digging holes in walls of vulnerable places and fitting computers (i.e. "hole in the wall") to be used as a self-organised learning environment
#H	**Social Finance**	NGO	United Kingdom	Low rates of reintegration of ex-cons and high rates of reoffense, due to the lack of support provided by the government	Provision of reintegration support by government agencies	Emulating performance-based funding schemes from the financial sector to promote a win-win situation for the government, business angels and ex-cons
#I	**Goats for Water**	Individual charity (then evolved into a for-profit social enterprise)	Pakistan	Lack of perennial water supply, due to lack of cash and poor access to formal markets	Provision of clean water by the government	A scheme to barter goats for water pumps

#J	**Elango**	Community leader	India	Caste prejudice and clashes between dalits and non-dalits	Changing social behaviour through education and law enforcement	Using a housing policy to address caste prejudice, by building twin houses, each occupied by a dalit + a non-dalit family
#K	**Deity Tiles**	Society at large	India	Public urination and open ditches	Changing social behaviour through education or law enforcement, and provision of infrastructure in public spaces (e.g. toilets and bins)	Installing tiles of Hindu deities on walls to prevent people to urinate or to dispose garbage in that location
#L	**Ugly Indian**	Informal organisation	India	Filthy, unsanitary public spaces	Changing social behaviour through education or law enforcement, and governments cleaning the spaces	Self-organized movements of anonymous volunteers to clean dirty areas, without receiving recognition or payments
#M	**Dharma Rao**	Individual	India	Open defecation and its associated health hazards	Provision of sanitation infrastructure and education	Transferring knowledge and facilitating the construction of biocompostable toilets in vulnerable areas
#N	**Kalpana Srivastava**	Individual - civil servant	India	High rates of child marriage	Law enforcement through responsible authorities (e.g. police)	Incentivizing children to monitor, report and, hence, prevent marriages in their communities
#O	**Mod Skool**	Informal civil society group	India	Eviction of the urban poor leading to loss of their assets, such as the materials used for construction that are destroyed	Changing laws (and law enforcement)	Easily assembled/disassembled houses, so the evicted population can prevent financial and material losses
#P	**Field Ready**	NGO	Nepal, South Pacific, Syria, Haiti, and US	Lack of materials for urgent humanitarian aid when/where they are needed	Improving logistics and reducing bureaucratic barriers to the prompt flow of goods	Using (and trasferring skills for locals to use) 3D printing and other emerging technologies to avoid imports
#Q	**Sikka**	Civil society group	Nepal	Difficulties in providing financial support to populations in remote regions	Improving access to banking systems	Use of blockchain and crypto-tokens for humanitarian aid, overcoming constraints of cash-based donations
#R	**Honey Bee Network, Gian, SRISTI and Palle Srujana**	Informal network + NGOs	India	Lack of access to formal markets by the ones at the grassroots	Promote consumption, i.e. the offer of products and services designed for the bottom of the pyramid	Cataloguing and supporting the development and diffusion of grassroots innovations
#S	**Four Thieves Vinegar**	informal organization (i.e. an online 'collective')	Unites States (but the solution is not jurisdictionally bounded)	High costs and, consequently, lack of access to healthcare products	Policies providing or subsidizing access to healthcare products	Open-source, automated lab reactor and instructions on how people can make their own healthcare products

The only thing these cases had to have in common, during the data collection stage, was the fact that they referred to unconventional solutions (i.e. deviating from the expected heuristics and rules of the game) to a perceived sustainability problem. Given this is the very definition of the concept, this was the only *sine qua non* condition. In other words, all the 19 cases of Sustainability Hacking introduced in this Chapter meet this definition: they were found and investigated for that specific reason.

For example, Case A addressed the problem of lack of access to medicines in remote areas of Zambia. Even when funding from governments and international organisations is available, medicines are rarely dispensed to the population living in remote rural regions – in the so-called Last Mile, where populations are disenfranchised from perennial access to public healthcare. Some over-the-counter medicines, such as diarrhoea treatment, could potentially be afforded by populations living in extreme poverty; however, they are not widely available through the private sector of these regions either. The systemic bottlenecks preventing medicines to be found in these areas are related to poor infrastructure, logistics and weak governance.

Despite being seen as the optimal solution to the problem, improvements in infrastructure, logistics and governance needed for perennial supply have timescales of decades for implementation, are very costly, and are highly susceptible to the impoverished and often politically unstable settings of low-income regions. In this context, ColaLife, a British non-profit organization, identified that there are self-organized value chains already in place that allow remote rural communities to purchase fast-moving consumer goods, like Coca-Cola. They have then emulated the value chains of Coca-Cola to make medicines available both through the public and private sector. The Sustainability Hack of Case A has clearly deviated from the expected heuristics and from the rules of the game, by pursuing an alternative and rather immediate solution. While long-term solutions to provide access to medicines are still important, this Sustainability Hack has improved health and saved thousands of lives in the interim, besides allowing the organisations involved to learn and scale-up faster – and, as a result, save more lives. Their approach might not be ideal but delivers good-enough results when stakes are high, information is limited, and resources are scarce.

Besides Case A, the sample presented in Table 13 covers very different sustainability problems and mechanisms of addressing them. They were also led by several different agents – including non-profits, individuals, civil servants, companies, communities, and informal organisations. The interviewees were based in Brazil, Germany, India, Nepal, Netherlands, Pakistan, United Kingdom, United States and Zambia – but, since System Hacks do not have to follow jurisdictional boundaries, their solutions may have been simultaneously implemented in multiple geographical locations. These Sustainability Hacks are only summarized in Table

13, but key characteristics arising from the cross-case analysis are detailed in subsequent sections of this Chapter.

Finally, it is important to highlight that, despite the initial intent of focusing on socioenvironmental problems, the sample was unintentionally biased towards social ones. Cases of System Hacks addressing environmental problems were difficult to find and the agents were unresponsive to my request of interviewing them. This is, therefore, one of the limitations of this work, whose implications for future research are explored in the last Chapter of this thesis.

5.4. Exploratory Analysis of 2 Cases

This section provides an in-depth, exploratory analysis of cases A and B. The choice for cases A and B result from the following reasons: 1) these were the first cases to have data collected, hence allowing more time to explore their content; 2) they have very distinct features (i.e. agents, locations, sustainability problems, and solutions pursued); 3) they provide an extensive dataset, both in terms of interview hours and insightfulness.

The analytical focus lies on descriptive features (i.e. *What was the problem? What was the solution? What was the role performed by the investigated agent?*) and the heuristics (i.e. *How was the solution pursued*?). On one hand, these exploratory and open-ended questions were particularly promising to reveal prominent characteristics. They opened up scope for 'excess of meaning', instead of closing down to a subset of previously defined categories. On the other, it simultaneously provided a structure that could be used to contrast cases A and B.

This section first describes Case A and the same structure is subsequently depicted for Case B. By exploring and contrasting these cases, the cross-case analysis was kick-started, providing a robust set of variables that could be investigated further with the remaining 17 cases, in a process that is portrayed in Section 5.5.

5.4.1. Case A[25]

- **<u>What was the problem?</u>**

Current systems are failing to make life-saving healthcare products accessible in remote regions of low-income countries – even for simple and relatively cheap medicines. Governance failures lead to unstable healthcare systems that rely too much on external funding for

[25] This section was adapted from a report that has not yet been published (please refer to footnote 38, on p.158). This section has been solely written by me. However, an earlier draft counted with the valuable comments from Cassi Henderson, Steve Evans, Simon Berry and Jane Berry.

procurement of medicines, oscillating according to the changing priorities of funding agencies. Furthermore, even when funding for medicine is available, they often do not reach the so-called Last Mile, since improvements in infrastructure and logistics needed for perennial supply have timescales of years or even decades for implementation, are very costly, and are susceptible to the unstable social, political and economic settings of low-income regions.

In addition, the most pressing healthcare challenges of these regions are not met by global markets, due to the low profit margins at the bottom of the pyramid and low purchase powers of their governments. Local industries are fragile and their middle and high-aggregated value sectors, such as healthcare, are often threatened by international competitors, or rely too much on intermittent procurement from international organisations. This consequently restricts the offer of locally produced goods, which are adapted to the needs of low-resource settings.

These agency failures result in lack of access even to simple measures, like over-the-counter healthcare products to treat diarrhoea: the second leading cause of death of under-five children in Sub-Saharan Africa, accounting for approximately 8% of childhood deaths worldwide (Liu *et al.*, 2015). Numbers of deaths due to diarrhoeal diseases reflect inequality in prevention and treatment across high and low-income regions – for example, Somalia's rate is 155 times higher than the one of the United Kingdom (Liu *et al.*, 2015). Diarrhoea can also cause more permanent problems to children that survive without adequate treatment, such as stunting and neural dysfunction.

The ideal solution to tackle diarrhoea, as stated by the World Health Organisation (WHO)[26], is prevention through what is often taken-for-granted in high-income regions: access to safe drinking water; improved sanitation; hand washing with soap; exclusive breastfeeding for the first six months of life; good personal and food hygiene; health education about how infections spread; and rotavirus vaccination. However, preventive solutions face multiple systemic constraints to deliver, including lack of funding, basic infrastructure, and poor governance.

Zambia, where Case A occurred, is one of the countries facing these challenges. With 64% of its population living on less than $1.25 per day and one of the highest mortality rates in the world, it is a particularly challenging setting to provide healthcare, particularly for the rural poor. Its government states that there should be a health facility within 5km of every household; yet this is only the case for 50% of rural households (Chankova and Sulzbach, 2006). According to an expert at the Centre for Infectious Disease Research in Zambia (CIDRZ), "*at the national level we take an integrated approach; [however] there are gaps and challenges with regard to*

[26] Available at: https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease [Accessed 05 February 2018]

how to comprehensively put all these things together" (A51). In fact, public responses require a high level of coordination, with comprehensive policies and investments in multiple fronts; conditions that are not currently met by local agents.

Given the high prevalence of diarrhoea among under-five children, improving access to treatment seems imperative, especially while complex preventive solutions cannot yet be delivered. The treatment for diarrhoea, as recommended by the World Health Organization (WHO) in 2001, is an over-the-counter (OTC) medicine combining oral rehydration salts and zinc (ORS+zinc) (WHO/UNICEF, 2001). ORS replaces lost fluids and essential salts, hence treating dehydration and shortening the duration of diarrheal episodes (WHO/UNICEF, 2001), and zinc supplementation decreases the length and severity of diarrheal episodes and the risk of subsequent infections in the 2-3 months following treatment (Bhutta *et al.*, 2000; Baqui *et al.*, 2002; Bhandari *et al.*, 2008). Despite being promoted by the WHO, 99% of diarrhoea cases in under-five children in sub-Saharan countries are not treated with life-saving ORS+zinc. Even in the rare cases where children receive medical treatment for diarrheal episodes, they are often treated with incorrectly administered antibiotics (Gill *et al.*, 2013).

The Zambian Ministry of Health recognizes that physical accessibility to treatment through the public sector is constrained by insufficient infrastructure; sparsely distributed population in rural settings; inadequate resources for outreach (e.g. vehicles); and poor scheduling of services (Ministry of Health, 2011). Ramchandani (2016) also finds other constraints, such as poor communication and transportation between health facilities and public warehouses. The Institute for Health Metrics and Evaluation (IHME, 2015) found in 2014 that 23% of rural health centres reported having stock-outs of ORS and 30% of zinc. Even when available in healthcare facilities, utilization rates of zinc are less than 1% (WHO, 2001).

Access to ORS+zinc through the private sector is also very limited, primarily taking place through pharmacies. However, a study published in 2008 (Rockfeller Foundation, Dalberg Global Development Advisors MIT-Zaragoza International Logistics and Program, 2008) reported that there were only 59 pharmacies in Zambia, 40 of which were in the capital, Lusaka. There were also less than 100 pharmacists (i.e. with a Bachelor degree) within the country. Since every pharmacy has to employ a registered pharmacist to meet the local legislation, the growth of these outlets are severely constrained (Rockfeller Foundation, Dalberg Global Development Advisors MIT-Zaragoza International Logistics and Program, 2008; Palafox *et al.*, 2012). When other options do not exist, there are general retailers, such as rural shopkeepers selling fast-moving consumer goods (FCMGs), like Coca-Cola, sugar, and cooking oil – and, sometimes, a very limited number of OTCs.

Despite the magnitude of the problem, most endeavours tackling lack of access to medicines in low-income regions either revolve around providing funding for procurement of medicines or improving infrastructure for delivery. These are often perceived as deep-rooted bottlenecks constraining access. However, the former does not ensure the perpetuity of access, oscillating according to the changing priorities of funding agencies. The latter is often very costly, can take a long time to be implemented and often fails due to unstable social, political and economic settings in low-income regions (England, 2007).

- **What was the solution?**

The non-profit ColaLife, registered in the United Kingdom, observed that while life-saving medicines are sparsely found, FMCGs – like Coca-Cola, sugar and cooking oil – can be purchased even in the remotest places of low-income regions. Why are they available, whereas life-saving medicines are not?

Given there is an aspiration for these products in remote areas, and they are not highly regulated, the value chains of FMCGs have evolved organically throughout time, pulled by demand. These value chains include value flows between multiple agents. More than a supply chain, a value chain can be thought of as an ecosystem of relevant players, processes and resources needed to effectively deliver a product or service to the end-user. It can be identified by analysing value added, captured and exchanged throughout the process (Burns *et al.*, 2002; Porter and Teisberg, 2006). By understanding how value flows from one agent to another, it is possible to uncover the economic, organizational and coercive activities across different sectors and between multiple stakeholders to understand how benefits can be generated and distributed (Kaplinsky *et al.*, 2002).

At first, ColaLife started piggybacking Coca-Cola's distribution chain, by fitting medicines in between the bottles in crates. Starting in 2012, the organisation implemented a quasi-experimental trial in two rural districts (Kalomo and Katete) with two comparators (Monze and Petauke), tapping into the value chains of FMCGs to make ORS+zinc available to end-users through the private sector.

Despite receiving several design awards for this solution, they soon realised that fitting medicines in between bottles was not good enough: "*on the time it finished going viral...we actually understood what a value chain actually is, because we have been to Zambia and we talked to SAB Miller, and we understood how their logistics work, so we realized that perhaps physically having the kit in the crate itself was not going to get the [anti-diarrhoea] kit to the villages in the proportions that we wanted, and in the way that we wanted, however willing*

Coca-Cola were. You know, it was a sexy idea, and it was a visual metaphor, but the practicality on the ground was not, and the trial actually showed that" (A1).

They then analysed and emulated how FMCGs, like Coca-Cola, reach consumers in remote areas of Zambia through the private sector. The organisation has, simultaneously, worked with caregivers to design Kit Yamoyo – an anti-diarrhoea treatment kit, co-packaging ORS+zinc. Within the span of one-year, the combination therapy for under-five children with diarrhoea increased from less than 1% to 46.6% across intervention districts, with no change detected in comparators.

Given the success of this initial trial, the initiative was scaled up to promote access both through the public and private sectors in 14 selected Zambian districts over the course of approximately 4 years[27]. The knowledge, design and technologies to produce the kit were then freely licensed to a local pharmaceutical company, i.e. Pharmanova. In the private sector, the kits are sold by trained rural shopkeepers, in addition to more traditional outlets, such as pharmacies, and supermarkets. In the public sector, the kits are freely dispensed to caregivers by health clinics, posts, hospitals and community health workers. Providing through both channels has shown to be critical. While through the public sector, a large number of children can be treated across the country, the private sector has proven essential to reach the most vulnerable populations, distant from healthcare facilities.

Towards the end of these projects, the local manufacturer was selling an average of 1400 kits/day: one of the best-selling and most promising products within their portfolio. Furthermore, uptake of ORS+zinc in intervention areas increased substantially, especially in regions that received medicines both through the public and private sector: jumping from 1% to 53% between 2015 and 2017.

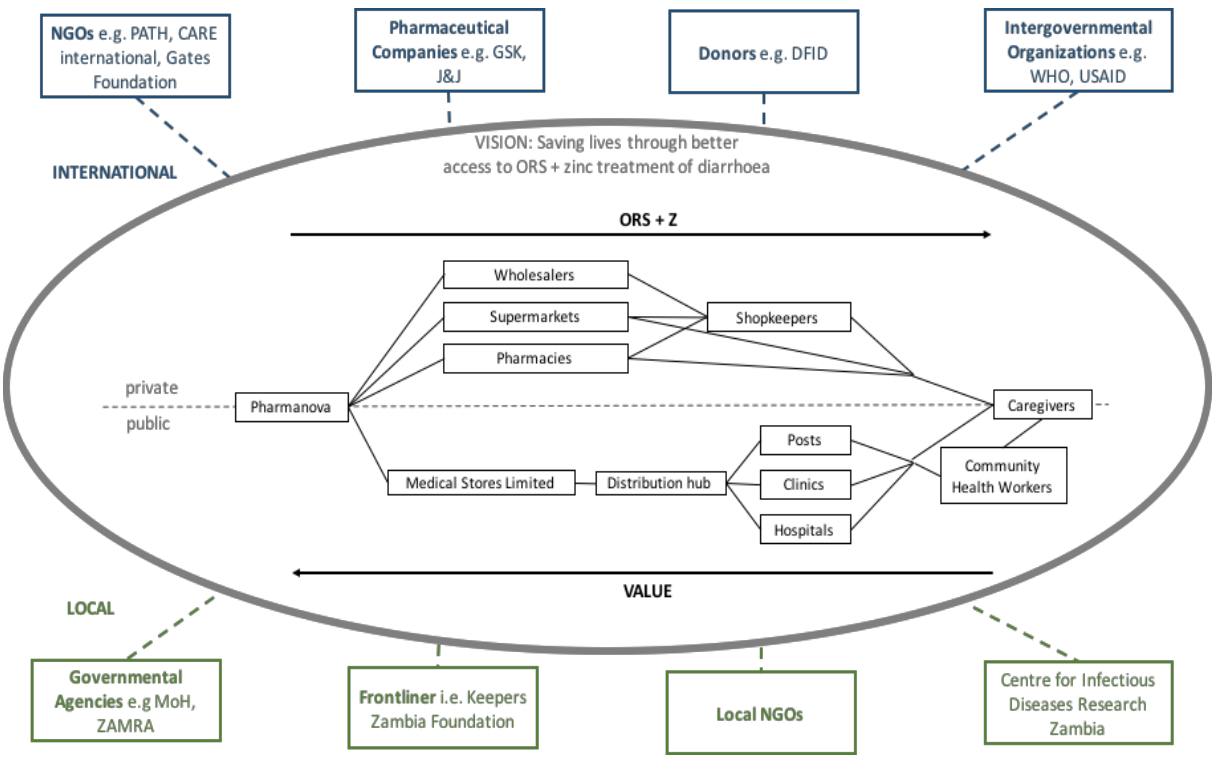
- **<u>What was the role performed by the investigated agent?</u>**

While existing value chains of FMCGs goods evolved organically in low-income regions, ColaLife performed the role of a value chain Catalyser. It was the main architect of a new value chain with a specific and deliberate intention. It has mapped the big picture and designed the interventions needed in pursuit of the vision, providing the impetus for change.

[27] One of these scale-up projects focused exclusively in the private sector and 4 peri-urban districts in Lusaka Province, funded by the United Kingdom Department for International Development (DfID), by an award from GlaxoSmithKline and Save the Children, by support from Isenberg Family Charitable Foundation and by individual donors. The other project focused on 14 of the most underserved rural districts of Zambia, through both public and private sectors, and is part of the local Scaling-Up Nutrition (SUN) Programme funded by the British, Irish and Swedish Governments, with match-funding from ColaLife's sources mentioned above and administered by Care Zambia.

ColaLife also aimed at being as invisible as possible, purposefully identifying itself as an external agent, responsible for setting up the value chain and the ecosystem that provides the conditions needed for the value chain to flourish. ColaLife acted as a trusted intermediary who did not aim at becoming part of the value chain and, consequently, it could not be seen as a potential threat to the operations of local individuals or organizations. For this reason, it is not represented in Figure 20, which portrays the value chain built for providing access to diarrhoea treatment in Zambia. As described by A2: "*not inserting yourself, as ColaLife, into the system, as part of the solution, [is fundamental] because that is not sustainable, we are not going to be there forever. There are lots of programs that start, 5 year programs, and they transform the landscape for 5 years, and then they go, and things get back to what it was before if not worse than before, because it was a temporary initiative. So right from the beginning, everything we do is about what happens when we leave, it is about planning for your own demise. Because if the solution depends on you being there all the time, well, first of all you have to commit to be there all the time, you have to get the money to be there all the time, you got to do it and to employ people to do it, you have to bypass people who were doing it already*".

Figure 20: The Value Chain Providing Access to Diarrhoea Treatment in Zambia



ColaLife has then acted as an outsider by making itself gradually more redundant by empowering local individuals and organizations. It also initially brought funds and intangible

resources from abroad, but it concomitantly focused on enabling local agents to become progressively more independent of international aid. Each agent throughout the value chain now captures value (most often as profit, but also through other intangible forms of value, such as satisfaction and ethics). That applies throughout the entire chain, from the manufacturing company to the final retailer. The principle is that when the system acquires a shared vision, empowered agents with strong connections, and where each agent is able to capture some value for itself, then ColaLife can withdraw and leave a self-sustaining legacy.

ColaLife also listened to local agents rather than imposing external frameworks, gathering resources to help solve problems, strengthening existing relationships and creating new connections to consolidate the value chain. For instance, ColaLife brought in the local pharmaceutical manufacturer, Pharmanova, and freely licensed the medicine for their production to the local market.

Alongside its non-rivalry stance, part of this trust was dependent on ColaLife's expertise and credibility, and their open model towards their tangible and intangible assets. As described by A1: "*[we have] a different institutional model. We harness philanthropic funds and expertise and we channel them through the envelope that is Cola Life. But it goes through, the intellectual property does not stick to us, the knowledge and the data does not stick with us, it is not protected, there is no wall around it, the funding does not stick with us, we take very very little of the funding because we do not need the fund*".

ColaLife also acted with the mind-set that urgent problems need addressed by immediate rather than perfect solutions. They recognized that medicines should ideally be dispensed for free across the country, funded by public governance, and accompanied by improvements in infrastructure, such as water supply and sewage, to prevent incidence of diarrhoea. However, they also recognized that this complex solution is not feasible in the short-term and, hence, adopted a good-enough approach of emulating value chains of FMCGs to make the medicine available both through public and private outlets.

- **How was the solution pursued?**

The heuristics of ColaLife to set up a value chain for diarrhoea treatment, as derived from the data analysis, consists of eight interconnected focal areas which are not necessarily sequential and are likely to be iterative. Table 14 outlines the focal areas and their critical success factors. In the following, each is described and illustrated with specific examples.

Table 14: Focal Areas for Value Chain Emulation

Focal area	What it entailed
Analysed the value chains of FMCGs in the target area	Determine what products are found in remote places
	Identify agents involved throughout the value chain and the roles they perform
	Map the interactions between these agents and the strength of these connections
	Reveal what tangible and intangible resources are employed
	Examine how value flows in the entire process
Set the main principles	Set up horizontal governance
	Ensure a self-sustaining legacy
	Map benefits from intended flow of value
	Mobilize agents around a vision (not around a project)
	Do not compromise the vision in response to external stimuli
Worked with locals	Find and work with a local champion
	Find and work with in-country manufacturer to develop the medicine
	Find and work with members of the supply chain (e.g. distributors, supermarket chains, wholesalers)
	Gain institutional and community support (e.g. international organizations, politicians, traditional leaders)
Drew the boundaries	Analyse systems, subsystems and critical boundaries for intervention
	Define inclusion based on the value to be delivered
	Act upon the trade-off between viability and urgency
	Understand and prevent negative impacts on other subsystems
	Draw the line of ownership
	Examine the characteristics, behaviours, desires and expectations of customers

Conducted human-centred design of products and packaging	Design products and packages that are desirable by the end customer
	Provide information (e.g. labels, instructions) that can be assimilated
	Design medicines and packages that meet the contingencies of the supply chain
	Build a product with a powerful name/brand
	Maximize usability, aesthetics/sensory appeal, symbolic value, and product differentiation
Influence the context	Pursue voluntary compliance
	Understand the context to leverage decision-making
Launched and adjusted	Experiment, prototype and pilot
	Build capacity
	Respond quickly to the monitoring
	Define an exit/redirecting strategy
Monitored and evaluated	Gather data of the most critical performance indicators of the value chain
	Keep a periodicity for data collection and include new variables if needed
	Process the data quickly
	Share analysis with key stakeholders regularly

Analysed the value chains of FMCG in the target area. ColaLife started by understanding the journey of a Coca-Cola bottle from the manufacturer to the end user in remote areas of Zambia. As described by A52, "*the logistics pathway for Coca-Cola, for cooking oil, exists… all you have to do is maybe use that same framework to move this product [Kit Yamoyo]".* It also engaged with different agents throughout Coca-Cola's value chain to understand not only product movement but also value delivery and flow, understanding what (and how) agents were interacting with each other, and what (and whose) tangible and intangible resources were employed. They soon realized that *"even without [a formal partnership with] Coca Cola…[medicines] can go as far as any place"* (A41), by understanding and transposing Coca-Cola's value chain to diarrhoea treatment.

This analysis included questioning, for example: "1) *ease of use and how the product will be used*; 2) *how it will be understood (cultural aspects, language, instructions);* 3) *how it will be perceived (brand, value, market position)*; 4) *costing and pricing, affordability; 5) where it can be available (regulation, knowledge of dispensers/sellers, diversity of outlet/multiplicity of channels to market)*; 6) *and how it will be transported (efficiency, value chains; packaging; design for value chain)* (A2)*".*

Through this big picture analysis of FMCGs, it was possible to better understand what works and why, and then infer what characteristics could be transposed, piggybacked, or adapted to access diarrhoea treatment through the private sector. That revealed what agents should be initially approached and nurtured, what connections should be established, and what institutional changes should be promoted to contribute towards their vision. For instance, when possible, they aimed at benefiting from the existing movement of goods and services to deliver unprecedented value, for example by tapping into the existing flows of products to wholesalers, pharmacies, supermarkets and rural shopkeepers.

Set the main principles. The interviewees agree that early definition of principles was fundamental to the success and robustness of the system intervention. Horizontality was the most critical one and includes shared goals, interdependency, cooperation and participation in decision-making processes. Horizontal governance was set up to ensure the integration of the interests of different agents during the process of value chain emulation. It implied that players had clear roles and benefits and that a decision outside the agency of a single player would ideally be deliberated by all involved.

Furthermore, the value chain was mobilized around a vision, i.e. transformational change in the access of medicines to save lives. This vision has not changed to fit within the scope of specific grants or to please external agents. In Zambia, ColaLife declined grants from funding bodies requiring changes in some of their principles, even when their funding was very scarce. For example, when applying for a grant from Grand Challenges Canada, the funding agency tried to change the proposal beyond what ColaLife found acceptable.

Worked with locals. To promote resilient and long-lasting changes, local agents were prioritised as they already know how to manoeuvre through the local system. Rather than create parallel systems, ColaLife catalysed existing systems by building capacity and promoting organizational change: "*because local partners understand the terrain, understand the industry, understand everything better, and it is easier to move, with a local partner, rather than someone sitting in Washington, and trying to make decisions based on statistics"* (A55). It was thus

critical to identify what agents were engaged, what authorities and regulations had to be complied with, how different players were connected, and the set of skills they needed to be provided towards the common vision.

It was particularly important to establish strong ties with a local champion, i.e. Keepers Zambia Foundation (KZF). This was necessary to nurture the most fragile agents within the value chain (e.g. rural shopkeepers and community health workers) and to understand and provide feedback on wider cultural and social influencers. ColaLife built capacity of the local champion both at an operational and a strategic level. Operationally, ColaLife enhanced KZF's ability of working with and monitoring key indicators of agents of the value chain (e.g. designing virtual information systems to collect and analyse data, and protocols for contacting shopkeepers). Strategically, ColaLife assisted KZF to apply for other sources of funding.

It was also crucial to assist a pharmaceutical company, i.e. Pharmanova, engaged in the value chain emulation, since it did not have the skills needed to offer the product with the required scope and scale. ColaLife has provided a free, non-exclusive license of the intellectual property of Kit Yamoyo to Pharmanova, allowing the company to have full ownership of the product, and helped with design, marketing and packaging of the product: "*ColaLife supported all that, for that matter, even [importing] sealing machines [for us]"* (A56). They have thus identified and addressed the bottlenecks within Pharmanova's production, to ensure that ORS+zinc could be locally produced "*and then put together as Kit Yamoyo"* (A56) with the quality and quantity needed to meet demands both from the public and private sectors.

Getting recognition and support, both locally and internationally, has also shown to be important to validate the vision. The projects in Zambia, for instance, aimed at diversifying the sources of endorsement (e.g. academia, governments, international organizations, traditional leaders). It was also fundamental to cross-fertilize different health-related initiatives led by national and international organizations to benefit from the flow of resources and efforts. For example, ColaLife and KZF have leveraged collaboration with a USAID-supported initiative, i.e. USAID Discover Health, which aims at improving district coverage both of health services and medicines through the private sector. The synergies between their initiatives allowed ColaLife to tap into the USAID project's marketing strategy and its training program for community health workers to expand awareness of the Kit Yamoyo alongside those within USAID's portfolio.

Drew system boundaries. Boundaries of the system were drawn according to the scope, feasibility and urgency of the desired change. For the projects in Zambia, the system was

primarily bounded according to geography (i.e. specific regions of the country), function delivery (i.e. focused exclusively on access to diarrhoea treatment), time and funding.

Otherwise, boundaries were kept relatively flexible through synthetic thinking[51], approaching new components and nurturing new connections depending on the value they could offer. The lines of ownership of outcomes, or the benefit of each agent, were discussed and ensured, but not imposed, avoiding interferences in viable market pricing. Each agent had distinct agency and benefits differently from their engagement. Towards the end of the project, the feeling of distributed ownership of the overall project was noticeable: "*key players, like Ministry of Health, local health facilities and the manufacturer, [who now] speak of Kit Yamoyo as 'our product', 'proudly Zambian' rather than it being 'a gift from the people of X aid agency'"* (A2).

The analysis also highlighted the importance of constantly unpacking the impacts of other systems in which ColaLife had no direct agency or that were not within its scope, even in initial stages of the value chain set up. For example, when testing a voucher scheme in the trial, ColaLife used an automated system in which credit can be transferred through mobile phones. However, "*the system had some flaws and some fraudulent activities*" (A8). As the project could not be complicit with corruption, they had to adopt an alternative system that was less efficient, but more robust.

Conducted Human-centred design (HCD). This has shown to be one of the most critical features towards guaranteeing the success of a value chain emulation for OTC medicines (Ramchandani, 2016). As described in Chapter 3, HCD is the form of design practice focused on the people for whom the product or system is intended (Giacomin, 2014).

In this case, HCD involved examining the characteristics, behaviours, desires and expectations of caregivers; designing products and packages that are desirable by the end-users; providing information (e.g. labels, instructions) that can be assimilated; designing medicines and packages that meet the contingencies of the supply chain; and maximizing usability, aesthetics/sensory appeal, symbolic value, and product differentiation. HCD has thus enabled the creation of a product that is desirable by end-users; hence, helping to emulate the value-pull of FMCGs.

It was fundamental to develop products and packaging adapted to the reality of the end-users and to contingencies of other components in the value chain. ColaLife assessed what end-users found desirable to design products, brands and packaging that considered not only quality, price and feasibility, but also usability, core benefits, sensory appeal, symbolic value, and differentiation (Moultrie, Clarkson and Probert, 2007). Through this design process, ColaLife

has also observed, for example, the importance of having both ORS sachets and zinc tablets packaged together for distribution in the value chain, as retailers would unlikely purchase all items separately. Co-packaging also helped to avoid failures in public sector dispensing (i.e. prescription of ORS without zinc) and confusion in home treatment of diarrhoea (Ramchandani, 2016).

Furthermore, most participants considered that the "*the reduction in the size of the ORS sachets"* (A7) was one of the most important outcomes of the HCD process. Previously, the sachets had been designed for institutional use and were produced and sold/dispensed in a 1L sachet. With children only needing to take 400mL/day and with many caregivers lacking access to refrigeration, this format resulted in wastage. In addition to the need for smaller ORS sachets, other important outcomes yielded by the HCD process were: "*orange flavoured and coloured ORS and orange flavoured zinc tablets"* (A1)*; "a locally meaningful name and branding"* (A2)*; "an idea of what people could afford"* (A1)*;* and *"packaging designed to measure each sachet"* (A2)*.* The package of the Kit then incorporated the functionality of a vessel that has its own indication of the amount of water needed, plus instructions that can be assimilated by caregivers.

Influenced the context. It was important to identify the most effective possibilities of influencing the context in which the value chain is going to be emulated. These include opportunities to achieve voluntary compliance by informing or leveraging the decision-making to change regulations, policy frameworks, market preferences and industrial infrastructures.

For example, the project involved an extensive engagement with the medicines regulator, i.e. the Zambian Regulatory Agency (ZAMRA), finding a balance between adapting to their expectations and defying an undesirable status quo. A1 described, for example, that ZAMRA *"advised that soap could not be placed in the same container as medicine*" as it was part of a different product class. Instead of confronting the agency, or merely conforming to these guidelines, ColaLife responded with the design of "*a tray to fit into the top of the 'aidpod' container to separate the soap from ORS and zinc. When the regulator saw this they were delighted and we have had a very, very strong relationship with them ever since*" (A1). Subsequently, the regulator accepted co-packaging with soap, once the benefit of delivering soap with the diarrhea treatment was backed up by the results of the human-centred design, and since the design of the aidpod consisted of an effective work-around to the regulatory constraints.

Moreover, ColaLife also benefited the overall design of the value chain by taking into consideration the complex behaviour of systems by looking at common denominators, and by

narrowing down from the big picture to evaluate important system features, such as stocks, flows, feedback loops and time delays, all in order to best leverage systemic change. In other words, they were aware of important characteristics of the system in which they were operating: the important players, how they are connected, the causes of deep-rooted inertial behaviour that prevents access to medicines, and the points of the system where a small alteration can lead to big changes in the system (Meadows, 2008).

Implemented and adjusted the value chain. The emulation of FMCGs to deliver OTC medicines was best conducted through experimentation. By doing so, it was possible to identify "*flaws that were in that system, and work on them, and see how you can ensure that they do not occur again"* (A8). This process approached agents involved in the value chain and the ecosystem to gather knowledge, institutional, human and social capital needed to scale up.

At this stage, it was critical to identify variables factoring in the performance. It was observed, for example, that the final price of the product in retailers may depend on multiple variables, such as size of the shop, distance to wholesaler, proximity to health clinic, and the stocking of other commodities. Experimenting with different approaches has then opened up scope for testing how to influence access and consumption.

Due to this experimental learning, the packaging has also changed multiple times. Initially, it was designed to fit within the bottles in a Coca-Cola crate *"so that along with Coca-Cola goes this medicine, reaching the people"* (A56). However, "*the packaging was quite expensive"* (A56) and wholesalers/retailers were not fitting the medicines in a crate; but, instead, strapping them around their bikes/motorbikes. This was then followed by other packages, testing how the market reacted towards different versions of the Kit. Packaging versions included one with and one without soap – the version containing soap is taxed with value-added-tax (VAT), whereas the other is exempted and, consequently, considerably cheaper. Furthermore, there were two versions of containers: a flexible and a screw-top. While the former was much cheaper, the second was more aspirational and was more intuitively used as a measuring vessel for ORS.

Channels and strategies to raise awareness were important to increase the pull from the end-user and were diversified. People in Zambia, for example, do not associate headache relief to paracetamol (the substance) but, instead, to Panadol (the brand). However, promotion had to concomitantly be "*limited to what is permissible within the regulations on advertising or promoting pharmaceutical products"* (A52). Different media formats have been pursued in Zambia, including *"social online media, television, and radio"* (A52), *"billboards"* (A8), as well as "*community-based activities, such as drama [performances] and community meetings,*

both at health centres and outside… and through promotional materials… [such as] posters, t-shirts, and bibs" (A5).

Working with community health workers has shown to be the best way to outreach at community-level in Zambia, especially in remote areas. They know "*the geography of the community"* (A4), they contact directly with caregivers in case of need, and they are able to identify *"which retailers we can be dealing with"* (A8), also assisting to "*explain the benefits it would bring to the community"* and how they can profit from it (A8).

Finally, it was critical to train agents in the public and even more so in the private sector on basic skills in different areas, ranging from stocking of medicines to their posology (i.e. how the medicines should be prepared and taken). Otherwise, the value chain could have been severely compromised after the end of the projects, or members of the value chain could have become too dependent on knowledge provided by external agents.

Monitored and evaluated. Monitoring and evaluation was fundamental to ensure quick responses when failures were recognized and efforts were redirected, especially to risks that can deeply compromise the resilience of the value chain. Since value chain emulation was experimental, important considerations here included frequency of data collection, quality of monitoring indicators, and agility in producing evaluative outputs that can inform decision-making.

It was crucial to collect data frequently – especially in the initial stages of the project, and to process the data quickly, even if that mean initially using simple statistical methods to inform decision-making. Later this was accompanied by more thorough research and evaluation. When needed, new sources of data were then included throughout the development of the project. It is also important to highlight that all data gathered by ColaLife is openly made available online.

In these projects, *"data was collected on a daily basis and synchronized every week to inform the project of the overall performance, challenges and lessons. The trends in the data were used to review implementation strategies, gather knowledge and provide lessons learnt for future project design"* (A9). There was quantitative measurement of the performance of different steps within the value chain; ranging, for example, from "*manufacturing, storage, distribution, storage at retail outlets, usage by caregivers and treatment outcomes"* (A52).

Particular emphasis was given to obtaining data of the most vulnerable agents within the chain. The local champion (i.e. KZF) collected primary data on key performance indicators of shopkeepers and wholesalers, selected early in the project design, such as stock levels, retail prices, and reported number of sales. Analysis of secondary data, on the other hand, faced more difficulties, since valuable data often *"could not be given by health facilities"* (A5) or, in cases

they were obtained, required going through several bureaucratic procedures to be granted authorization.

5.4.2. Case B[28]

- **What was the problem?**

According to data sourced from the World Bank, Brazil had the ninth highest GDP in the world in 2016. In the same year, it was ranked 76th in Transparency International's Corruption Index[29]. A study revealed that the average annual cost of corruption in Brazil ranges from 1.4% to 2.3% of its GDP (FIESP, 2010). If these numbers are accurate, the cost of corruption could potentially reach up to USD 53 billion per year.

In 2011, the Brazilian government passed the Information Access Law[30], which makes open data compulsory for all public bodies. This led to the emergence of institutional mechanisms leveraging the use of open data to encourage democratic participation and to tackle corruption. Nonetheless, open data in Brazil is still underutilised, and anticorruption enforcement is weak. Efforts to translate the increasingly available data into understandable information that can guide practical actions are still incipient (Iglesias, 2017).

Whilst major corruption schemes are progressively under the investigation of the responsible governmental agencies, other kinds of inappropriate expenses are harder to assess and investigate, requiring human and technological efforts that go beyond the current capacity of investigative bodies. This includes the so-called Quota for Parliamentary Activity, or QPA (*Cota para o Exercício da Atividade Parlamentar,* CEAP[31]), a fund that provides up to approximately 50 thousand Brazilian Reais[32] per month to reimburse each congressperson for meals, flights, fuel, car rentals and other routine payments incurred while performing their parliamentary activities[33]. The team responsible for receiving and processing reimbursement claims in the Lower House of the Congress receives an average of 20 thousand receipts per month. The process of checking receipts is manual, leaving room for mistakes and corruption to pass undetected.

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[28] This section was adapted from a publication (see Savaget et al, 2018). This analysis was solely written by me. It has, however, counted with the valuable comments from my co-authors Tulio Chiarini and Steve Evans, as well as from anonymous peer-reviewers.

[29] Corruption perceptions index 2016. Available at: https://www.transparency.org/news/feature/corruption_perceptions_index_2016 [Accessed: 11 October 2017]

[30] Law n. 12,527/2011. http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2011/lei/l12527.htm [Accessed: 11 October 2017]

[31] http://www2.camara.leg.br/legin/int/atomes/2009/atodamesa-43-21-maio-2009-588364-norma-cd-mesa.html

[32] Approximately 10 thousand British Pounds (exchange rate of 08/03/2019)

[33] http://www2.camara.leg.br/legin/int/atomes/2015/atodamesa-4-25-fevereiro-2015-780188-publicacaooriginal-146197-cd-mesa.html [Accessed: 11 October 2017]

- **What was the solution?**

In 2016, a multidisciplinary group of individuals started an open and autonomous project named '*Operação Serenata de Amor*' (OSA)[34], which deploys Artificial Intelligence (AI) to empower civic auditing of the public administration. Thanks to the ever-continuing advances and diffusion of a constellation of interconnected technologies – such as semiconductor chips, transistors, computer processors, memory capacity, the World Wide Web, cloud storage, big data analysis software and sophisticated neural networks – AI has gained momentum to progressively shape sociotechnical system change (Schatsky, Muraskin and Gurumurthy, 2015; Makridakis, 2017).

AI-based technologies in general, and machine learning, in particular, can be major drivers pulling civil society closer to the public administration by allowing citizens to tackle stable and predictable problems for which large volumes of data are relatively easy to collect. This happens through what the Organisation for Economic Cooperation and Development (2016) calls 'applied AI': systems to accomplish specific problem-solving, hypothesis-driven tasks via allowing data processing at enormous scales, hence accelerating the discovery of anomalies and patterns.

This scenario has become more promising with the sheer volume of governmental open-data associated with the proliferation of AI-based technologies and libraries (e.g. Google's TensorFlow) and online repositories for open-source coding projects (e.g. GitHub). These have lowered barriers to entry and, consequently, widened opportunities for developers around the world to engage with public data. The open-data movement has grown considerably since the Open Government Partnership, which welcomes more than 70 countries (including Brazil), covers a third of the world's population and has resulted in over 2,500 governmental commitments to disclosing public data. The idea of opening governmental data means public information should be freely available to access, use, modify and share without deliberate mechanisms of restriction or control[35].

Although information has become increasingly more available, their accessibility is still a bottleneck. The great volume and different formats of data constrain analysis through traditional bookkeeping processes of responsible agencies associated to governments. Therefore, despite being made available online, "*datasets are often difficult to be fully digested and comprehended by the civil society*" (B3). As described by B2, "*movements of democratic accountability and*

[34] https://serenatadeamor.org/ [Accessed 02 November 2016]
[35] Definition available at: http://opendefinition.org/licenses/ [Accessed 22 October 2017]

transparency revolve around making data available, but it does not mean data are being made accessible to the society at large (...). [The civil society] can and should directly benefit from the achievements of the open data movement".

OSA has then tapped into this void to analyse and report, through AI, potentially inappropriate public expenses, starting with the QPA. After raising over 80 thousand Brazilian Reais[36] through a crowdfunding campaign to kick-start the project, the group created an open source AI robot, known as 'Rosie', that uses algorithms to automatically read receipts claimed through the QPA; it then calculates the probability of irregularities and justifies its conclusions.

The deployment of AI involves a deductive, hypothesis-driven method that learns and improves itself throughout the process. OSA created hypotheses according to the understanding of the specificities of the QPA laws and by examining the dataset, then identifying potential sources of inappropriate public expenses. Hypotheses included, to cite a few, over-invoicing, reimbursements issued by bogus companies and expenses with products/services that are not specified (or allowed) by the law.

Thanks to AI's continuous developments, OSA was able to gather, process and analyse an incredible amount of data that are openly available. These were used to run plausible hypotheses and find anomalies in thousands of reimbursement claims. Independently of congresspeople's political affiliations, all anomalies were reviewed by the OSA team and reported to the responsible governmental body, following the procedure established by the Information Access Law. The responsible authority analyses each report and, if it agrees with the legitimacy of the complaint submitted, the congressperson has to justify the expense and/or give the money back.

Approximately six months after deploying AI to investigate the QPA, more than 8 thousand potentially irregular expenses were identified, and 629 of them – exposing 216 of the 513 congresspeople at the time – were reported to the responsible authorities.

The ultimate goal was to "*use technology to empower political change*" (B1) by promoting civic auditing of the public administration. According to B1, "*we do not claim we are fighting corruption, which is a very broad, confrontational and imprecise term. We are assisting society to have more control of public expenses, to keep track of how public money is being used*".

Besides revealing an unprecedented number of potentially irregular expenses to the responsible authorities – and observing the increasing awareness and engagement of a society that has been disenfranchised from political participation beyond voting in elections – OSA measures its success by when congresspeople respond to these claims publicly and when irregular expenses are recognised and paid back. Indirect impacts included, for example, a vast

[36] Approximately 16 thousand British Pounds (exchange rate of 08/03/2019)

number of collaborators who were learning-by-doing about AI while engaging with OSA, hence improving their professional outlooks. As OSA strictly followed an open-code policy, other groups might use their technologies and knowledge for other purposes, potentially spilling over to existing industries and indirectly assisting the generation of new endeavours.

- **What was the role performed by the investigated agent?**

Case B shows the pioneering use of AI-based technologies to audit public expenses, both conducted and funded by civil society groups in Brazil and hold possibilities of being adapted to (or even replicated in) other countries. It sheds light on how civil society groups can deploy modern technologies in general and AI in particular to nurture social control of public expenses, fight corruption and, more broadly, to promote political participation beyond choosing political representatives in sporadic elections.

There are other initiatives of the Brazilian civil society that do not use AI, "*composed by experts who do everything manually, trying to identify outliers and then going, for each potential case of corruption, through dozens of websites and formal processes to obtain and contrast data. It is like finding a needle in a haystack*" (B1). Conversely, through deploying AI, efficiency grows exponentially. A civil servant responsible for auditing governmental expenses told B2 that OSA "*in a week revealed more suspicious claims than what the responsible governmental agency did in a year*". Initiatives such as that of OSA are nonetheless very rare.

The case of Brazil demonstrates there are powerful vested interests constraining the use of data for enforcement of anticorruption policies. It also shows institutional resistance to deploying cutting-edge technologies to process enormous datasets, which are often processed manually by understaffed and under-budgeted governmental agencies or non-profits. AI thus opens up unprecedented mechanisms for the civil society to process underutilised datasets and, hence, explore participatory mechanisms that influence political activities. As described by B1, "*not only should technology be used by whom is providing information, but also by the ones who should be consuming this information*".

OSA had a team of eight members, horizontally coordinated and working from different geographical locations both within and outside Brazil, whose expenses were covered through crowdfunding. Furthermore, as the entire project is open source, OSA also worked with a group of more than 500 volunteers interacting through social media, such as GitHub and Telegram, to improve Rosie's algorithms and to assist in easing the mechanisms of reporting irregular expenses, in order to meet the bureaucratic procedure established by Brazilian law.

The algorithms and results were fully open, meaning anyone could contribute to their development, access results online or assist with analysis and reporting. Besides the formal

complaints, OSA also publicized irregularities through online social media, such as Medium, Twitter and Facebook (on which they had thousands of followers), allowing the media and the general public to be informed and to contact a given congressperson to ask for clarification. Over 70 media channels have already reported results from this project (B4). The OSA team planned to scale up to investigate reimbursement claims from the Brazilian Senate, public procurement of the Brazilian federal government and public administration of Brazilian cities, as well as expand to international jurisdictions that have also implemented open-data policies.

- **How was the solution pursued?**

The analysis of OSA's case has revealed key characteristics, as presented in Table 15. It describes five focal areas, their dominant traits and 20 features characterising them. In the following, each focal area is described and illustrated with specific examples.

Table 15: Key characteristics of diffused political participation enabled by AI

Focal Areas	Dominant Traits	Descriptive Features
Funding	Decentralized	Crowdfunding Third sector and individuals In-parallel for-profit services
Governance	Horizontal	Ethics and clear goals Organizational culture Workflow Curate and review Partnerships
Human Resources	Diverse	Multidisciplinary Sofa activism Safety net
Operations	Lean	Fill gaps Technologies for empowerment System flow Pilot and experiment Immediacy, practicality and malleability
Public Relations	Openness	Funding accountability Open code Legality and liability Report findings

Funding. Deploying AI to tackle governmental problems by tapping into emerging open-data contexts has low barriers to entry. However, as a citizen-led initiative, OSA needed funding both to kick-start new projects and to scale-up existing ones. Funding was needed not only to purchase eventual technologies and licenses, but also to allow citizens – especially ICT geeks – to dedicate their time to designing and running these projects.

Funding arising directly from governments could have potentially delegitimized their initiatives, even if following rigid and transparent ethical procedures. Public procurement also tends to be keener on focusing exclusively on very mature technologies and to be influenced by vested interests, which are opposed to the very purpose of these initiatives. For these reasons, OSA preferred to be funded in a very decentralized fashion, mostly by civil society itself.

Crowdfunding has proven to be particularly good to kick-start the project, also empowering the civil society to participate and to join the project, building up momentum for positive and collective change. According to B2, not only was crowdfunding very helpful for funding, but also "*to push our initiative to create and to test a concept*", similar to the creation of an open and easily comprehended business plan that would be presented to potential funders. B1 added that crowdfunding "*promoted autonomy, both to people who are leading the project and to the ones supporting the project*". At the same time, it nurtured "*micro-communities and it deals better with the lack of trust of the civil society*" (B1) towards governments and large organizations.

After kick-starting, OSA used recurring crowdfunding, in which donors commit a certain monthly amount to the project. B3 emphasized that this posits a pressure to keep up and to constantly present results. However, this source of funding was unlikely to meet all expenses, especially when incrementally expanding the initiative towards new jurisdictions or adding new functionalities. Donations and grants from third-sector organizations, such as private foundations, or wealthy individuals were seized to fill this gap. These were unlikely obtained to kick-start novel projects led by diffused civil society groups; however, once the results were unpacked and the initiative gained more support and visibility, it became better positioned to apply for grants and donations. Similar to crowdfunding, grants often come with strings attached. On one hand, a grant does not provide permanent stability to the initiative and financial security to its most engaged members, but it sets models in the form of discrete projects, from design to implementation of these initiatives, with the potential to be replicated or adapted elsewhere.

Financial security was indeed an important matter factoring the development of their initiatives. B2 declared, "*we cannot work full-time for free (...) but we cannot let OSA die either".* This idea was endorsed by all other interviewees, some of whom emphasised that a possible alternative was in-parallel for-profit services to clients demanding AI solutions. The core team created a company, hoping to raise enough revenue streams through in-parallel services to sponsor most of their expenses with OSA. The latter would still be kept as an open-source, not-for-profit project. It is interesting to observe that, after starting OSA, the core members not only benefitted from it by using the project as a 'lab' to experiment and develop

their AI skills, but also improved the outlook of their resumes and gained more credibility to start a company with a proven track record and portfolio.

Governance. Horizontal governance was not only desirable, but also seemed a matter of analytical rigor to the eyes of the interviewees who aimed for civic engagement. They, nonetheless, highlighted that, when integrating a wide range of collaborators, the initiative inherently risks shying away from its main targets if these collaborators adopt a rather aggressive, confrontational approach that could undermine the credibility of the project (B1, B2, B4).

Ethical standards and goals were thus made explicit and shared among all collaborators. It was critical to emphasize that the initiative does not aim at fighting corruption, but rather at empowering civil society to take more ownership of public administration. Otherwise, as described by B1, "*a collaborator can Hack private details of a potentially corrupt politician, such as his address, and start sending pizzas to his house. However, this is not what we want to do (...). We do not want to make the lives of politicians a hell and shame them in public arenas*".

OSA's members also aimed at ensuring an organisational culture based on trust, as well as a tolerant, diverse and collaborative organisational culture. B5, for example, emphasized that she does not "*like working in environments where I feel affected for being a woman, and this happens a lot in technology (...). I could be doing millions of other things, working for a large company, but they are often misogynist, and I feel comfortable and respected working at OSA*". B6 described that "*social control of the government was never something very dear to my heart (...). I wanted to work with data analysis, and the team members know a lot. Working with governmental data came as a cherry on the top of the cake. My main incentive though is learning*".

One of the most challenging features of horizontal governance, with the team performing fluid roles and working remotely and flexibly, was managing workflow. OSA attributed great importance to maintaining stable communication. According to B6, "*we have daily meetings, at 9 am, lasting 15 min each. The idea is to present what you did the day before, what you will do today, and to tell if you need something (...). With this brief communication, we know what is being done, by whom, and when it will be delivered"*. They also used two other techniques, well-known among programmers. One is called time-boxing, in which a fixed maximum time period, or 'time box', is allocated to each planned activity, and, "*if that time was not enough, you skip that task and still go to the following one*" (B5). The other consists of remote pairing, in which two programmers in different locations work together on a task, using tools such as a

collaborative real-time editor, shared desktop and time markers – "*not to tell how many hours per day you have to work, but rather to show your availability to perform that task*" (B5). This was particularly helpful to improve team satisfaction, knowledge sharing and reduction of code defects.

The participants also emphasised the importance of ensuring a process of reviewing codes and curating analytical content, especially from new or infrequent collaborators. B1 described that OSA has an implemented system of code review, in which "*we read the code from all collaborators, to identify if there is a loophole, if it makes sense mathematically, and if it is coherent with the hypothesis (...) as there are barriers that are technological, but also ones that are related to legal knowledge*". It was also important to curate analytical content. B1 illustrated with a case in which "*I gave a feedback to an analysis that used the language of 'criminal' to refer to the politician. Nevertheless, we are only dealing with suspicious things, we are not the judicial system. Then I explained we are talking about statistics, probabilities, hence we need to use the language of 'suspicious expenses'*".

Partnerships were very important. In the beginning, they happened mostly with given individuals acting as mentors who were willing to share knowledge and expertise on critical and complementary topics. OSA consulted with three individual mentors with very different expertise when kick-starting: a specialist in open-data and data science, a lawyer who helped identifying legal processes and liabilities of OSA's operations and another who helped with fundraising. After kick-starting, the project was better positioned to interact with mainstream agents, including members of non-profits working towards similar purposes and employees of governmental bodies auditing public expenses. These partners were very important to "*identify the best pathways to pursue, where the bottlenecks are*" (B1). However, especially within the government, "*some of them might not want to identify themselves*" (B3) in order to avoid political clashes and retaliation. Therefore, support tended to be individualized rather than institutionalized.

Human resources. The team had to redefine problems outside rigid disciplinary boundaries and focus on finding complementarities. As a result, it improved the likelihood of coping with changing political scenarios, deploying emerging and uncertain technologies and approaching complex multi-stakeholder situations. Although the majority of team members had programming knowledge, they deliberately involved other complementary skills, such as administrative, journalistic and legal ones. Besides better end results, B5 emphasized improved internal and external communication – for example, as laws "*are difficult to understand, written by lawyers and for lawyers, we created a simple version, that anyone can understand, by*

summarizing what can be done and what cannot". B6 also described "*we are constantly learning from others and, as we recognize skills and appreciate different inputs, decision-making happens without conflicts*".

The citizens programming AI algorithms were from the so-called millennial generation, which is marked by being very urban, having an increased familiarity with digital technologies and presenting a more liberal approach towards politics. This generation is also more prone to adopt what B2 described as 'sofa activist approach' towards political engagement. Critics have characterised this behaviour by labelling them 'slacktivist'. UNAIDS (2010, pp. 142–143), for example, described slacktivists as people who support causes by performing simple, 'feel-good' measures instead of being "*truly engaged or devoted to making a change*". However, as highlighted by B1, "*sofa activism might not be as useless as it seems (...). OSA was done entirely by people on different sofas. I was programming while sitting on my sofa with my dog underneath my feet*". In order to leverage this generational and rather international culture, they used open-source and open-code tools, and developed codes and conducted most technical communication in English. As emphasized by B4, "*we had to opt between a few people who know how to program but do not speak English, or people in the entire world seeing and potentially collaborating*".

It was also very important to manage these communities. As described by B1, "*we give them an explanatory map, like the one you receive when you go to the museum with the galleries (...) and show what we understand as good practices*". B5 emphasized the need for "*non-violent communication*", since "*we are dealing with an open group [for political engagement], and we will not expel anyone*". Coding sprints, according to B6, were very beneficial in building up momentum and engaging people who cannot steadily work on the project. These sprints consisted of getting developers to work on a given project for a set period of time, often a weekend.

Furthermore, consistent with literature on entrepreneurship that shies away from neoliberal worldviews (e.g. Blanchflower and Oswald, 1998; Tennant, 2015), the participants, especially the ones who were fully dedicated to kick-starting these projects, had a safety net. When their basic needs are met, such as housing and food, and when they have a strong social capital, it is easier to take risks and to renounce stable jobs in order to pursue more pleasurable professional options. In the beginning, OSA was led by people who were more affluent than the population's average and who knew that, if OSA did not succeed, they would not face socioeconomic deprivation. As highlighted by B1 and B2, OSA started as a project they conducted in their free time, and then they decided to take the risk and dedicate themselves fully to making it work. B6 accordingly said that "*OSA is something I will work on, earning money or not. If it ends, I*

would eventually have to search for something else, but OSA will still be part of my daily routine, because I do it for pleasure".

Operations. The initiative was financially constrained and counted on little institutional support before kick-starting. The team was scattered among multiple geographical locations, contributions were fully transparent, and barriers to entry and to scaling up these initiatives to other jurisdictions were low. For these reasons, operations focused on filling existing gaps, or finding the highest returns for minimal effort. OSA, for example, identified that the responsible auditing authorities were already putting great effort into revealing grand corruption schemes, such as the ones involving public procurement. According to B1, these agencies are "*doing it well, and we need to understand that to avoid overlaps and time loss*". However, they could not investigate suspicious expenses that are relatively small, as the amount of investigations would be too high to be done manually. B2 described being told by an employee of an auditing agency that "*expenses lower than approximately 50 thousand Brazilian Reais*[37] *cannot be properly investigated. If agencies look at big, we [OSA] can look at small, and then citizens will not have blind spots*". AI-based technologies could thus fill this gap while concomitantly building up momentum to mobilize the civil society to take more active political roles.

AI-based technologies were used in this case to empower citizens to participate in politics. It was people-centred and used to fill gaps, such as small irregular expenses that pass unnoticed by auditing agencies but whose data is openly available. As described by B2, "*we want to put the citizens in the conversation (...), to debate the use of public money. Not only the bombastic political news… We want them to think about the day-to-day of politics, the expenses happening on Monday, to let them interact directly with the politician*".

The analysis has also shown the potential of exploiting leverage points of the system. OSA identified, for example, that, while highlighting individual irregular expenses signals potential wrongdoings of politicians and mobilizes routine political participation, these spotlights have little potential to cause short-term stress in the dominant political system. By grouping thousands of inappropriate expenses together, OSA could then amplify its capacity to advocate for changes in the legislation, so as to eliminate what they consider to be spurious or unnecessary public benefits to politicians on the grounds "*that they have been systematically misused*" (B1).

OSA also recognised that the initiative would have higher likelihood of succeeding if they piloted and experimented. It was particularly critical to learn, test and validate concepts and

[37] Approximately 10 thousand British Pounds (exchange rate of 08/03/2019)

variables in early stages, as well as to rollout endeavours. As described by B2, OSA "*did a pre-analysis of the data even before launching the crowdfunding to be sure 'there were wrong things there that can be found'. Then the first round of crowdfunding was mostly to develop the concept even further and to validate our assumption that a robot could audit public expenses*".

Participants also emphasised that, in a time when information is increasingly more diffused, decentralized and fast-paced, technology-intensive operations promoting transparency, accountability and political participation should aspire to immediacy and practicality. As described by B1, "*there are lots of complex theoretical criticism to representative democracy, but in practice change happens only by trial-and-error, experimenting to see what is effective and what is not*". Practicality was also evident in the choice of the QPA to kick-start the project: "*we could start with it, because the database was very organized and very transparent*" (B4). OSA's immediacy derived from the fact that it was a financially unstable initiative and mostly composed of millennials, who are more likely to commit to pursuing short-term outcomes: "*we had to promise something that people would see results in as little as 2 months*" (B2).

Public Relations. This term is often used to describe means of establishing and maintaining connections with target audiences. However, in the OSA case, the public was not merely an audience. Instead of only reporting to them, they aimed at constantly integrating the civil society into their processes. The case has shown how openness and transparency permeated their relationships with different civil society groups. Their bookkeeping is openly available to society at large and those who donated through crowdfunding.

A very important characteristic of OSA is that all their codes were openly available on GitHub to potential collaborators or to those who want to verify the results they find and report. OSA not only tapped into a vast pool of collaborators to develop their AI, but, by keeping their initiatives transparent, they were better shielded from criticism. As described by B1 "*if we did not have open-code, we could easily be labelled and delegitimized as leftist, or rightist, or serving interests of conspirators*".

Following legal procedures was essential to avoid liabilities that could have undermined or even obliterated their initiatives, possibly compromising the lives of those actively involved. The participants had to be careful with how results were reported and the language used in order to, for example, avoid legal suits of defamation after publicly exposing politicians' names. To circumvent this liability, OSA first reported suspicious expenses to public authorities; then, after receiving their responses, the information could be fully disseminated, as the team's work is backed up by an official public response.

Besides anticipating liabilities, they aimed to expand the reach of their reporting and the scope for direct involvement of citizens. OSA reported findings through online social networks, such as Facebook and Twitter, and received frequent coverage by the media. The former had become progressively more important in allowing civil society to engage with everyday politics: for example, by contacting politicians to request justifications. Outreach through media was also very relevant, since traditional broadcasting has more outreach to those excluded from online social networks (i.e. the elderly, members of lower social strata and residents of remote geographical locations). B4 emphasized their "*commitment with ensuring the media will always publish the entire data*". In other words, OSA only assisted media channels if they committed to publishing the data as they were received, thus avoiding the use of OSA's results to privilege vested political interests of media corporations.

5.5. Expanding the Analysis: Comparing Cases A and B

The Triage Checklist for Sustainability Hacking from Chapter 4 was the result of the research conducted with 12 self-declared Hackers and cybersecurity experts. This list was not, until this moment, analysed across the 'real-world' Sustainability Hacking cases, because, as described in the beginning of this Chapter, they could not bias data collection and analysis with the conjectures of Chapter 4.

Cases of Sustainability Hacks were, as a result, identified and investigated in an exploratory fashion, based only on the definition of the term and the criteria indicated in Section 5.3. Only after concluding the exploratory analysis of cases A and B, using open-coding techniques, I was equipped not only to verify if the 9 dominant traits of System Hacking would apply to 'Sustainability Hacks in the Real World', but also to reveal other dominant similarities and differences across cases.

This Section, therefore, portrays the three-step process deployed to investigate the dominant traits – i.e. the similarities and differences – of Sustainability Hacking, based on the analysis of Cases A and B. Section 5.5.1 employs the Triage Checklist for Sustainability Hacking from Chapter 4 for these cases. Section 5.5.2 reveals other similarities of Sustainability Hacking that only emerged through the exploratory comparison of Cases A and B. Section 5.5.3 then presents and discusses the dominant differences between these cases. Concluded the cross-case analysis of Cases A and B, it was possible to expand the analysis to the remaining 17 cases, as presented in Section 5.6.

5.5.1. Step 1: Employing the Triage Checklist for Sustainability Hacking

The 9 variables described in this subsection are the dominant traits identified after interviewing 12 self-declared Hackers and cybersecurity experts. At this research stage, each of the 9 variables was analysed for Cases A and B. In other words, here I aimed at revealing if the dominant traits of "System Hacking" also apply to "Sustainability Hacking", based on Cases A and B.

Table 16 depicts the results of this analysis. This table will be gradually built upon in subsequent sections of this Chapter, with the inclusion of the remaining cases – keeping the same framework and colour-coding patterns. Green indicates confirmation, i.e. that the variable is undoubtedly confirmed by the case; yellow signalizes lack of clarity, i.e. there is a high degree of subjectivity to interpret, or if the variable is not applicable to the case; and red indicates rejection, i.e. that the characteristic is undoubtedly refuted by the case.

Table 16: Triage Checklist for Sustainability Hacking - Cases A and B

	External	Urgency	Practicality	Resourceful	In Beta	Distributed Ownership	Arbitrary Boundaries	Self-Entitlement	Democratized Agency
A									
B									

Despite having 18 cells (i.e. 9 traits x 2 cases), the remainder of this sub-section will only detail the analysis of the first trait, i.e. 'External'. The analysis of the other 8 traits are not presented here, since the data backing up these results are too lengthy to fit within the word limit of this thesis. The same analytical rationale shown for 'External' was employed for the analysis of the remaining traits too, but the results were more straightforward, given they were all undoubtedly confirmed. 'External' was thus chosen to illustrate this analytical stage, given it is the only trait whose results present a dubious interpretation, opening up more scope to clarify the comprehensiveness of this analysis. Furthermore, Table 17 portrays selected quotes for the remaining traits, providing a very summarized set of evidence to illustrate how these conclusions were reached.

<u>'External' – Cases A and B</u>

As described by Chapter 4, one of the dominant traits of System Hacking is that this phenomenon is carried out by external agents, who are often invisible, at the fringe of the system. Hackers are not believed to be the ones responsible for managing a system. They, nonetheless, feel empowered for taking agency beyond what is socially expected from them, by acting in disregard for institutional limitations and standard heuristics in the pursuit of alternative approaches to address problems.

ColaLife, the Sustainability Hacker of Case A, indubitably meets this trait. The organisation purposefully identifies itself as an external agent and acts accordingly. It is an outsider committed to making itself gradually more redundant. As described by A2, *"we were just the glue. We did not see ourselves as a thing, we saw ourselves as a glue that helped others that were already there to stick together".* The principle is that when the system acquired a shared vision, empowered agents and strong connections, ColaLife could withdraw and leave a self-sustaining value chain.

That is reinforced by the fact that the organisation is not from Zambia, the target country for the Sustainability Hack. This has helped the organisation to perform an external role that has shown to be critical to their success: *"[it is crucial] not inserting yourself, as ColaLife, into the system, as part of the solution, because we are not going to be there forever. There are lots of programs that start, 5 year programs, and they transform the landscape for 5 years, and then they go, and things get back to what they were before if not worse than before... So right from the beginning, everything we do is about what happens when we leave, it is about planning for our own demise. Because if the solution depends on you being there all the time, well, first of all you have to commit to be there all the time, you have to get the money to be there all the time, you got to do it and to employ people to do it, and you have to bypass people who were doing it already"* (A2).

The Sustainability Hackers of Case A have also highlighted that, differently from companies, that are motivated by infinite targets (i.e. profit and longevity), NGOs should be motivated by finite and achievable goals. However, they also tend to focus on longevity, shying away from adopting a desirable 'external' approach towards addressing problems: "*most NGOs are working on a solvable problem, and yet they have no intention whatsoever of not existing in 10 years' time, and that is a contradiction. Is what you are working with solvable or never to be solved? If it is solvable, where is your plan for your own demise? Of course no one wants to do this, but it is a business*" (A1). In contrast, ColaLife has adopted an external posture as a principle, from the very beginning: "*we do not need to chase funding, because we are so small. Before doing this we were on another Charity, and we had 15 employees and you could not have done that…otherwise how would you fund the salaries next month? We do not have this pressure, we can stay true to our philosophy and approach. If we do not get funded, then we just do not get payed, and we have to make do or whatever, find money in other ways"* (A2). Accordingly, A2 adds that "*for DfID's reports [one of their funding agencies], we have to show how we are going to grow, how we are going to become self-sustaining, but we say 'we do not want to grow, and we do not want to exist in 10 years' time. If we are successful, we will not be here in 10 years' time!'. I have to do a budget every year projected 5 years into the future for*

the auditors and charity commission, but it is a fiction. They want us to have a reserve to grow our organization, but we do not want to grow our organization!"

Differently from Case A, the analysis of Case B indicates a dubious interpretation of this trait. On one hand, the OSA group – as an informal civil society group – is not expected to act upon the problems they are addressing. The responsibility for monitoring and reporting potentially inappropriate public expenses lies on governmental agencies, such as ones within the congress house and the judicial system. For this reason, they can be seen as externals, who are taking ownership of a problem they are not accountable for. On the other hand, the group opposes the perception that the role of the civil society is confined to electing politicians who, in association with a bureaucratic machine, are in charge of running the public administration. Instead, they believe the civil society should be empowered to progressively engage with the matters of the public administration.

Although there is no formal expectation that OSA should act upon the system, the group and their supporters seek active roles in politics – instead of being merely outsiders. They are, therefore, external, but do not want to be. As described by B2, this applies even more so to computational geeks, like most of the ones involved with OSA: "*there is a very specific group that has never gotten involved in politics. Who am I talking about? The technological nerds, the geeks, who have a libertarian tendency of breaking rules. This group is mostly seen as contesting politics, instead of as politically active. This project started by people who like programming; not necessarily the Hackers who steal credit card numbers – this is not the IT public we are talking about. But the ones who like programming to build things together, that like open data and free information, and who appreciate the cultural legacy that found space in the internet a few decades ago. And it is possible [for this people] to do things connected to the government, which is a black box… So this is our first focus, to find a way of getting this people, who were 'apolitical' [word air quoted by the interviewee, meaning 'not politically active'], more politically engaged*".

Table 17: Examples of Quotes for Cases A and B for the Remaining Traits

		Dominant Characteristics - Triage Checklist for Sustainability Hacking							
	External	Urgency	Practicality	Resourceful	In Beta	Distributed Ownership	Arbitrary Boundaries	Self Entitlement	Democratized Agency
A	Described in text	"By the end of the trial we got treatment rates of less than 1% to about 45% in the trial in 2 remote districts. We had 2 remote districts, each with its own comparative control district. That was in 12 month distribution period"	"You know, it was a sexy idea, and it was a visual metaphor, but the practicality on the ground was not, and the trial actually showed that [then we changed accordingly]"	"Everything is sort of on the laptop, on the phone, on the web, in our heads and embedded into the relationships we have"	"He was also another 'let's go with the flow, it's gonna happen, let's do it'. He said a couple of times 'this may or may not work, but we have to try'."	"We harness philanthropic funds and expertise and we channel them through the envelope that is Cola Life. But it goes through, the intellectual property doesn't stick to us, the knowledge and the data doesn't stick with us, it is not protected, there is no wall around it, the funding doesn't stick with us"	"We used all of the money and the resources that we had to do...the best job that we possibly could using local knowledge, using a marketing expert, trying to deploy the limited funds we had, not in a national launch because we didn't have that kind of money but in a pragmatic way and focussed on the target group that we did have money for"	"We didn't say "Uh, funding opportunity, let's go for it", we had a vision and a plan and we determined we wouldn't write this plan to fit in with funder requirements. Because we built it up from the bottom and it was what people at the bottom wanted, they didn't want us to completely rewrite it and skew it"	"The key thing about a smart network is that at the centre of the network is the vision, not Cola Life. So the vision is to transform access to diarrhea treatment through the private sector and everyone subscribes to it"
B	Described in text	"we had to promise something that people would see results in as little as 2 months"	"we could start with it, because the database was very organized and very transparent"	"sofa activism might not be as useless as it seems (…). OSA was done entirely by people on different sofas. I was programming while sitting on my sofa with my dog underneath my feet".	"there are lots of complex theoretical criticism to representative democracy, but in practice change happens only by trial-and-error, experimenting to see what is effective and what is not"	"we want to put the citizens in the conversation (…), to debate the use of public money. Not only the bombastic political news… We want them to think about the day-to-day of politics, the expenses happening on Monday, to let them interact directly with the politician".	"movements of democratic accountability and transparency revolve around making data available, but it does not mean data are being made accessible to the society at large (…). [The civil society] can and should directly benefit from the achievements of the open data movement".	"we do not have to ask for permission, the main concern is not if I can do something, but rather if I should do it".	"we are dealing with an open group [for political engagement], and we will not expel anyone"

5.5.2. Step 2: Finding other similarities across Cases A and B

Concluded the analysis of the Triage Checklist for Sustainability Hacking, the following step was to identify similarities across Cases A and B that have not yet been captured. In other words, the starting point here was not the framework from the previous chapter, but rather the comparison of Cases A and B. By systematically contrasting these cases to find their points of convergence, a more comprehensive picture of what Sustainability Hacks have in common was then be portrayed. Table 18 presents the List of Similarities across these cases, highlighting the added ones in red. Each of these added similarities is then briefly scrutinised for both cases.

Table 18: List of Similarities Across Cases A and B

List of Similarities		
Dominant Characteristics - Triage Checklist for Sustainability Hacking		Added Similarities of Sustainability Hacking
External	Urgency	Horizontal Governance
Practicality	Resourceful	Decentralized Funding
In Beta	Distributed Ownership	Open PR
Arbitrary Boundaries	Self Entitlement	Lean
Democratized Agency		Clear Ethics/Vision
		Leverage Points
A		
B		

Horizontal Governance

Nobody owns the emulated value chain of Case A: it is composed by a wide array of stakeholders, with different interests who are performing distinct functions. Organising a value chain inevitably implies in interdependency and cooperation of local agents. Governance had to be horizontal enough to guarantee all interests were assessed and integrated and that players had clear roles and benefits. Horizontality hence means establishing a shared vision and participatory mechanisms for decision-making, and it is instrumental to enhance the resilience of the emulated value chain.

For Case B, horizontality was not only instrumental. It was a matter of coherence, given the ultimate goal is to empower political participation of the civil society. Despite being led by a fully dedicated team, everybody could join the open platform, which was built on tolerance, diversity, collaboration and openness. With everyone working remotely and flexibly, some of the most challenging features of governance in this case was managing workflow, such as curating, coding, reviewing and reporting content.

Decentralized Funding

Case A counted with a wide array of funding sources, ranging from international development organisations to companies, charities and individual donors. Since it involved profit for private agents (e.g. wholesalers, retailers, pharmaceutical company), there were also tangible and intangible investments of members of the emulated value chain. Interestingly, the Sustainability Hacker of this case, ColaLife, did not have to systematically chase for funding for themselves, given the staff of the organisation is very small. They could then assist other members of the project to obtain funding, without great concerns of covering their overheads.

OSA also has multiple sources of funding, but it was under more financial pressure than ColaLife. The project was from and for the civil society; and, hence, had to be cautious about not compromising its credibility by receiving funds from politically suspicious sources. From the outset, they have focused on crowdfunding to kick-start the project, providing the money needed to purchase eventual technologies and licenses and for the remuneration of the ones who were fully dedicated to the project. Given difficulties of covering scaling-up expenses exclusively through recurring crowdfunding campaigns, they started searching for donations from third sector organisations, combined with in-parallel, for-profit services to clients demanding AI solutions.

Open Public Relations

Both Cases A and B have an open public relations policy. All data collected are openly available online. ColaLife, for example, frequently monitors and evaluates data of the value chain, especially of its most vulnerable agents, such as shopkeepers and caregivers. As soon as the data is processed by ColaLife and the local champion, i.e. KZF, it is uploaded to the website of the former.

Case B adopts an ever stronger open public relations policy, given that the public is not merely an audience. Instead of only reporting results, OSA aims at integrating the civil society into their processes. Codes, results and bookkeeping are openly available through different online platforms – not only as information sources, but also for active engagement. Both cases are very active in online social networks. Whereas Case A has a stronger presence on Facebook, Case B taps into many other social networks and broadcasting media channels to communicate and report their results.

Lean Operations

Cases A and B adopted very lean operations to perform their respective Sustainability Hacks. The value chain emulation from Case A was conducted through constant experimentation, aiming at learning about variables factoring in the performance and testing different approaches to increase impact. This occurred throughout the entire intervention, but even more so at the pilot – stage in which ColaLife employed human-centred design techniques to ensure the solutions would be adapted to the characteristics and contexts of users and to the contingencies of other agents involved in the value chain.

Case B also adopted a very lean process from the outset, deliberately aiming at finding highest returns for minimal effort. The technologies employed were people-centred and their operations aspired immediacy and practicality. Similar to Case A, the initiative was also kick-started by conducting a pilot. This was particularly critical to learn, test and validate critical aspects in early stages, before rolling out the endeavour.

Clear Ethics and Vision

Both cases had clear ethics and vision, which were made explicit and shared among stakeholders. ColaLife's vision was to leave a self-sustaining legacy: a fully functioning and resilient value chain for diarrhoea treatment. It has the ethics of a Catalyser, i.e. an outsider that adopts a non-rivalry stance, making itself gradually more redundant by empowering local individuals and organizations.

Differently, OSA's vision consists of promoting a more participatory democracy, by opening up mechanisms for the civil society to engage with the public administration. Its ethics are highly associated to the one of the open-data movement, i.e. information should be freely available to use, modify and share, without control or restriction. They adopt a 'sofa activist approach' towards political engagement – a work ethos that taps into the opportunities presented by information and communication technology to engage with political change. Furthermore, similar to ColaLife, OSA's stance is the one of avoiding confrontational or aggressive attitudes, which can undermine the credibility of the project.

Leverage Points

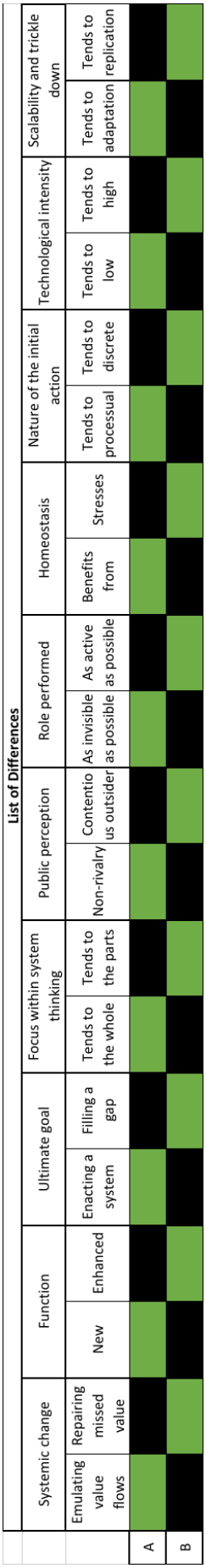
Cases A and B explored leverage points of the systems upon which they were acting. Their approach towards leveraging change was based on the analysis of the complex behaviour of systems, looking at common denominators and narrowing down from the big picture to evaluate important system features such as stocks, flows, feedback loops and time delays. In Case A, leverage points consisted of regulations, policy frameworks, market preferences, and industrial infrastructures. They aimed at achieving voluntary compliance and nudging changes in inertial social behaviour and in decision-making of influential agents, such as the medicine regulator and the Ministry of Health.

Case B explored other leverage points, by focusing on the ones they observed as capable mechanisms of causing short-term stress in the dominant political system beyond mobilizing participation of the civil society. The most notable one was grouping thousands of relatively small inappropriate expenses to amplify its advocacy capacity to change the legislation from within the established political system.

5.5.3. Step 3: Finding differences across Cases A and B

After revealing the List of Similarities, the following step was to pinpoint the main differences between these cases. As portrayed in Table 19, 10 dominant differences were identified. The colour green in the Table means presence, and black absence (this colour-coded pattern will be maintained in future sections too). This section briefly scrutinises them, providing evidence from cases A and B to illustrate and justify each of these empirical observations.

Table 19: List of Differences Across Cases A and B



List of Differences																																	
	Systemic change		Function		Ultimate goal		Focus within system thinking		Public perception		Role performed		Homeostasis		Nature of the initial action		Technological intensity		Scalability and trickle down	
	Emulating value flows	Repairing missed value	New	Enhanced	Enacting a system	Filling a gap	Tends to the whole	Tends to the parts	Non-rivalry	Contentious outsider	As invisible as possible	As active as possible	Benefits from	Stresses	Tends to processual	Tends to discrete	Tends to low	Tends to high	Tends to adaptation	Tends to replication
A																				
B																				

Systemic Change

According to Yang et al (2014), 'value absence' is something required that does not exist, and 'value surplus' something that exists that is not required. The Sustainability Hack of Case A started with the observation that there is value absence for diarrhoea treatment in remote regions of low-income countries, since they are needed, could be potentially afforded even by people living in extreme poverty, but cannot be found. There is, on the other hand, a value surplus for Coca-Cola: the space in between the bottles in the crates that are already used for distribution in these regions. The Sustainability Hacker has then developed the design of a medicine that could tap into the value surplus of Coca-Cola and piggyback its distribution in order to tackle the value absence for diarrhoea treatment. However, throughout its trial, ColaLife observed that merely tapping into Coca-Cola's value surplus was not enough. They had to emulate the value flows – how value is added, captured and exchanged (Burns *et al.*, 2002; Porter and Teisberg, 2006) – of fast-moving consumer goods, such as Coca-Cola, to create a similar value chain for diarrhoea treatment. By understanding how value flows from one agent to another, it was then possible to uncover the economic, organizational and coercive activities across different sectors and between multiple stakeholders to understand how benefits can be generated and distributed (Kaplinsky *et al.*, 2002).

Value had to be captured by all agents within the chain – otherwise, they would not have incentives to keep performing their functions. Value can be tangible and intangible and expectations vary according to agents. For example, value for community health workers was the satisfaction of promoting healthcare in their communities; for a public clinic it consisted mostly of meeting the targets defined by the Ministry of Health; for a wholesaler it may be the combination of profit and corporate social responsibility. It was therefore critical to know what values were expected by each agent and if they were satisfied with the amount of value captured. Strong and resilient value chains make sure that all actors are receiving appropriate value for their efforts.

Differently from Case A, the Sustainability Hacker of Case B leveraged the opportunities of capturing value missed, i.e. value that exists and, in principle, is required, but has not yet been explored. Since the Open Data movement, which Brazil was a signatory country, a lot of data has been made available, opening up scope for more accountability and transparency of the public administration. However, as described by B2, "*movements of democratic accountability and transparency revolve around making data available, but it does not mean data are being made accessible to the society".* OSA is, therefore, a group of the civil society who recognised this source of value missed and developed an open-source Artificial Intelligence robot that identifies suspicious expenses of politicians and reports them back to the

society at large and to the responsible governmental agencies. The latter, who lack operational and technological capacity for auditing public expenses, can then verify the claims of the Sustainability Hackers and officially take action.

Function

There is a clear distinction between Cases A and B in what regards the functions they delivered. ColaLife has emulated an unprecedented value chain for diarrhoea treatment. The appropriate diarrhoea treatment is now perennially made available both through the private and public sector in the intervention areas. Even the medicine itself (i.e. Kit Yamoyo) did not exist before the Sustainability Hack. Given that the uptake of diarrhoea treatment prior to it was of less than 1%, it is not inaccurate to claim that the performance was new for the system upon which they acted.

OSA, on the other hand, enhanced mechanisms of promoting accountability over public expenses. Some governmental agencies and other civil society groups were already auditing public expenses. However, they did not have the operational capacity to audit the vast amounts of data that have been recently made available – especially the public expenses that are relatively small, since the number of investigations would be too high to be done manually. Expenses lower than approximately 10 thousand British Pounds are not fully investigated by governmental agencies, leaving blind spots for corruption. Furthermore, due to the limited technological expertise of existing agencies, investigation that requires analysing and comparing large databases is also limited. OSA has then explored emerging technologies, i.e. artificial intelligence and machine learning, to enhance the performance of the system they acted upon.

Ultimate Goal

The ultimate goals of Cases A and B are very different. ColaLife aimed at enacting a system to provide a new function. It has, respectively, designed the value chain; experimented through a trial to reveal what were the critical variables that would factor in that system; set up the value chain and then developed, learned and fixed problems that have arisen throughout the process; and finally implemented efforts to make the system more resilient and progressively more independent from external support.

Alternatively, Case B aimed at filling a gap within an existing system for auditing public expenses. There are many agents, including governmental agencies and civil society groups, who are already performing a similar role. However, they do not have the operational and technological capacity to process the vast amounts of data that have recently been made

available since Brazil has issued the Information Access Law. OSA has then aimed at filling the gap within the existing system, by developing and deploying an artificial intelligence robot to identify suspicious expenses and then report them back to the responsible authorities, as well as to the civil society at large.

Focus within Systemic Thinking

Both Cases A and B present a broad perspective of system change, assessing overall structures, patterns and dominant characteristics of the systems they were acting upon. Both shy away from a linear, reductionist thinking of cause-and-effect, understanding that systems are formed by complex interrelationships, with components affecting each other in various and often unexpected manners. However, there is a clear distinction in their analytical foci.

Case A focuses on the whole, on enacting a value chain for medicine that integrates multiple agents around a shared vision. ColaLife has nurtured individual parts of the system, such as retailers, wholesalers, and a pharmaceutical company. The focus was, nonetheless, on the whole, on the big picture. By constantly assessing the whole, they could zoom in and then zoom out again to quickly identify next steps and act accordingly. Success of their Sustainability Hack is associated to the entire system delivering a function, not the performance of individual components.

Case B, on the other hand, after analysing the whole, identified a form of filling a gap within the system: using artificial intelligence to reveal and report suspicious public expenses. Success is measured as the performance of the 'added function', of the gap that has been filled. OSA aimed at repairing a part of a complex system, which could then cause multiplying – and rather unexpected – effects over other components of the system. For example, by focusing on a part of the system, they had the expectation of inducing a positive feedback loop: the more the civil society learns about and engages with the public administration, the more it will likely want to do so. The focus is, therefore, on the part that may have a big impact on the whole.

Public Perception

Cases A and B generate very distinct public perceptions. The former adopts a stance of non-rivalry. The principle is that when the system acquires a shared vision, empowers agents with strong connections, and when each agent is able to capture value, then ColaLife can withdraw and leave a self-sustaining legacy. It acts as a trusted partner, who does not aim to be part of the value chain, and as a result is not seen as a potential threat to the operations of local individuals or organizations.

OSA is, instead, seen as a contentious outsider. By revealing suspicious expenses, OSA is inherently antagonistic towards the politicians they investigate. However, being contentious does not necessarily mean being confrontational. OSA has made ethical standards explicit among all collaborators, to ensure the group would perform their desired function without compromising the credibility of the project. It is meant to be independent of political parties, simultaneously shying away from vested interests and from deliberately picking fights against politicians.

Role Performed

Whereas ColaLife aims at being as invisible as possible, OSA attempts to be as visible as possible. ColaLife designed, mobilised and organised the components and interactions of a value chain around a vision shared by local agents. From the outset, the basic premise was of not inserting itself into the system, since the funded projects – and ColaLife's presence – in Zambia were only temporary, but their legacy should be long-lasting and resilient. The organisation supresses its brand: it appears nowhere on the product or the advertising. Caregivers, retailers, wholesalers and distributors are unaware of its existence. Furthermore, it has progressively phased-out, by strengthening the robustness of local agents and their connections. As described by A1, "*everything is about what happens when we leave, it is about planning for our own demise*".

OSA, on the other hand, is centred around the idea of promoting political participation by tapping into opportunities opened up by emerging technologies. They have a clear dissatisfaction with the disenfranchisement of the civil society in political processes and decision-making. They understand that civil society's engagement is often limited to sporadic elections of representatives, instead of actively engaging with daily political matters. The group thus aims at being as active and open as possible: it is meant to be a decentralized and diffused initiative, progressively integrating more collaborators and expanding its scope to cover multiple sources of public expenses.

Homeostasis

Cases A and B have different approaches towards the homeostasis of the systems they act upon. Homeostasis is the inherent ability of a system of maintaining stability and coherence of its functions (Meadows, 2008; Blizzard and Klotz, 2012). Systems spontaneously present mechanisms for self-organisation, self-reproduction and, consequently, resistance to change (Kauffman, 1995). Deliberate attempts of changing functions of a system can thus benefit from, or stress, its homeostasis.

Case A purposefully benefitted from self-organised systems for fast-moving consumer goods. They have from the outset planned to understand and tap into the existing components, interactions, and value flows of this existing system to deliver another function: access to diarrhoea treatment. As described by A2: "*we are not fighting against something chaotic, we are playing along with it. If there is a flood, water will go where it goes, and you can build a damn, or you can dig a riverbed, but it will go where it goes, and you are actually far better off observing where it goes and then trying to arrange to go with it. We were learning to observe and go with, instead of fighting*".

OSA, on the other hand, aimed at stressing the homeostasis of the system they acted upon. Undesired characteristics of representative democracies are self-reinforced, and may constraint the incorporation of mechanisms for political participation. More civic participation thus means opposing to engrained characteristics of a political system that purposefully or not disenfranchises citizens. Therefore, by creating an open artificial intelligence to engage with daily politics, this civil society group created a momentum to persistently stress characteristics of the dominant political system that lead to exclusion and to which they vehemently oppose.

Nature of the Action

The nature of the actions performed by Cases A and B were different from the outset. Whereas Case A was designed as a process since the beginning, progressively phasing out to discrete sets of actions, Case B started with relatively discrete sets of actions, which then became processual throughout time. The Sustainability Hackers of the former left their jobs to pursue their idea when it was still very incipient: "*I was on a contract with the government at the time, she was doing consultancy, and we decided we would stop what we were doing and give ourselves a year to see if we could make something happen... we didn't really know what we were doing*" (A1). After conceptually exploring their ideas, they designed, received funding and implemented a process, a quasi-experimental trial that lasted a year, and subsequently scaled up to many other areas. When the value chain was set up and became more independent, the processes were replaced for more discrete sets of actions, phasing out from an intense engagement to only providing remote support for value chain members.

Differently, Case B only started off after receiving endorsement for their idea through a crowdfunding campaign. Prior to that, they had only performed a quick pre-analysis to verify the validity and feasibility of what they were proposing. The proposal was defined as a discrete project, lasting for only 2 months, and aiming at developing and deploying an artificial intelligence to reveal suspicious public expenses in the so-called Quota for Parliamentary Activity. This period was quite intense, but their commitments were time-bounded by the

campaign – as described by B2, "*we had to promise something that people would see results in as little as 2 months*". The group also leveraged discrete events that are common among computational geeks, such as coding sprints and Hackathons. After this period, the core members of the group – that were fully dedicated and funded by the project – decided to continue their engagement and focus on promoting a perennial and stronger engagement of the civil society with the public administration. It has, therefore, evolved from a relatively discrete set of events, to a more processual initiative.

Technological Intensity

The Cases have different technological intensities: Case A tends to low, while B tends to high. The former did not require the generation or diffusion of technologically-intensive solutions. The product that was created by the project, i.e. Kit Yamoyo, has been recognised for its very innovative design, which resulted from the human-centred design conducted during the trial. However, it did not require sophisticated technologies. The combined treatment of ORS+zinc, in fact, is not protected by intellectual property rights, and is very simple and cheap to be produced. The same applies to the packages used, whose materials were not sophisticated. The differentiation was, therefore, in a design adapted to the contingencies of the users and the distribution chain. Furthermore, the operationalisation of the value chain emulation did not require the deployment of very novel technologies either: ColaLife leveraged the resources that were available in low-income regions, such as widely accessible information and communication technologies (e.g. tablets, for collecting data).

Alternatively, the great differential of Case B was seizing opportunities that were only made possible by the development and deployment of a key-enabling technology, i.e. artificial intelligence. The auditing of public expenses already existed, led by governmental agencies and other civil society groups, but due to their limited operational and technological abilities, their capacity of processing large datasets was very restricted. Therefore, by developing an AI robot, OSA could contribute to the overall performance of the system, by revealing and reporting suspicious expenses that would otherwise pass unnoticed. Furthermore, their governance and operationalisation were also more technologically intensive, using a diverse source of open-source tools (e.g. GitHub) to collaborate and communicate among themselves and with their stakeholders.

Scalability and Trickle Down

Both Sustainability Hacks are scalable. Scalability can be seen as a spectrum, ranging from easily replicated (i.e. organically trickling down the system) on one side, to requiring adaptation

and systematic efforts to promote expansion, on the other. Whereas the Sustainability Hack of Case A has sets of principles and designs that can be adapted but not necessarily replicated to other settings, Case B presents a high degree of replicability.

For Case A, it seems clear that reduced access to medication, even simple over-the-counter measures like ORS+zinc, limits good healthcare in remote areas. Emulating the value chains of goods that already reach these areas has shown to be successful in overcoming this barrier. When the emulated value chain in Zambia becomes progressively more resilient, it is likely that expansion of access to ORS+zinc to other regions within the country can happen fairly organically. However, organic trickle down seems limited to Zambia and to ORS+zinc. The principle of value chain emulation can be incorporated into other scenarios, but that would require a higher degree of adaptation to different contexts and contingencies. An active and coordinated engagement of agents in other regions, combined with a greater understanding of the process that occurred in Zambia, can provide a good starting point for those who wish to adapt it to other contexts and to provide access to other healthcare products[38].

Case B, alternatively, has developed an open-source artificial intelligence that can be deployed in other geographical contexts, since the technology presents very minimal barriers to entry and may require little customization to be applicable to other geographical and political settings. In fact, given this Sustainability Hack has an open-code practice and there is no ownership involved, the possibilities of scaling up become fundamentally distributed. Expansion is difficult to track, since initiatives do not need to directly involve the original team. Furthermore, virtually every public expense can be audited by the civil society, so long as there is governmental open-data available. These characteristics indicate that the Sustainability Hack can trickle down, without a structured, systematic, and coordinated effort.

5.6. The Process of Gradually Including the Remaining Cases

The previous section has introduced the Lists of Similarities and Differences, which combine results from Chapter 4 with the analysis of Cases A and B. These lists were the starting

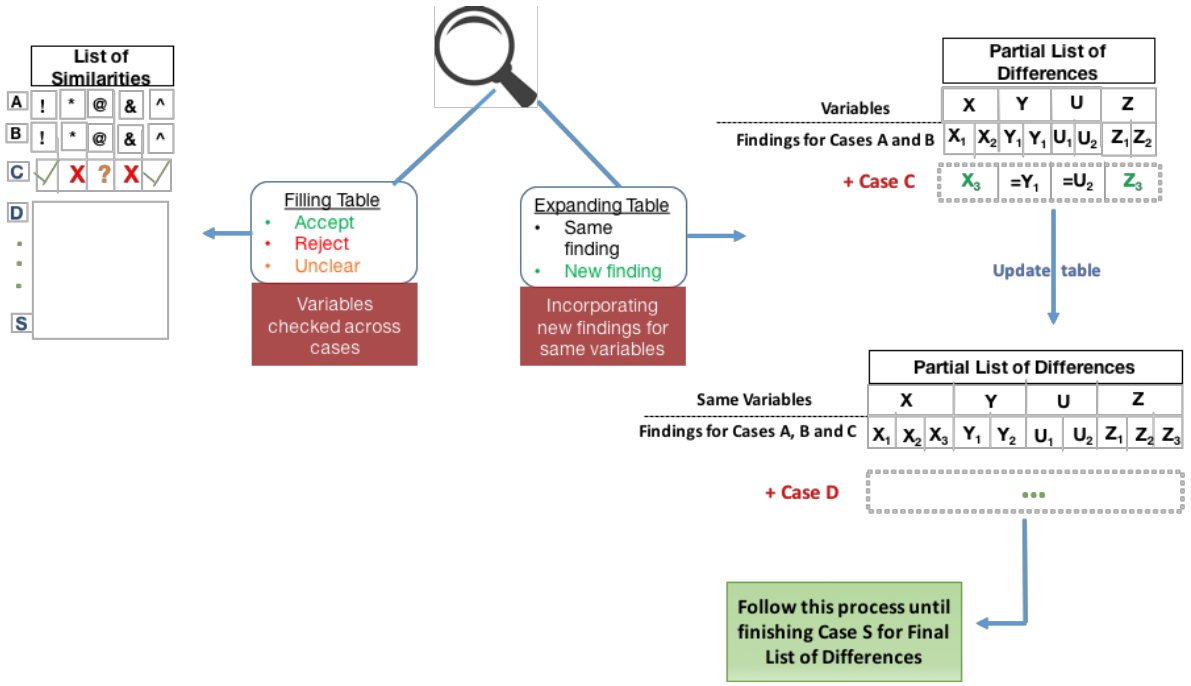
[38] In 2018, after receiving an award from IBM, I wrote a 'playbook' (with my supervisor, Steve Evans, and another PhD student, Cassi Henderson) that can help to scale up this successful initiative to other low-income regions. The framework on how to set up value chains for over-the-counter medicines outlines a stepwise process, scrutinizing what are the value chain focal areas, what they entail, how they are meant to be addressed, and the expected timeframe for each activity. These frameworks delineate critical success factors observed for value chain emulation, which should take into consideration when scaling it up to other geopolitical settings. This report will soon be published by IBM. It will be freely available and an earlier draft has already been used for outreaching, i.e. finding agents, starting in Ghana, who can use the playbook and tap into the existing networks of ColaLife to emulate value chains of fast-moving consumer goods to provide access to medicines. See: http://www.eng.cam.ac.uk/news/sustainability-Hacking-better-healthcare-system [Accessed: 13 January 2019]

point for the inclusion of the remaining cases. Their contents were coded according to the variables revealed up to this point. In other words, the remaining cases were individually and gradually cross-checked against the List of Similarities and the List of Differences.

Each similarity was verified and the results were colour-coded[39], depending if they were confirmed, non-applicable/unclear, or rejected. The analysis here was simply verifying validity; i.e. do they apply to all cases? Why?

The variables differing across cases, however, were expanded depending on the results of the verification process. This was a stepwise process, building upon previous findings. The analysis of new cases could then add new findings to a variable, in case they have not yet been captured by the analysis of the previous cases. For example, if Case C, for the variable "Systemic Change", did not match the options of "Emulating value flows" or "Capturing missed value", that were revealed by Cases A and B, then a new column was added to describe the systemic change it perpetrated. This was gradually performed for all cases within the sample, as illustrated in Figure 21.

Figure 21: The Stepwise Process for Inclusion of Cases



[39] As described in a previous section, green indicates confirmation, i.e. that the variable is undoubtedly confirmed by the case; yellow signalizes lack of clarity, i.e. there is a high degree of subjectivity to interpret, or if the variable is not applicable to the case; and red indicates rejection, i.e. that the characteristic is undoubtedly refuted by the case.

This section will demonstrate how this stepwise approach was conducted for Case C, in order to clarify not only its results, but most specially to illustrate how the process was diligently conducted. It starts by providing a brief description of the case. This is followed by the verification of the validity of the List of Similarities. Finally, it demonstrates how the List of Differences was analysed for Case C, focusing particularly on what findings were added with the inclusion of this case.

5.6.1. Description of Case C

The Sustainability Hacker leading this case is a Dutch physician, who describes herself as "*not feeling at home in a white coat*" (C1). Besides her medical degree, she also went to art school, which according to her made her "*look beyond the first possibilities*" (C1). In the mid-1990s, she became an abortion provider in the Netherlands and volunteered for Greenpeace as a ship's doctor. When working for the latter, she had seen "*many women brought in with severe bleeding*" (C1) due to illegal abortions. That was the moment she noticed the "*connection between the law and the fact women are dying*" and that the "*law does not stop women from needing or having abortions, it just makes them unsafe*" (C1).

In fact, according to estimates from the World Health Organization, there were, in the period ranging from 2010-2014, an average of 55.7 million abortions per year worldwide. Out of these, approximately 45% were unsafe – and 97% of all unsafe abortions were in developing countries (Ganatra *et al.*, 2017). Abortions are increasingly interpreted by academics, policymakers and international organisations as a serious healthcare challenge, instead of merely as a contentious, moral issue. Illegal abortions configure as one of the leading causes of maternal mortality (Sedgh *et al.*, 2012); about one in eight pregnancy-related deaths worldwide (Maclean, 2005). According to the Guttmacher Institute[40], one in three women in the world will have an abortion in her lifetime, and at least 22,800 women die worldwide per year as a result of complications of unsafe abortions. Between two and seven million of the ones who survive will sustain long-term health damages, such as sepsis, uterine perforation, and injury to other internal organs.

Noticing the scale of the problem and the legal constraints preventing access to safe abortions, the founder asked the captain of Greenpeace's ship: "*how can we create a space where the only permission a woman needs is her own?*" (C1). The captain replied with a provocative thought: "*if you had a Dutch ship, you could take women aboard and sail to international waters, legally helping them with a safe abortion*" (C1).

[40] Induced Abortion Worldwide". *Guttmacher Institute*. 2016-05-10. [Accessed 15 October 2018]

This idea led her to kick-start Women on Waves, in 1999: a group of activists providing safe abortion services to women residing in countries where abortions are illegal. On a vessel in international waters, 12 miles offshore, the laws of the flagship country apply. By renting Dutch boats, Women on Waves only has to conform to the laws of the Netherlands when in international waters – hence, abortions are legal. Once pregnant women aiming to terminate their undesired pregnancies go aboard the boat, they sail to international waters accompanied by health professionals volunteering for the organisation. They are then provided a safe abortion through abortive pills, given to them in the boat's licensed mobile clinic, i.e. "*a shipping container, outfitted on the inside with a treatment room*" (C1). According to C1, "*we did not need a full clinic to give abortion with pills, but we built it to help us get the [Dutch] medical license*".

In the clinic, they provide a combination of two pills: Mifepristone and Misoprostol. Both have been on the Essential Medicines List of the World Health Organisation since 2005. When combined, these pills are 95% effective and can potentially save thousands of lives. Only "*1 in 500.000 women dies from a safe abortion. That is way safer than giving birth and equally safe to a miscarriage*" (C1). C2 explains that: "*the best way is to first use the Mifepristone, which works against the pregnancy hormone... This has the effect that the foetus stops growing and sometimes it dies. Then it gives the signal to the brain: miscarriage is likely going to start. The brain then starts to make the uterus more sensitive for the second medicine, Misoprostol, which induces contractions [i.e. to push out the foetus] … If you do not take Mifepristone, you can still do the medical abortion with Misoprostol alone. But you need much more of these pills, it gives more side effects, takes longer and it is a little bit less effective*".

Whereas Mifepristone is often unavailable, Misoprostol is found in the pharmacies of most countries, including where abortion is illegal. Its wide availability is associated to the fact that provoking abortions is Misoprostol's side-effect, not its intended aim. Its therapeutic indications are, instead, of preventing and treating stomach ulcers and postpartum bleeding due to poor contraction of the uterus. It can, nonetheless, be used off-label to safely induce abortions, with 94% of success rates if properly taken within the first 12 weeks of pregnancy. In other words, using it without Mifepristone is not the best form of terminating a pregnancy, but it is 'good-enough' when the combined treatment is unavailable. In the unlikely case the pill causes worse side-effects than expected, or in case of too much pain, the woman can go to a doctor where she resides and "*say she had a miscarriage, since the doctor cannot know the difference*" (C2) to an abortion induced by Misoprostol: the symptoms are the same.

The first campaign happened in 2001 in the Republic of Ireland, the country which had the most restrictive abortion law in Europe. This was funded by an art grant, that covered the

expenses to build the mobile clinic, and by donations from 10 women sponsoring other costs, such as renting a boat, purchasing medicines, and other resources needed. Since then, Women on Waves has launched several campaigns, with volunteers sailing to several other countries where abortion was illegal, such as Poland, Portugal, Morocco, and Ecuador, to cite a few.

Although the original idea was limited to providing abortion services in international waters, after the first boat campaign, they realized the initiative could go beyond service provision. As described by C1, "*I was totally scared, overwhelmed with what happened. All main news agencies were there. CNN, New York Times, BBC... It was huge in the media. So, we suddenly existed! Suddenly there was the Abortion Boat and everybody heard about it… We realised this actually has a lot of other potentials beyond just doing abortions*". The goal of the organization has thus expanded from simply providing safe, non-surgical abortions for women who live in countries where abortion is illegal. It also includes raising awareness and stimulating changes in legislations that they consider restrictive to women's rights and, ultimately, to their health.

Aiming at scaling up its impact to a greater number of women worldwide, a twin-organisation was created in 2006 to help women accessing abortive pills up to 9 weeks of pregnancy where no safe options are found. As described by C1, "we have been able to find the legal loopholes to make this possible. Governments can stop the ship, but they will never be able to stop the internet". Also registered as a non-profit, it provides support in several languages: "*we have Spanish, Portuguese, Polish, Arabic, German, Italian, French, Japanese and Korean*" (C3). Women hoping to terminate their pregnancies first go through an interactive web-based questionnaire, followed by interactions with non-medical volunteers. If needed, they are referred to an online consultation with a medical doctor. If no contraindications are identified, women receive a package containing Mifepristone, Misoprostol, and a pregnancy test, most often delivered to them by courier or by mail. Women are asked to make a donation of approximately 70 euros, but they receive the package regardless.

When medicines get increasingly held by customs, they send instead a medicine for rheumatism, i.e. Arthrotec. This contains an inner layer of Diclofenac, to address the swelling, and an outer layer of Misoprostol, to prevent side-effects of the former on the stomach. This medicine is sent "*together with a prescription of a Dutch doctor*" (C2) to get through customs. They then inform women to "*keep Arthrotec under their tongue and let it dissolve. When they see that the outer layer [Misoprostol] is fully dissolved, then they have to spit out the rest*" (C2).

The twin-organisations have to be resourceful, adapting their approach towards different contextual characteristics and to diversify their mechanisms of promoting abortion rights. For example, recently, they experimented with drones for delivery of medicines. They recognise

this transportation mechanism is not highly efficient, but attracts public attention and raises awareness for the cause, especially in regions experiencing a growing momentum for legal change. Where the courier system is not efficient and packages will unlikely arrive on time, but Misoprostol is found in pharmacies, women are instructed on how to purchase and use the medicine, instead of receiving the package at home. In Tanzania, they had to adopt a different approach, since Misoprostol "*was not widely available in pharmacies*" (C1) and courier systems were not efficient. They assisted grassroots groups to start their own pharmacies: "*[these groups] hired pharmacists and started their own pharmacies to distribute, amongst others, Misoprostol. There were really small women's groups that hadn't been doing that before and, right now, they have 8 pharmacies across Tanzania*" (C1). There are also other exceptional cases, such as Brazil, where Misoprostol is prescription-only and dispensed exclusively in hospitals. Authorities have been checking and barring couriers with medicines from abroad. Women on Web then informs Brazilian women to exploit another legal loophole: it is legally permitted to receive a safe abortion, in a public hospital in Brazil, if the woman claims she was raped. She can then, in principle, be provided a safe abortion by a medical doctor, without being harassed by the police or other authorities.

Besides providing abortion services, Women on Waves/Web have also published several academic articles with their data, aiming at nudging top-down change, at the policy-level, as well as bottom-up change, by actively supporting grassroots movements. Measuring outcomes of abortion provision is relatively objective (e.g. over 100,000 emails responded/year, more than 6000 packages delivered/year, 99% of women reported high satisfaction with the service). Outcomes of awareness and political change are, on the other hand, more subjective. For example, in a campaign in Portugal, Women on Waves faced one of its most contentious political backlashes, which unpredictably contributed to advocate for deep-rooted legal changes. When sailing towards the Portuguese coastline, the captain of the Abortion Boat was informed the local "*government had sent two warships to stop it from sailing into national waters*. *It was clear that the government was violating all international and national agreements. A country can only refuse access to national waters when there is an imminent threat to the security of this country"* (C1). The violation is even more evident given the boat was Dutch, and both the Netherlands and Portugal abide to European Union laws on freedom of movement and residence. C3 describes that "*in the beginning we were very pissed off, thinking the campaign was failing, because the ship could not get in. But then, at a certain point, we realised that that was the best thing that could ever happen. We got media coverage from everywhere. The warship was even more spectacular than the abortion boat itself*".

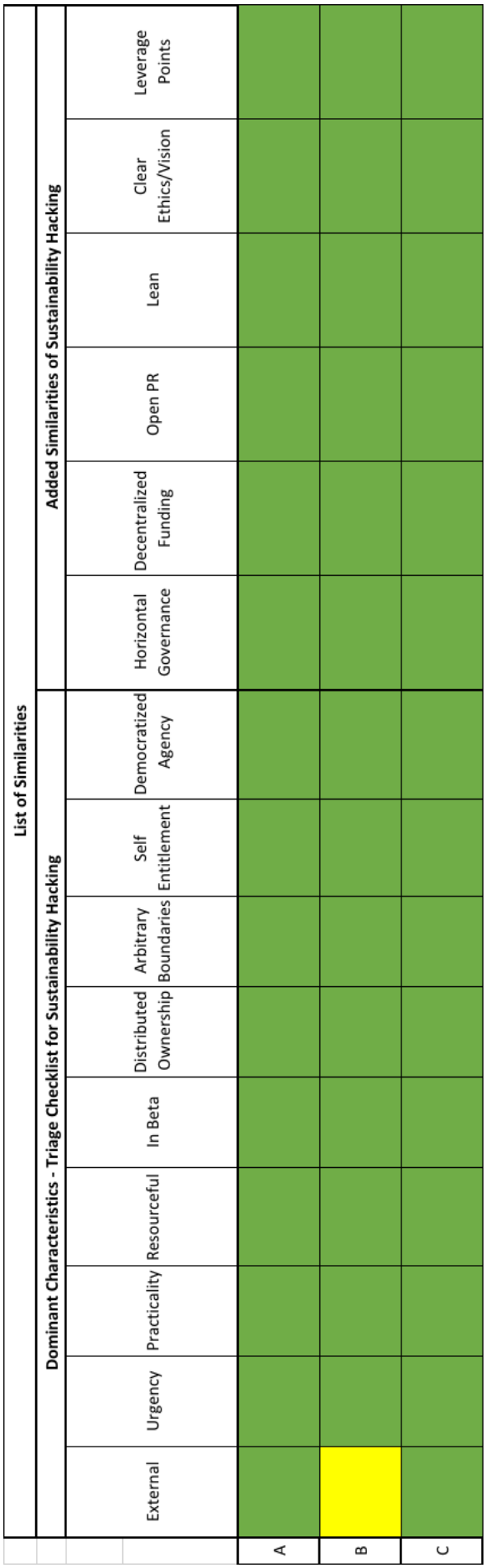
The founder then leveraged the opportunity by presenting, in an open TV channel in Portugal, step-by-step instructions on how local women could autonomously use the abortive pill found in pharmacies. "*After this was announced, and also uploaded to our website, it was all over the media, we could barely manage the number of emails… The decision to publicly announce how women could do an abortion themselves with Misoprostol on live television was a very important change in the strategy, because it suddenly meant it was out of control of the medical professions and that it is something that women can actually handle themselves*" (C1). Women on Waves brought a case against Portugal to the EU courts and won. More important than the judicial battle was, nonetheless, the uproar and mobilization of local grassroots movements. That is claimed to have contributed to a far-reaching change: two years after the campaign, Portugal legalized abortion. "*The campaign had a huge positive impact in changing the law, you cannot just attribute to someone that success, but of course the campaign was very important*" (C4), creating momentum and social mobilization in the country. In C1's words, "*in our case, we know bypassing [laws] is actually facilitating legal change as well…it catalysed the possibility for the mainstream political organisations to take a stance and because they also saw the outrage of the people that the military was actually intervening with something like this. It really supported the mainstreaming of abortion discourse in Portugal".*

5.6.2. The analysis of Case C: Lists of Similarities and Differences

The tables in this section demonstrate a partial analysis of the results, after aggregating the analysis of Case C to the ones of Cases A and B. The stepwise process for gradually including cases, described in the beginning of this section, is thus depicted here for Case C.

All traits of the List of Similarities were verified and undoubtedly confirmed by Case C, as demonstrated in Table 20. Since there is no doubtful or wrongful interpretation compromising the validity of these traits – and these have been previously elucidated with data from Cases A and B – for brevity reasons this section will not present data from Case C backing up the analysis of these traits.

Table 20: List of Similarities After Adding Case C



List of Similarities	Dominant Characteristics - Triage Checklist for Sustainability Hacking										Added Similarities of Sustainability Hacking						
	External	Urgency	Practicality	Resourceful	In Beta	Distributed Ownership	Arbitrary Boundaries	Self Entitlement	Democratized Agency	Horizontal Governance	Decentralized Funding	Open PR	Lean	Clear Ethics/Vision	Leverage Points
A															
B															
C															

Concluded a partial analysis of similarities, Case C was analysed against each feature of the List of Differences. As demonstrated in Table 21, Case C had similar findings either with Case A or B in what regards the following variables: “Function”, “Focus within system thinking”, “Public perception”, “Role performed”, “Homeostasis”, “Nature of the initial action”, “Technological intensity” and “Scalability and Trickle Down”. However, the variables “Systemic Change” and “Ultimate Goal” provided new findings, different from Cases A and B. A column was then added for each of these new features, as indicated in red. For brevity, this section will only detail and illustrate with data from Case C the analysis of the features that were introduced at this stage, namely: “exploiting loopholes” and “confronting undesired rules”.

Table 21: List of Differences After Adding Case C

	List of Differences																				
	Systemic change			Function		Ultimate goal			Focus within system thinking		Public perception		Role performed		Homeostasis		Nature of the initial action		Technological intensity		Scalability and trickle down	
	Emulating value flows	Capturing missed value	**Exploiting Loopholes**	New	Enhanced	Enacting a system	Filling a gap	**Confrontation**	Tends to the whole	Tends to the parts	Non-rivalry	Contentious outsider	As invisible as possible	As active as possible	Benefits from	Stresses	Tends to processual	Tends to discrete	Tends to low	Tends to high	Tends to adaptation	Tends to replication
A																						
B																						

Exploiting Loopholes

At the core of the systemic change of Case C is the exploitation of loopholes in the rules of the game. The Sustainability Hacker of this case has kick-started the initiative by exploiting the 'legal vacuum' of international waters: offshore the coastline of countries where abortion is illegal to legally provide abortion services. They have subsequently scaled up their impact by exploiting another legal loophole, the one of providing medical information through a helpline – and, where off-label abortive pills could not be obtained, sending them by post with the prescription of a Dutch doctor. The legal grey area here is that, while telling women how to do an abortion may be illegal in some countries, providing scientific information is not, independently of the region where they are. As described by C1, the volunteers in the helpline "*would not say 'you can do an abortion' but instead they say 'scientific research has shown that'...*".

Furthermore, the organisation has identified and tapped into several context-specific loopholes. That includes instructing women to purchase Arthrotec in countries where this medicine is found, but Misoprostol alone is not. Arthrotec is a medicine for rheumatism that has an inner layer of Diclofenac, but the outer layer if Misoprostol: then women are instructed to let the outer layer dissolve and spit out the rest. An even more context-specific loophole is the one exploited in Brazil, where women are 'scientifically informed' of the possibility of legally receiving a safe abortion, in a public hospital, if they claim they were raped.

Despite being trialled in many places, the founder and other members of the organisations have never been arrested: "*we have constant legal challenges, and we have had many court cases. But, what we are good at, is to analyse the possible legal risks beforehand. Yes, we pursue loopholes, but with them we are also kind of stretching the laws sometimes, so that we have a really good case that what we are doing is in fact legal, that it is within the legal frameworks" (C1)*

Confronting Undesired Rules

The Sustainability Hacker of Case C is working with a very controversial and morally contested issue, i.e. abortion rights. This contrasts with Case A, whose goal of providing access to ORS+zinc is undisputed: there is no implicit reason for dissent. It also differs from Case B, whose objective of revealing suspicious public expenses only contests the interests of an influential minority involved with politics and with vested interests. Case C directly confronts social groups with different sets of values (e.g. religious groups) and the rules that constraint women from receiving a safe abortion.

Their confrontation of formal rules is related to the identification and exploitation of loopholes and vulnerabilities within legal frameworks. They also antagonize informal rules, by adopting a fierce and controversial approach to boost its impact in terms of awareness and social mobilization. Among the many examples is the campaign in Ecuador. When Women on Waves reached the country, they realized local groups they had partnered with had not had much press coverage for their activism, so they needed to do something big to raise awareness. They have then hung an abortion banner to the Virgin [i.e. a Catholic statue in Quito of Virgin Mary]. The press release was 'The occupation of The Virgin'. Despite the fear of local groups of going to jail, the founder, in her own words, convinced them that "*there is no such thing as bad press, except for an obituary… when people move beyond the fear of backlash, they can do actually much more than they were made to believe. What I learned was that you always have to have an offensive strategy in order to create change, because the fear of backlash is the same of self-censorship*" (C1).

This case is thus driven by the legal confrontation and resistance towards the rules they strongly oppose. Since their approach is based on loopholes, their actions are, consequently, limited by their existence and identification, as well as the contingencies involved in their exploitation. In C1's words, "*there is a natural limitation to what we can do, which are the countries where we can do the campaigns, etc. [Our actions] are limited by laws, by the logistics, by all these things*".

5.7. The Complete Cross-Case Analysis

The remaining cases were analysed, following the stepwise approach illustrated with the inclusion of Case C in the previous section. This Section presents the final analysis, aggregating all cases within the sample. This consists, respectively, of the Lists of Similarities and Differences.

5.7.1. Similarities

The List of Similarities has cells in green (i.e. confirmation), yellow (i.e. lack of clarity or subjectivity), and red (i.e. rejection), portraying the final analysis, resulting from the incorporation of Cases D to S to the Table 22. The variables were explained in a previous section of this chapter. The rationale for the ones in green and yellow were also already illustrated. Therefore, for brevity, this section only describes a variable in red, i.e. 'Horizontal Governance', with the intent of justifying and illustrating the reasoning for 'rejection' that has appeared for the first time with the inclusion of Case F, and observed again with cases I and P.

Table 22: The Complete List of Similarities

	List of Similarities														
	Dominant Characteristics - Triage Checklist for Sustainability Hacking									Added Similarities of Sustainability Hacking					
	External	Urgency	Practicality	Resourceful	In Beta	Distributed Ownership	Arbitrary Boundaries	Self Entitlement	Democratized Agency	Horizontal Governance	Decentralized Funding	Open PR	Lean	Clear Ethics/Vision	Leverage Points
A															
B															
C															
D															
E															
F															
G															
H															
I															
J															
K															
L															
M															
N															
O															
P															
Q															
R															
S															

Horizontal Governance

Horizontal governance is a recurring feature across the sample, with the exception of Cases F, I and P that cannot be characterised as horizontal. Case F, i.e. Vigie Aqui, was conducted by a business holding which has over 80 employees. The core of their activities consists of for-profit services, provided by their incumbent companies and start-ups. In addition, the holding pursues not-for-profit projects, which according to F1 differentiates it from most businesses:

"*we are a company, not a non-profit, but we describe ourselves as in sector 2,5*". Their Sustainability Hack – a browser plug-in that highlights names of investigated politicians every time they appear, informing what they are being prosecuted for and the verdicts they received – was performed as a non-profit project: "*everything is transparent to show it is a social project, like the ones of the third sector itself*" (F2). Even though the Sustainability Hack itself is not owned by anyone and can be replicated elsewhere and by others, its operationalisation was undoubtedly controlled by the holding. They cooperate with others, including universities, but the governance was determined by (and aligned with the interests of) the holding.

The governance of the Sustainability Hack of Case I, i.e. Goats for Water, was also centralized since its early stages. Despite its constant engagement with multiple stakeholders, the responsibilities for the Sustainability Hack lie on a few individuals, most especially the founder. She initially developed it as a charitable initiative to provide solar-powered water pumps and solar home lighting systems to poor, rural regions in Pakistan. Her target population is cash strained and, hence, cannot purchase diesel to fuel pumps and electricity – let alone to purchase a solar-powered technology. According to I1: "*I wanted to help this community and I was comfortable with this being charity. But if I could recover that money then I knew that I could work in more villages instead of sinking a huge chunk of money into one... Then I played with the idea of getting monthly payments all of that but just seemed really inefficient. Then we saw that there are lots of goats and I asked them if they would be able to give me goats and they said 'yeah'"*. She has then bartered the pumps for goats and sold the latter during the festival Eid-ul Azha, when the price for them "*go up 3-4 times*" (I1). With this, she has more than recovered the money spent for the solar technology. At that moment, she realised this Hack could be converted into a permanent service to communities who, despite having assets, such as goats, are either excluded from formal markets or exploited by intermediaries: "*that is when the idea came together that this is a sustainable, viable model… we launched something called 'Pay as you Goat'. So, instead of paying cash, they can just pay in goats or a combination of cash and goats because cash is the constraint. We want to scale this model to any commodity that rural communities need to improve their lives*" (I1). She has then created a social enterprise, with a team working on developing and scaling up the model and with the support of an accelerator. The model and principles are not protected – in fact, the organisation has freely transferred their knowledge to promote the uptake of their model in Somalia. However, it seems clear that the decision-making and operationalisation of this Hack was rather centralized.

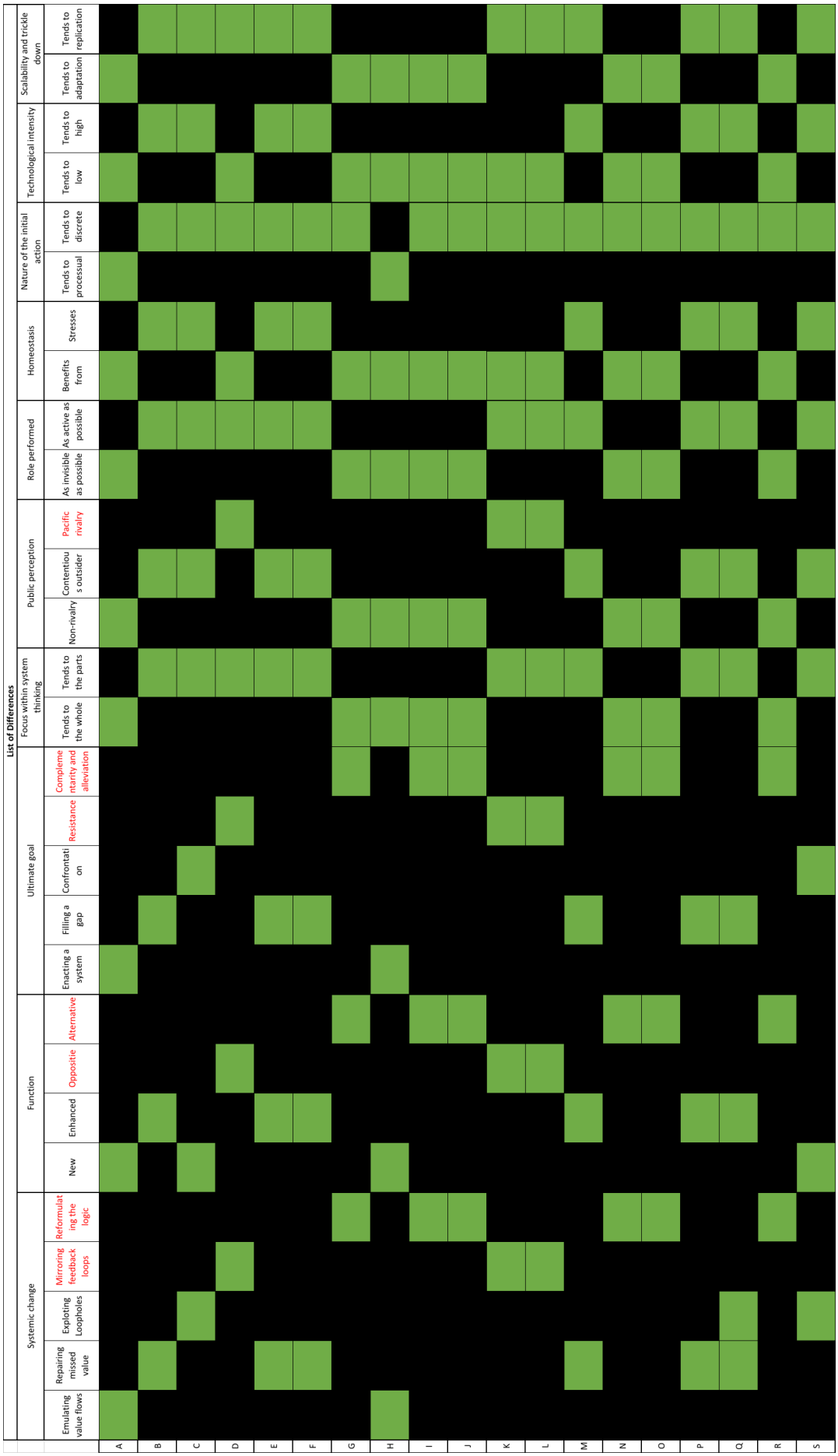
Despite closely working with others, and having an open model that can be replicated in other places, governance of Case P is still centralized by the Sustainability Hacker. Field Ready, realised that humanitarian efforts rely too much on imports. However, low-income and

relatively unstable regions often overtax imports and have poor logistics, leading to long time lapse for delivery. As described by P1, *"aid organisations and NGOs realised that just relying on imports for their essential items was essentially flawed and so a lot more focus has been put on procuring things locally. If you make it locally you avoid the tax, you avoid the lag time from order to delivery, you avoid all of the procurement challenges that come from ordering from a foreign company and customs officials here [in Nepal] kind of expect payments just to let things in the country".* When aid is urgently needed, such as after the earthquake in Nepal in 2015, these difficulties compromise basic relief efforts. Field Ready has then undertaken the role of a service provider, trying to repair "*a system that, to us, looks broken*" (P1) by tapping into the potential of 'localization' and decentralization of the production of important humanitarian materials, machines, and replacement parts through additive and digital manufacturing, like 3D printing. The non-profit then acts as a supplier of manufacturing services to organisations working on-the-ground. However, it is progressively moving towards a more horizontal approach, by acting as a research hub focused on transferring knowledge and technologies for locals: *"the ethos of Field Ready is not that we want to grow and grow and grow. We want to do these things and transfer them. We do not want to ride the wave of making a 1000 airbags or whatever. We would rather see local organisations do that while we work on the next step... Actually, I think our role is not making stuff per se, it is not just being a producer. It is more like we are leading with prototyping, with design, with proofs of concept, with evidence to get organisations on-board"* (P1).

5.7.2. Differences

The List of Differences portrays final results of the stepwise process for inclusion of cases D to S. Since most findings have already been presented and justified with data from Cases A to C, this section focuses solely on the new ones, i.e. those that were only incorporated to the Table through the analysis of cases D to S. These are coloured in red in Table 23 and scrutinised in the following.

Table 23: The Complete List of Differences



Mirroring Feedback Loops + Opposite + Resistance + Pacific Rivalry

A new set of findings were identified, through the analysis of cases D, K and L, for the variables 'System change' (i.e. inclusion of 'Mirroring Feedback Loops'); 'Function' (i.e. 'Opposite'); 'Ultimate Goal' (i.e. 'Resistance); and 'Public Perception' (i.e. 'Pacific Rivalry'). They will be scrutinised below, providing evidence from these 3 cases.

At the core of the systemic change of Cases D, K and L is the idea of mirroring feedback loops. These systemic characteristics happen when the effects of a small disturbance on a system include an increase in the magnitude of the perturbation. In case of positive feedback loops, the more something happens in a system, the higher the likelihood of it happening with greater intensity. This characteristic attributes homeostasis to a system: its inherent ability to maintain coherence, of resisting to changes. The agents of Cases D, K and L were clearly frustrated with positive feedback loops leading to rather persistent behaviours. For Case D, the more indigenous rights are disrespected, the higher the likelihood of these violations becoming institutionalised and banal to society at large, hence leading to more violations. For Cases K and L, the more people urinate or leave trash in a public space, the dirtier the place will be, and the more socially acceptable it will be to urinate or dispose waste in that location.

At the core of these Sustainability Hacks was an attempt of mirroring a feedback loop: tapping into the homeostasis and self-reinforced nature of systems, but aiming at opposite results. For Case D, by writing an open letter announcing their mass suicide, the indigenous population aimed at shocking the civil society and public authorities. That (consciously or not) stressed the system, generating a momentum to mirror a feedback loop: the more people became aware and concerned about their rights, the more their rights could be preserved. For Case K, by installing tiles of Hindu deities on walls, these individuals aimed at leveraging people's belief systems. By shaming them in the eyes of a God, this Sustainability Hack has stressed self-reinforced behaviours, leading to the reduction of urination in the location of the tiles. Then, the same principle applies: the cleaner the place is, the more people will refrain from urinating there. Case L adopted a different heuristics of Case K, albeit for a similar objective. It consists of self-organised movements of anonymous volunteers cleaning filthy areas. The cleaner the place was, and the more by-passers saw the efforts of these volunteers, the more people would feel embarrassed to make it dirty again.

By mirroring positive feedback loops, the functions the Sustainability Hacks performed were opposite to the ones that were being delivered by their respective systems. Instead of dirty, they aimed for clean; instead of violation, they aimed for respect. The ultimate goal was, therefore, of resistance towards undesired feedback loops. This tactic among activists aims at raising awareness, changing behaviour and engaging others with their cause. In other words,

they stressed systems without adopting a confrontational approach. They aimed at nudging change in social behaviour by stimulating embarrassment or shame, not anger or resentment; hence, increasing the likelihood of gathering support from multiple agents who hold plural normative and ontological perspectives of systemic change. By pacifically rivalling against other agents, without offending, conflicting or causing hostile reactions in others, they have attempted at leveraging homeostasis in the opposite direction.

Reformulating the Logic + Alternative + Complementarity and Alleviation

A new set of findings were identified, through the analysis of cases G, I, J, N, O and R, for the variables 'System change' (i.e. inclusion of 'Reformulating the Logic'); 'Function' (i.e. 'Alternative'); and 'Ultimate Goal' (i.e. 'Complementarity and Alleviation'). For brevity, these findings will be justified and illustrated only with the examples of the first 3 cases.

Sugata Mitra, the Sustainability Hacker of Case G, has leveraged in the early 1990s the potential of self-organised learning environments – a logic that has been unpacked by the advancement of information and communication technologies. Efforts aiming at expanding access to knowledge tended to rely on providing schooling through a combination of: a classroom, a teacher, a hierarchical structure (e.g. teachers dictating the rules), a pre-determined time for classes, physical materials (e.g. books), and the 'obligation' of attending classes. In his exploratory experiment "Hole in the Wall" (i.e. he dug holes in walls of public spaces in India and left computers there to be freely and autonomously used), the Sustainability Hacker has reverted the logic: there was no classroom, no teacher, no hierarchical structure, no pre-determined time, no obligation and no physical materials. Instead, the youth organised themselves autonomously to learn from the resources available online and from one another. Interestingly, the alternative logic was not thought through before the experiment: "*the main thing about 'The Hole in the Wall' experiment was that it did not have a research question. It had no hypothesis… It was simply to see what happens if a child is in front of a computer*" (G1).

Case I, Goats for Water, started as a one-off charitable initiative which ended up revealing the possibility of tapping into an alternative logic of commercialization to improve the livelihoods of impoverished, rural populations in Pakistan. Despite having assets (i.e. livestock), these populations are often disenfranchised from accessing formal market; and, consequently, are cash strained. That leads to lack of access to products and services that are critical to improve their livelihoods, and to their exploitation by intermediaries. The conventional logic of dealing with this problem is to expand access to cash-based transactions. That often requires combining the provision of financial services and formal markets (e.g. improved banking systems); physical capital (e.g. trucks) to commercialize with vendors in

urban areas; and incentives for new organisational arrangements (e.g. cooperatives), capable of reducing fixed costs and enhancing their bargain power. The Sustainability Hacker has explored an alternative logic: instead of tapping into cash-based commercial transactions, she has explored bartering goats for solar-powered water pumps and home electricity systems.

The Sustainability Hacker of Case J realized that the problem of caste prejudice in India tends to be addressed by law enforcement and affirmative policies to change social behaviour. Discrimination of Dalits is illegal, but it is still common practice. Despite the combination of law enforcement with policies aiming at changing social behaviour, the caste system is highly engrained in the social fabric. Instead of focusing on the logic of law enforcement or affirmative action, Elango, who was the Panchayat Raj President[41] (World Bank, 2000) of the village Kuthambakkam in Tamil Nadu, leveraged a housing policy budget to also address this problem: "*I used it to construct twin houses, one side a Dalit family, the other side a non-Dalit family*" (J1). He convinced the impoverished non-Dalits, until then living in meagre huts, to accept the offer of sharing a public-funded twin house with a Dalit: *"[I told them] 'the space is available only with the Dalit community. If you are interested, instead of 50 houses, we will make 100 houses; 50 houses you people can come and occupy, 50 houses let the Dalit people occupy'…In the history of India, this was the first time in a village where the so-called non-Dalits came forward to live with the Dalits*" (J1). Furthermore, the logic of public procurement for housing construction was also altered. Instead of hiring civil construction companies, Elango, who is an engineer, led the construction of the houses repeatedly hiring the beneficiaries themselves as construction workers. By doing that, he also fostered social capital, trust and solidarity across castes throughout the construction process. As a result, according to J1: "*the generation for whom the houses were allocated, the adults, was of casteist people, whereas the new generation, the children who are coming out now, they are growing and they are not practising caste because they are living with Dalits*".

The functions delivered by these Sustainability Hackers are not enhanced, opposite or new: they are alternative. Sugata Mitra, for example, was clearly interested in improving access to education. This is not a new function: there are many existing efforts promoting access to traditional schooling, and it will be hardly claimed that schooling can be fully replaced by "holes in the walls". His experiment did not enhance traditional educational systems through schooling either. Instead, his Sustainability Hack ran in parallel, delivering an alternative

[41] This is a traditional system of assembly in villages for governance of public matters. It has been institutionalised in 1992, following Gandhian ideals of promoting decentralized forms of government, where the grassroots populations in villages could be empowered to take ownership of their own affairs.

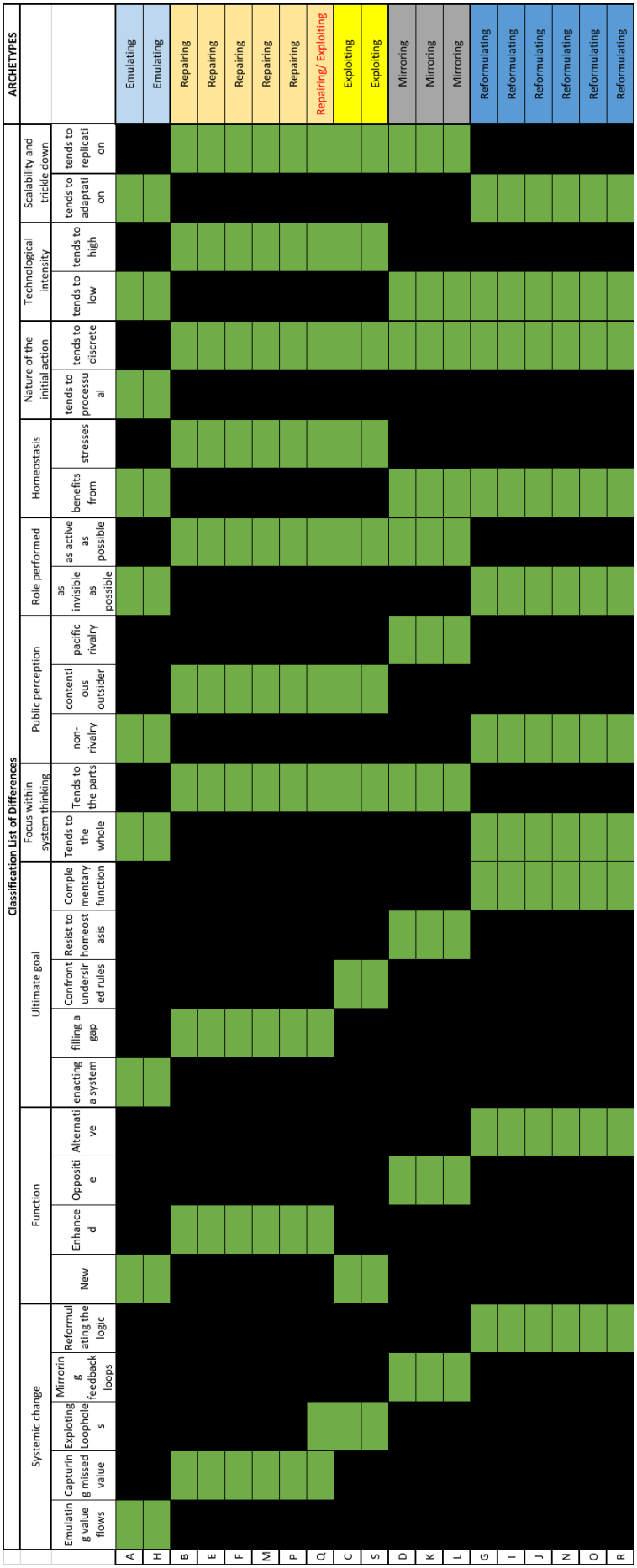
function: self-organised learning environments that can be complementary to schooling, or alleviate the problem when schooling is not a feasible option.

Similarly, it seems evident in Case I that rural populations should not remain excluded from direct access to formal markets and cash-based transactions to rely exclusively on bartering. Goats for Water provided an alternative function, which can be complementary to efforts of strengthening access to financial systems and formal markets, or alleviate the problem in the meantime. Case J also presents similar findings: the function delivered was clearly alternative. It is hard to believe that the problem of caste prejudice will be fully solved through housing policies. Law enforcement and affirmative policies are holistic approaches towards changing social behaviour, reaching wider scale. However, given they are poorly delivered or too complex to solve the problem within a short timeframe, tapping into housing policies can provide an alternative function.

5.8. The Archetypes of Sustainability Hacking

The analysis of the List of Differences revealed patterns across cases. Table 24 demonstrates a rearranged version of this list that sheds light on the existence of 5 patterns of distribution of findings across cases. These patterns are hereby described as Archetypes of Sustainability Hacking. They were named after their respective findings for the variable 'Systemic Change': i.e. 'Emulating' (Cases A and H); 'Repairing' (Cases B, E, F, M, and P); 'Exploiting' (Cases C and S); 'Mirroring' (Cases D, K, L); and 'Reformulating' (Cases G, I, J, N, O and R). The findings for each of the 10 variables have become traits of the Archetypes. For example, 'Enacting a System' was until here portrayed as a finding of the variable 'Ultimate Goal', found in cases A and H. Now, it is described as a trait of the Archetype 'Emulating'.

Table 24: Revealing the Archetypes of Sustainability Hacking



Given all variables and their respective findings were already scrutinised in previous sections, the focus here lies on outlining the validity of these archetypes as conceptual tools, signalizing how they can potentially contribute to shape theory and practice.

It is firstly important to emphasise that they do not represent hypotheses, average types, or ethical ideals, and are not intended to perfectly represent empirical instances. An archetype, similarly to the Weberian notion of an 'ideal type' (Cahnman *et al.*, 2016), is an analytical construct that serves as a measuring rod of 'reality', helping to pinpoint important similarities and deviations in concrete cases by combining selection and abstraction of critical traits. These constitute intelligible entities, serving as frames of reference for comparative studies. For these reasons, archetypes can never do full justice to the diversity of particular phenomena, but can provide tools for the interpretive and comparative understanding of reality.

The archetypes found in this study seem to constitute robust, yet generic frames of reference to support future academic contributions in this area of research. They can help categorizing cases according to notable traits and investigate them accordingly. In fact, from the sample of 19 cases, 18 were fully represented by a single Archetype. The only exception is Case Q. Despite sharing the 10 traits of the Archetype 'Repairing', it also has a trait that is solely characteristic of 'Exploiting'. It presents, simultaneously, two characteristics of 'Systemic Change': it captured missed value and also exploited loopholes in the system. Given this is the only exception, its careful examination can help to clarify the comprehensiveness and validity of the Archetypes as frameworks that can be drawn upon to support further development of theory and practice on Sustainability Hacking.

The Sustainability Hacker of Case Q, Sikka, has been primarily focused on repairing the system by capturing missed value. They realised that cash-based transfers in rural regions of Nepal were constrained by the lack of financial services and poor infrastructure. This means that organisations working on humanitarian aid, such as World Vision International (i.e. the non-profit that funded Sikka's Sustainability Hack), faces difficulties to provide cash and goods to their beneficiaries, because they either have to carry bags of cash and hand them directly or ask beneficiaries to cash a coupon in the nearest bank, which often requires them to take long journeys. As described by Q1, "*currently, more than 50% of Nepal is unbanked. So, to get financial services, beneficiaries have to go out do the district headquarters which is at least a day or two away from their village… sometimes they [aid agencies] do it through banks but sometimes they also carry bags. They first transfer it to bank and then they take out the money from the local bank in bags and go out to hand over the cash… It was really insecure and then they had to bring in a lot of staff to see that the cash was taken to the actual field. Then there is this high overhead cost associated with it because whenever you carry out cash you… have*

huge staffing requirements. Then after that there is monitoring and evaluation which cost them at least like 25-30% of the actual program cost".

Additionally, there is little accountability of transactions. The funds often come from a large development organisation (e.g. DfID), going through a large non-profit responsible for on-ground aid provision (e.g. World Vision International), who either hands the cash directly to beneficiaries or works with local cooperatives. It is difficult to keep track of all cash transactions and, even more so, to ensure that the money is being used for its intended aim. Q1, giving the example of aid for education, illustrated that with cash-based systems, "*they do not know if the beneficiaries actually use it for education of the child or if they go out to local liquor shops and buy alcohol*".

Sikka has then captured missed value, by developing and deploying a solution based on blockchain and crypto-tokens, created according to the interests of the funding agencies and transferred to the beneficiaries through SMS messages. These tokens are issued and pegged according to the briefing of the funding agency: "*if they have a cash for work program, it would be like exchanging Sikka tokens for cash. If they have some kind of agricultural program, where they need tools and some kind of other required products for agriculture, they would only go out and exchange Sikka tokens for these commodities*" (Q1). Beneficiaries can then exchange tokens for cash or products – depending on how the crypto-token was pegged – with local shopkeepers or cooperatives, who then receive cash (i.e. Nepalese Rupees) from the aid agency. In that case, only one or a few cash-based transactions are needed, instead of thousands. Furthermore, since all transactions are recorded, they can be easily monitored, there is more certainty that funds are used as outlined by the funding agency, and beneficiaries cannot speculate (since the vouchers are pegged and can only be traded with a few partnering vendors or cooperatives). Besides more transparency and efficacy in the allocation of resources, the operations became much more lean: "*if they had to conduct normal cash distribution, without Sikka, it would have cost like $6.97 per beneficiary. But by using Sikka they got the costs down to $1.5 or $1.6 for beneficiary. It is like 80% savings in cost*" (Q2).

This Sustainability Hack has, therefore, enhanced the performance of an existing system. It presents the same patterns of the Archetype 'Repairing'. However, as previously described, it also shares an exclusive characteristic of 'Exploiting'. Without exploiting a system loophole, Sikka might not have been able to capture missed value. This is connected to the fact that cryptocurrencies are illegal in Nepal. They have then framed their approach differently: a crypto-token, instead of cryptocurrency, to work around this legal constraint. As described by Q1: "*we were planning to build something like a cryptocurrency… [However, the] Nepal*

Rastra Bank[42] *gave out a notice banning all cryptocurrencies…they did not differentiate between blockchain and cryptocurrencies. So, that is why we had to draw a clear line between what Sikka was and what cryptocurrency or other blockchain-based currencies are. We had to design Sikka into a token, so that it would not go against Nepal Rastra Bank's directives... We are working on a grey zone with all the national banks directives. I think we need to work with the government as well to clear out that it is blockchain we are using – and not the cryptocurrency part of it*".

Having Case Q as an exception is consistent to the expectations of Archetypes as frames of reference; they do not have to be mutually exclusive neither comprehend the diversity coexisting in complex phenomena. The Archetypes can, nonetheless, provide means of categorising and explaining Sustainability Hacking – which may be helpful for future studies in the field – as well as of communicating them to different audiences. Besides, if further developed, they may offer generic mechanisms to actively assist in Sustainability Hacking processes, bridging descriptive observations to prescriptive inferences. Next chapter will discuss the theoretical contributions of this chapter and explore this descriptive-prescriptive bridge.

5.9. Summary and Final Remarks of the Chapter

- What was found and how?

This chapter has described the results of the cross-case analysis of Sustainability Hacking. It has started by introducing the diverse sample – 19 cases addressing multiple sustainability problems, conducted by different agents, spread across several national jurisdictions, and deploying different heuristics. It has then walked the reader through the stepwise approach to analyse data, which has revealed the main similarities, differences and the Archetypes of Sustainability Hacking.

Due to the richness of the whole dataset and novelty of the topic, it is important to recognise that some empirical traits may have unintendedly passed unnoticed. However, everything reported here was rigorously analysed and backed up with data. The identified findings were not hypothesised prior to the analysis: an exploratory approach was undertaken both for data collection and analysis to avoid biasing the results, while simultaneously allowing the researcher to unpack insights with greater breadth. Observations have arisen through the careful examination of data, based on rigorous qualitative methods (scrutinised in Chapter 2), and

[42] i.e. Nepalese Central Bank

following a stepwise process, detailed throughout this Chapter, for including and contrasting cases, progressively building up (and examining the robustness of) conclusions.

This methodological approach has revealed 15 similarities, cross-checked for 19 cases. From these, 5 were undoubtedly confirmed by all cases, providing strong evidences of their generalisability. Two were rejected by a few cases, indicating they may be useful as traits to analyse cases of Sustainability Hacking, but most certainly not all of them. The remainder presented lack clarity for some cases, indicating they are likely to apply – but their relevance and applicability should be interpreted with care. These can, therefore, serve as a reference of dominant traits, i.e. aspects that are likely to influence Sustainability Hacks, although it would be inaccurate to claim they are *sine qua non.*

Furthermore, 10 variables differing across cases were revealed and scrutinised, unpacking an array of findings for each. Five archetypes emerged from the List of Differences – providing a frame of reference for future research and practice. These results, systematically endorsed with qualitative data, can then be used by research delving into this nascent area, as well as guidance for practitioners exploring possibilities of addressing pressing sustainability challenges.

- What next?

Chapter 6 first synthetises and discusses the findings of the 3 sequential research stages, presented in Chapters 3, 4 and 5. It then connects the empirical evidences with existing literature, elucidating the most notable contributions of this work to existing theories. Chapter 6 also elucidates further how the Archetypes of Sustainability Hacking can be used for future contributions to theory and practice, and contemplates questions that emerged as potential avenues for future research. It then concludes by reflecting if a Hack can save the world and on the strengths and weaknesses of this thesis.

6. Discussion and Conclusion

"I say: The Real is neither in the departure nor in the arrival: it offers itself to us within the journey"
(Guimarães Rosa, Grande Sertão Veredas, p.52) [43]

6.1. Introduction to the Chapter

At this point, the results of the 3 sequential research stages, introduced and methodologically justified in Chapter 2 (i.e. Research Design), have already been scrutinised. Chapter 3 exposed the theoretical foundations of sociotechnical system change for sustainability through a systematic literature review. Chapter 4 has subsequently unpacked, through a Phenomenon-Driven approach, the definition and most notable characteristics of 'System Hacking'. Chapter 5 has then presented the results of the cross-case analysis of Sustainability Hacks, revealing the Lists of Similarities and Differences, besides introducing Archetypes that can serve as frames of reference for future studies in this nascent research area and as guidance for practitioners.

Many research opportunities were in fact unpacked throughout the 3 stages of this research, from which only a subset was fully pursued. Since the main contribution of this thesis is developing the concept of Sustainability Hacking, this Chapter naturally focuses on discussing and building upon this concept.

Particularly important to this Chapter is to discuss the generalisability of this study, i.e. the possibility of inferring about the unobserved by drawing on conclusions from particular instances (Lincoln and Guba, 1994). The adoption of an inductive, qualitative approach for the 2nd and 3rd stage prevents me from statistically extrapolating the findings to the wider population. The focus lies instead on transferability, i.e. discussing how the findings may have relevance to other problems and how they can be transferred to other contexts and situations faced by academics and practitioners.

Section 6.3 synthesises the most notable contributions of this thesis, both for theory and practice. The subsequent section elaborates on the potential uses of the Archetypes of Sustainability Hacking, most especially how they can be deployed as frames of reference for

[43] My translation, from Portuguese to English.

theoretical development and as tools guiding future pursuits in the 'real-world'. Section 6.5 contemplates grey areas of this research, that emerge as potential avenues for future academic contributions: What problems are best addressed by Sustainability Hacks, as opposed to governance mechanisms? When does a Sustainability Hack stop being a Hack to become something else? How to scale up a Sustainability Hack? Section 6.6 concludes this work, by examining its strengths and weaknesses, and by reflecting if a hack can save the world.

6.2. Synthesis of Contributions

This research has been designed with 3 sequential research stages. This means that 3 sets of research questions have been consecutively addressed. Chapter 3 portrays the findings for the question: "What are the theoretical foundations of sociotechnical system change for sustainability?". Chapter 4 scrutinises the results of the following research questions: "What the heck is 'Hacking'? What are its dominant characteristics?". Chapter 5 finally describes the results of the last stage of this research, addressing the question: "What are the dominant similarities and differences of Sustainability Hacking in the real-world?". Successfully addressing these interconnected sets of questions was, naturally, the main accomplishment of this work.

Interestingly, each of the 3 research stages has revealed multi-folded contributions[44] – and opportunities for future research – that are somewhat independent of the following Chapters. For example, Chapter 3 presents 15 theoretical foundations and demonstrates how they can be used as starting points either for gap filling, to refute an existing foundation, or to create new foundations. Examples were given for each, but this research has only followed a specific opportunity track: the one of investigating 'Hacking'. The other ones have an unexplored value to theory that can be leveraged by future research, independently of the tracks followed in the subsequent research stages of this thesis.

Likewise, Chapter 4 has revealed the definition and characteristics of 'System Hacking' and discussed some of the most relevant opportunities of contributing to theory of sociotechnical system change in light of the findings. Only the idea of investigating Sustainability Hacks in the 'real-world' was fully pursued. Future research can, for example, focus on discussing System Hacking more broadly (i.e. not only motivated by Sustainability), without necessarily tapping into the results presented in Chapter 5.

[44] In fact, partial results were published or presented in conferences (and others are currently in preparation for submission). The list of articles can be found in 'Dissemination'.

Furthermore, the potential application of the findings on System Hacking (in Chapter 4) and, more specifically, on Sustainability Hacking (in Chapter 5), depend on the levels of generalisability of each finding. For example, a similarity found across all 19 cases, like 'Urgency', has higher generalisability than one that was present in only 12 cases, such as 'Decentralized Funding'. Similarly, an Archetype matched by 6 cases, like 'Repairing', may be more transferrable to other settings than one that only has 2 cases, such as 'Emulating'.

This section, however, does not trace back these fragmented results, since they have already been portrayed in previous Chapters. It focuses instead on the 'whole' of the thesis: synthesising the main contributions from theories on sociotechnical system change for the formulation and exploration of Sustainability Hacking, as well as inferring about what contributions of this PhD thesis can help furthering development of theories and practice. It also briefly describes contributions to the 'real-world' that resulted from my close engagement with Sustainability Hackers throughout the course of the 3rd stage of this work.

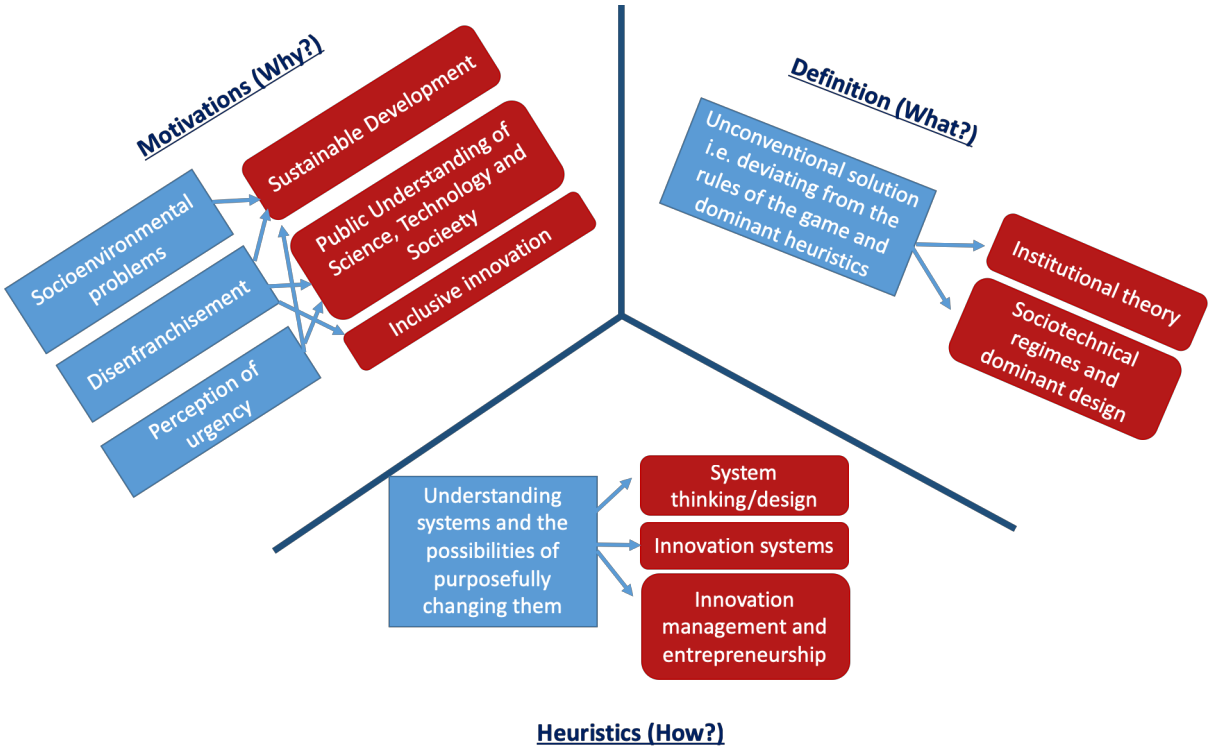
6.2.1. Theoretical contributions

This section starts by summarising how each of the theories identified in the literature review have contributed to the development of this thesis. It subsequently focuses on the opposite direction: the most notable contributions of this thesis for theoretical development.

a) From Theory

Figure 22 highlights the most notable contributions from all research areas reviewed in Chapter 3 in supporting the formulation and exploration of Sustainability Hacking.

Figure 22: Most notable contributions from theory



Sustainability Hacking is unsurprisingly motivated by the socioenvironmental concerns raised by studies on Sustainable Development (e.g. Brundtland, 1987; Kates, Parris and Leiserowitz, 2005). Hackers are also disgruntled with their disenfranchisement of formal power structures, motivating them to take action as 'external' agents. This feeling of disenfranchisement has been covered by studies on Sustainable Development; by research on Public Understanding of Science, Technology and Society, which have called for the democratization of processes of appraisal and deliberation upon the multiple, coexisting alternatives for system change (e.g. Ezrahi, 1990; Leach, Scoones and Stirling, 2007); and by concepts of inclusive innovation, created for and/or by the disenfranchised – such as frugal or grassroots innovation (e.g. Basu, Banerjee and Sweeny, 2013; Gupta, 2016). The perception of urgency, i.e. of what is seen as a pressing problem, is deeply connected to the concerns of social inclusiveness and environmental resilience from studies on Sustainable Development, as well as to constructivist research shedding light on the plurality of understandings of what shall be prioritised (e.g. Stirling, 2009; Jasanoff, 2010).

Since a Sustainability Hack is an unconventional solution that deviates from the 'rules of the game' and the dominant approaches towards problem-solving, the most notable theoretical contributions to the definition of Sustainability Hacking came from institutional theory (e.g. North, 1990; Hodgson, 2005) and from the concepts of sociotechnical regime and dominant design (e.g. Utterback and Abernathy, 1975; Nelson and Winter, 1982).

Finally, the most relevant contributions from the reviewed literature to the identified heuristics of Sustainability Hacking came from studies covering the components, connections and functions of complex systems (e.g. Senge, 1990; Meadows, 2008), as well as from the ones that investigated different mechanisms to purposefully steer system change (e.g. Tidd, 2001; Elzen, Geels and Green, 2004; Goffin and Mitchell, 2010).

b) To Theory

Due to the interdisciplinary nature of this work, its contributions to theory are multi-folded. It impacts areas of sustainability science, system thinking and design, innovation studies, and institutional theory, to cite a few. This subsection lists some of the most notable contributions of this work to different theories on sociotechnical system change for sustainability, by connecting the findings with the literature described in Chapter 3.

- **New change driver**

As demonstrated in Chapter 3 and further discussed in Chapter 4, literature tends to describe change drivers of sociotechnical systems either as revolving around long-term governance (e.g. Kates and Parris, 2003; Smith, Stirling and Berkhout, 2005; Voß, Smith and Grin, 2009; Sachs, 2015), or the support to the generation and diffusion of innovations with cascading impacts on the functions of systems (Malerba, 2006; Lundvall *et al.*, 2009; e.g. Ekins, 2011; Sushandoyo and Magnusson, 2014). Little scope is left for change drivers realised through actions that do not occur through the marketplace, or that do not require the coordination of multiple agents.

The concept of Sustainability Hacking addresses part of this void, contributing to theory by clarifying a yet unexplored change driver. By exploring real life phenomena happening 'here and now' that purposefully promote improved socioenvironmental functions of a system, this work widens the understanding of the multiple forms of exerting agency over sociotechnical systems and, most especially, of mechanisms that can be employed to steer system change towards more desirable directions.

- **Potential responses to institutional pressures**

Institutional theories have contributed greatly to the understanding of the 'rules of the game' (North, 1990), shaping and limiting potential responses of agents, the solutions to be prioritised and the strategies of different actors (Ostrom, 2000; e.g. Hodgson, 2005). Literature in the field has mostly focused, however, on changing or coping with these rules. Academic analyses often lie on revealing institutional pressures, both to understand and to indicate viable pathways that

can be pursued. The scope of potential responses, in these cases, have been greatly explored by literature in the field.

The concept of System Hacking, derived in this work, sheds light on a rather different approach. Hackers intentionally ignore or bypass institutional pressures and expected heuristics to pursue alternative routes, in the hope of reaching immediate, good-enough solutions. By defying engrained societal rules, they are then able to address problems that are otherwise difficult to tackle by mainstream means. This concept has, as a result, contributed to the understanding of a different response to institutional pressures that has not yet been captured by institutionalist theories.

- **Working with and around complexity**

Complexity is a critical feature both to understand and steer system change. It emphasises the existence of multiple agents dynamically interacting in convoluted networks, besides the accompanying feedback loops that constantly change systems in a rather unpredictable way (Senge, 1990; e.g. Meadows, 2008).

Responses to systemic problems tend to be simultaneously self-evident and complex. Self-evident, because recommendations often lie exclusively on acting against their perceived bottlenecks. For example, when analysing a complex underdeveloped healthcare system and realising that lack of infrastructure is a bottleneck, the conventional response will likely be to invest in infrastructure. Despite consisting of rather obvious responses, they are inevitably complex, since they are already moulded by prevailing institutions that shape not only the kinds of changes seen as viable, but also the dominant heuristics. Keeping the same example: improving infrastructure involves multiple agents that need to be closely coordinated, transactions between multiple parties, funding that needs to be raised (often from multiple sources), governance of many public agencies, compliance to labour laws and environmental regulations, and public expectations of the civil society. As a consequence, responses to systemic problems often face agency failures, such as being sluggishly operationalised, or not brought to fruition.

Little is known, in literature of sociotechnical system change for sustainability, of how to work around complexity. Sustainability Hacking emerges as an alternative. Indeed, Chapter 5 has scrutinised how agents have bypassed rules of the game. They recognise complexity of systems and their engrained problems. However, they are also dissatisfied with the resulting agency failures of working with complexity. They prioritise acting, instead, in a self-entitled

way around complexity, by experimenting and using resources available at hand to pursue immediate, good-enough solutions to problems.

- **Important traits to analyse sociotechnical system change**

Chapter 5 has listed 15 similarities and 10 differences across cases of Sustainability Hacking. These traits are clearly relevant to the phenomena of Sustainability Hacking, but may also factor in the performance of other change drivers of sociotechnical systems, such as innovation (e.g. Freeman and Soete, 2000) and system design (e.g. Charnley, Lemon and Evans, 2011), independently if motivated by socioenvironmental goals or business-as-usual.

By listing and clarifying these traits, this work has thus contributed to enhance the academic understanding of important features moulding the multiple, coexisting possibilities of deliberately changing a sociotechnical system.

- **Ownership, accountability and legitimacy of sociotechnical system change**

Literature emphasises contentious matters of legitimacy, ownership and accountability of sociotechnical system change (Stirling, 2008; e.g. Markard, Wirth and Truffer, 2016). If sociotechnical systems do not have owners: 1) who owns – or should own – the outcomes of sociotechnical system change? 2) Who has the legitimacy to change systems, and in what circumstances? 3) Who is accountable for changing a system, and why? Answers to these questions often lie on the importance of fostering democratic accountability over the multiple, co-existing alternatives to intentionally steer sociotechnical system change. Many authors (e.g. Millstone, 2007; MacKerron and Berkhout, 2009; Savaget and Acero, 2017) have emphasised the recurring attempts of technocratic governments of cloaking tensions under a vest of 'impartiality' in order "to manufacture public trust and legitimation" (Wynne, 1996, p. 51). They present decisions as if there was only 'one way forward', or as if they were exclusively informed by evidences – and not shaped by vested political and institutional interests.

Far from providing answers to these questions, this work contributes, instead, by adding more layers of complexity. How legitimate are Sustainability Hacks, given Hackers do not own the sociotechnical system they are acting upon and are not accountable for the problem they are addressing? If democracy is at the core of legitimacy, is a Sustainability Hack less or more democratic (and, hence, more legitimate) than a project undertaken by an elected government? Whereas Sustainability Hacking is democratised in terms of 'access' (i.e. everybody can Hack), the latter is, in principle, formulated and enforced by representatives of the people. The contributions here are, therefore, not to provide answers, but rather to highlight that these issues

are essentially questionable, depending on ontological and normative perceptions that are essentially plural.

- **Multiple approaches towards different sustainability problems**

As described in Chapter 3, the term Sustainability has interpretive flexibility. It often refers to meeting inter and intra-generational needs, by seeking the intersection of the so-called triple bottom line (i.e. economy, environment, and society) (e.g. Brundtland, 1987; Elkington, 1999). Given these are rather vague definitions, the term has been used to justify the most varied efforts, ranging for example from controlling inflation to inhibiting biodiversity loss. This vagueness is taken by some as a weakness (e.g. Middleton and O'Keefe, 1993), who believe that the lack of focus hampers the coordination of agents towards shared goals. Others have described it as a strength (e.g. O'Riordan, 1993). By keeping its interpretation malleable, different interests and priorities can be assessed and efforts adapted to their respective contexts (e.g. Stirling, 2008).

Despite different interpretations of the term, cooperation is seen as the most important means to address sustainability goals. The 17 Sustainable Development Goals (SDGs) (United Nations, 2015), for example, are the most notable example of global efforts pinpointing priorities and indicators for each, as well as monitoring mechanisms to keep track of progress. The SDGs consist of social, environmental and economic goals, with the exception of the last one, i.e. "partnership for the goals". This is seen as instrumental, as the most important means to reach the other 16 SDGs. However, not all attempts to tackle socioenvironmental problems need to – or should – necessarily place coordination at its core. Some sustainability problems are extremely urgent. Solutions requiring a high level of coordination have an increased possibility of not being taken ahead, or being sluggishly operationalised.

This work has described the phenomena of Sustainability Hacking as a change driver that is particularly promising for situations where information is limited, resources are scarce, stakes are high, and decision-making, urgent. In this avenue, this work has great contributions to theory. It is far from opposing to coordination. However, it sheds light on its associated weaknesses, that often hinder sustainability goals to be promptly addressed, and indicates a viable alternative for pressing problems.

6.2.2. To the 'real-world'

The most notable contribution to the 'real-world' was the engagement with Case A, which occurred since early stages of data collection for the 3rd research stage and resulted in an award

from IBM. With the support of two other researchers, I developed an intervention model based on the experiences observed in Zambia[45]. The idea, supported by the Sustainability Hacker (i.e. ColaLife), was to publish an open access report to be published by IBM, that could guide other agents, in different contexts, keen on implementing a similar initiative; and, consequently, help amplifying the access to medicines in remote regions of low-income countries. Box 7 contains the executive summary of the report[46].

[45] See footnote 21
[46] The report has not yet been published by IBM and is subjected to changes.

Box 7: Executive Summary of the Report

Current systems are failing to make life-saving healthcare products accessible in remote regions, especially in low-income countries – even for simple, over-the-counter, and relatively cheap medicines. Governance failures lead to unstable healthcare systems that rely too much on external funding for procurement of medicines, which oscillates according to the changing priorities of funding agencies. Furthermore, even when medicines are available, they often do not reach the so-called Last Mile, since improvements in infrastructure and logistics needed for perennial supply have timescales of years or even decades for implementation, are very costly, and are susceptible to the impoverished and often unstable settings of low-income regions.

This report presents a Call for Action, based on an innovative and very successful approach undertaken in Zambia by the non-profit ColaLife, which bypasses these deep-rooted bottlenecks for medicine delivery. This experience started with the observation that 'Coca-Cola seems to get everywhere in developing countries, yet life-saving medicines do not'. The non-profit has then analyzed how fast-moving consumer goods, like Coca-Cola, get into the hands of people living in remote areas of Sub Saharan Africa (SSA). This analysis sparked the idea of emulating Coca-Cola's value chain to improve access to diarrhea treatment – the second biggest infectious killer of under-five children in the region. More than a supply chain, a value chain can be thought of as an ecosystem of relevant players, processes and resources needed to effectively deliver a product or service to the end user. As a result, in 3 years (2015-2017) uptake of this treatment in the intervention areas has increased from less than 1% to 53%, where medicines were made available both through the public and private sector, and from 13% to 33% in the Lusaka province where the medicine was only made available through the private sector.

We draw upon this experience in Zambia to provide practical guidance on the key success factors for enabling access to medicines through value chain emulation. We believe our frameworks can be applied in other geographical settings and, potentially, to provide access to other healthcare products. This is, therefore, valuable for policymakers and organizations working on access to healthcare.

First, we introduce the role of the Catalyzer, which has shown to be critical to designing and organizing a value chain. This can be performed by anyone (or any organization), as long as they do not wish to become an integral part of the emulated value chain. The principles Catalyzers must abide to, their zones of agency, and their scope for action are explored to provide guidance to those aspiring to perform a similar role in other contexts.

Second, we scrutinize a stepwise process for how to set up a value chain, focused on over-the-counter medicines. This explains the value chain focal-areas, what they entail, how they are meant to be addressed, and the expected timeframe for each activity.

Third, we reflect on the requirements to ensure that the emulated value chain becomes self-sustaining and gradually more independent of the Catalyzer, of foreign aid, and more resilient towards unforeseen events, given the unstable nature of some low-income contexts.

Lastly, we discuss the possibilities of scaling-up access within Zambia, to other geographical regions, and to cover a broader spectrum of healthcare products. We combine the perceptions of stakeholders in Zambia, directly and indirectly involved in the project, with knowledge of experts in healthcare and development based in other regions, to explore the most notable challenges to expand access to life-saving healthcare products.

The process of scaling up the Sustainability Hack through this playbook is still in its early stages. In October 2018, the researcher has outreached in Accra (Ghana), with the intent of finding agents willing to uptake a similar initiative and to receive feedback on contextual peculiarities that have not been previously considered. The contacts included academics, intergovernmental organisations, and an association of hundreds of non-profit organisations working on healthcare in Ghana, who demonstrated interest in learning and, potentially, adopting in Ghana a similar role that ColaLife performed in Zambia.

Other engagements with ColaLife were also fruitful. They have realised the importance of publishing articles in a medical journal, since this increases the likelihood of influencing top-down, healthcare policy change, such as at the World Health Organization (WHO), to enhance access to ORS+zinc. In particular, they realized the existence of a leverage point: if they influence the inclusion of co-packaged ORS+zinc on the Essential Medicines List of the WHO, there would likely be a positive cascading impact to the procurement of several low-income countries. In this avenue, the researcher presented an article at a conference and is currently preparing an improved version to submit to a medical journal.

Besides ColaLife, the researcher has engaged with other agents throughout the 3rd stage of this research. Since interviewing the founder of Goats for Water (Case I), the researcher has accompanied their evolution and attempted to assist with her intent of scaling up. We have jointly applied for a grant[47], proposing a project in which my supervisor and I would assist Goats for Water in converting their Sustainability Hack into a scalable and profitable social enterprise. Although we did not obtain the grant to take the project further, our proposal led to a brief reflection on what the organisation needs to fulfil to scale up, and can potentially be used as a starting point to apply for future funding opportunities.

It is also important to highlight other contributions to the 'real-world', that were not featured in this thesis but were part of the process of data collection. I explored a case in Brazil, which was dismissed from my dataset because it did not fit well the definition of Sustainability Hacking. My supervisor and I have teamed up with the organisation Fa.vela to win two grants from the Newton Fund[48]. These grants allowed us to accelerate over 90 businesses of low-income entrepreneurs living in favelas of Belo Horizonte (Brazil) and neighbouring cities.

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[47] Developing Inclusive and Creative Economies (DICE), from the British Council. See: https://www.britishcouncil.org/programmes/dice [Accessed: 11 September 2018]

[48] See: https://www.gatescambridge.org/news/promoting-enterprise-belo-horizonte [Accessed: 11 September 2018]

6.3. Opportunities deriving from the Archetypes of Sustainability Hacking

Chapter 5 has revealed 5 Archetypes. They were named after their respective findings for the variable 'Systemic Change': i.e. Emulating, Repairing, Exploiting, Mirroring, and Formulating. This section synthesises how they can be used as frames of reference to: 1) provide guidance for practitioners evaluating possibilities of addressing pressing sustainability problems; and 2) to support future academic contributions in this nascent field of research.

The figures below represent the systemic change at the core of each Archetype and list their respective traits. It keeps the same visual narrative of Chapter 4, where System Hackers have been portrayed as aliens, given they are *external* to the system they are acting upon.

Figure 23: Archetype 1 – Emulating

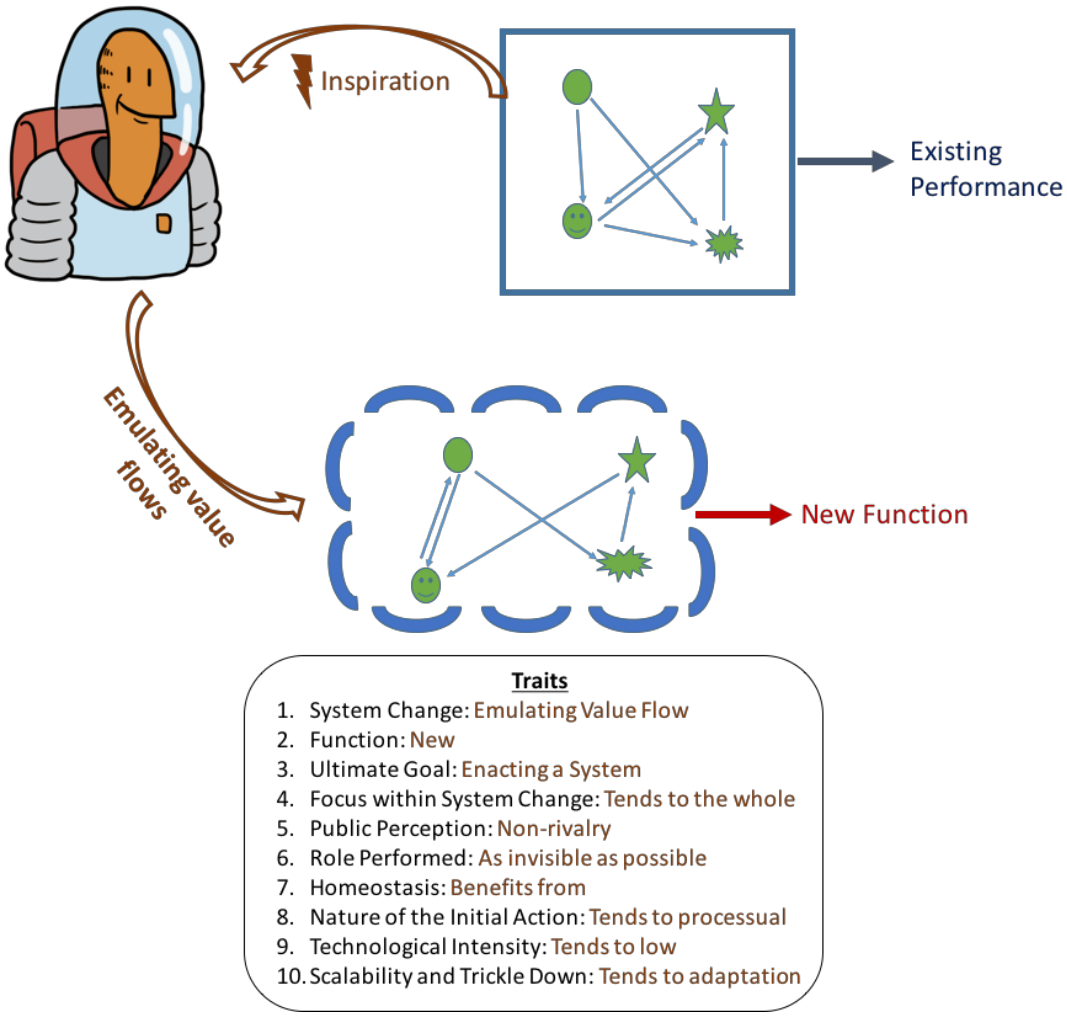
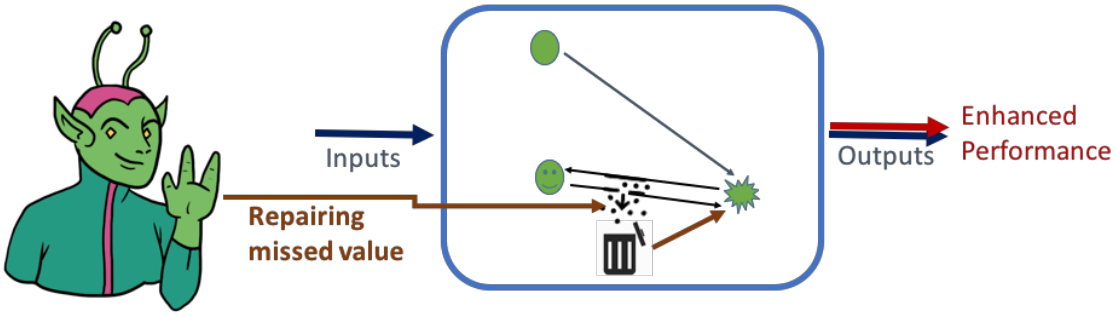


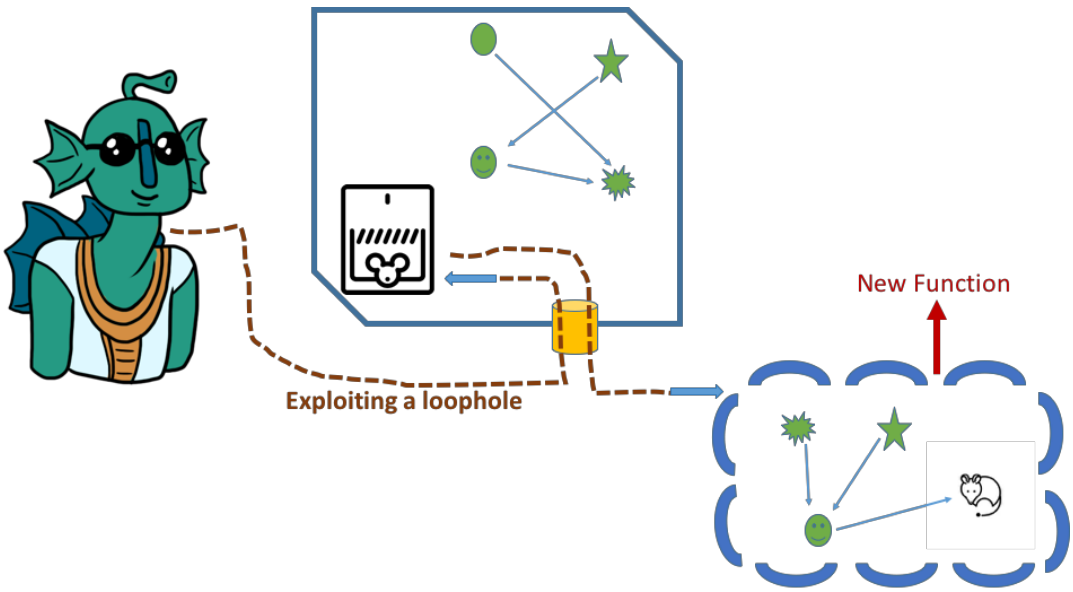
Figure 24: Archetype 2 – Repairing



Traits

1. System Change: Repairing missed value
2. Function: Enhanced
3. Ultimate Goal: Filling a gap
4. Focus within System Change: Tends to the parts
5. Public Perception: Contentious outsider
6. Role Performed: As active as possible
7. Homeostasis: Stresses
8. Nature of the Initial Action: Tends to discrete
9. Technological Intensity: Tends to high
10. Scalability and Trickle Down: Tends to replication

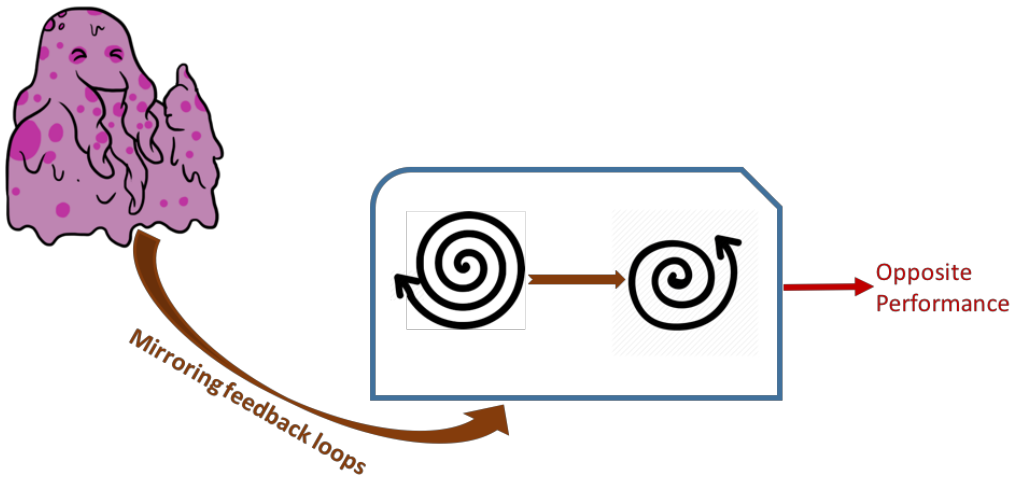
Figure 25: Archetype 3 – Exploiting



Traits

1. System Change: Exploiting a loophole
2. Function: New
3. Ultimate Goal: Confronting undesired rules
4. Focus within System Change: Tends to the parts
5. Public Perception: Contentious outsider
6. Role Performed: As active as possible
7. Homeostasis: Stresses
8. Nature of the Initial Action: Tends to discrete
9. Technological Intensity: Tends to high
10. Scalability and Trickle Down: Tends to replication

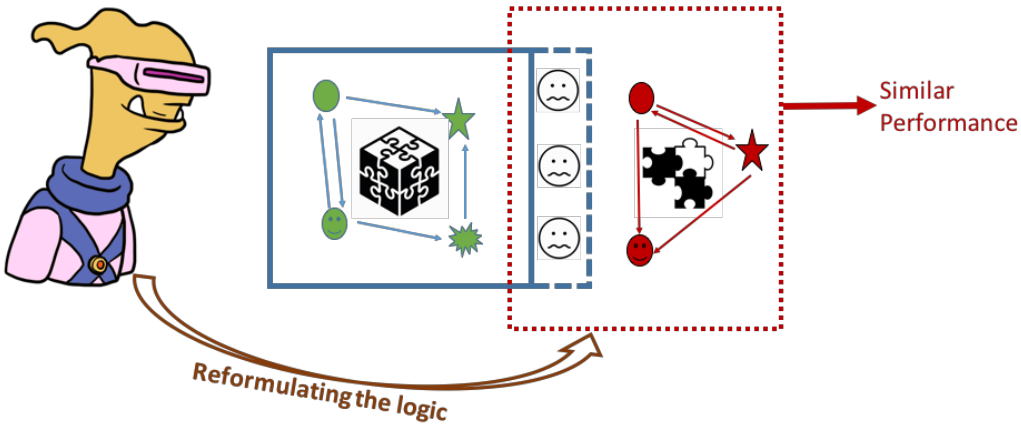
Figure 26: Archetype 4 – Mirroring



Traits

1. System Change: Mirroring feedback loops
2. Function: Opposite
3. Ultimate Goal: Resist to homeostasis
4. Focus within System Change: Tends to the parts
5. Public Perception: Pacific rivalry
6. Role Performed: As active as possible
7. Homeostasis: Benefits from
8. Nature of the Initial Action: Tends to discrete
9. Technological Intensity: Tends to low
10. Scalability and Trickle Down: Tends to replication

Figure 27: *Archetype 5 – Reformulating*



Traits

1. System Change: Reformulating the logic
2. Function: Similar
3. Ultimate Goal: Complementary function
4. Focus within System Change: Tends to the whole
5. Public Perception: Non-rivalry
6. Role Performed: As invisible as possible
7. Homeostasis: Benefits from
8. Nature of the Initial Action: Tends to discrete
9. Technological Intensity: Tends to low
10. Scalability and Trickle Down: Tends to adaptation

6.3.1. For academics

Multiple research opportunities can be unpacked when leveraging the Archetypes of Sustainability Hacking as frames of reference for comparative studies. As described in Chapter 5, these Archetypes do not represent average types, hypotheses or ethical ideals, and do not intend to perfectly represent reality. They are, instead, analytical constructs serving as a 'measuring rod of reality' to identify similarities and deviations through the selection and abstraction of critical traits.

Deductivist approaches, deploying quantitative methods, suit particularly well attempts of testing the results found in this research. However, given this is still a nascent research area, most opportunities will likely adopt inductivist approaches, using qualitative research methods for data collection and analysis of phenomena. Whereas cross-analysing qualitative data of Archetypes seems as a promising route to provide broader insights on Sustainability Hacking, future studies can also opt to investigate them individually. Each archetype has its own peculiarities; hence the individual investigation of archetypes can go in-depth to find variables that have passed unnoticed or were not within the reach of this work.

Box 8 illustrates research opportunities, categorised according to the core of their expected contributions (Whetten, 1989). They are not intended to be exhaustive of all opportunities opened up for academics, but rather to shed light on the multiple, viable research routes that can be pursued.

Box 8: Research Opportunities based on the Archetypes

a. Focus on 'Why', i.e. underlying motivations

- Is Sustainability Hacking socially desirable, independently of the Archetype?
- In what circumstances is Archetype 1 preferable to Archetype 2?
- Does a Sustainability Hacker have legitimacy to change a sociotechnical system, independently of the Archetype?

b. Focus on 'What', i.e. dominant characteristics

- What pervasive traits across Archetypes have not been captured by Chapter 5? What traits are specific to Archetype 1 and not to the others?
- What kinds of socioenvironmental problems (e.g. hunger, biodiversity loss, corruption) are best addressed by Archetype 2?
- Chapter 5 indicates that scaling up for Archetypes 2, 3 and 4 tends to replication. How similar/different is the replication of each?

c. Focus on 'How', i.e. relationships and causality

- How differently do institutional constraints/enablers affect each archetype?
- How do Sustainability Hackers of Archetype 1 fund their initiatives?
- What characteristics of each Archetype factor in their likelihood to thrive?

d. Focus on 'Where', i.e. geographical contexts

- What Archetypes are more prone to occur in the United Kingdom?
- Is Archetype 4 more likely to happen in a low, middle or high-income region?
- How is Archetype 2 affected by boundaries imposed by national jurisdictions?

e. Focus on 'When', i.e. timeframe

- How long does a Sustainability Hack of Archetype 5 take, in average, to be implemented?
- What are the differences in speed between Archetype 2 and 4?
- What Archetype suits best circumstances in which the sustainability issue is extremely urgent (e.g. people are dying)?

f. Focus on 'Who', i.e. agents

- What organisations (e.g. NGOs, governments, companies) are more prone to fit Archetype 3?
- What are the differences in the educational outlook of Sustainability Hackers across Archetypes?
- What are the dominant characteristics of Sustainability Hackers of Archetype 1?

6.3.2. For practitioners

Practitioners keen on tackling pressing sustainability challenges can benefit from the knowledge reported in this thesis. That includes individuals, governments, intergovernmental organisations, companies, and organisations of the third sector, independently of the regions where they operate. This subsection focuses on synthesising opportunities deriving from the use of the Archetypes of Sustainability Hacking for the ones acting in the 'real-world'.

The answer for a single or a few traits can be used as starting points to shepherd practitioners towards other characteristics that should receive careful examination. This applies, for example, if: 1) the Sustainability Hack has already been implemented; 2) an idea is still in an early stage; and 3) the potential Sustainability Hacker only knows the problem that needs addressed.

1) When the Sustainability Hack is already implemented, the Archetypes can shed light on important features that should be taken into consideration to improve its chance of succeeding. The impact of using the Archetypes, in such cases, is more incremental than when the idea is incipient. However, it may shed light on features that have been ignored. For example, if a Sustainability Hacker is knowingly reformulating the logic (i.e. Archetype 5), but is focusing too much on the parts of the system (i.e. Trait 4), the analysis indicates the importance of zooming out to look at the 'whole'. Important insights to improve the performance – or even the likelihood of succeeding – can thus be obtained from similar exercises with the 10 traits of Sustainability Hacking.

2) If the idea is still in an early stage, many contributions can be obtained from the analysis of the Archetypes. For example, if the 'Function' to be delivered has been recognised as *new* (i.e. Trait 2) to the system, the practitioner should consequently look closely at Archetypes 1 and 3. Is the idea *exploiting a loophole* or *emulating value flows* (i.e. Trait 1)? Do they aim at leveraging the unexplored potential of a radical *technology* (i.e. Trait 9)? Are they keener on adopting a *non-rivalry*, or a *contentious outsider* approach (i.e. Trait 5)? These are examples of questions that can be raised thereafter, in order to enhance the robustness of the early stage idea before implementation.

3) The biggest scope for contributions lies, naturally, on assisting those who only know the problem that needs addressed. The following box illustrates a fictional and reflexive exercise that can assist potential Sustainability Hackers to design a viable idea. The same logic can be autonomously conducted in circumstances where the problem is known, but the solution is not.

Box 9: From problem to ideas – fictional example

You became aware of the difficulties faced by the refugees who have safely arrived in Germany, but have not yet fulfilled the bureaucratic requirements to obtain a work permit. You have no idea of how to address that problem. Then you can systematically reflect upon the 10 traits, independently of their order. The attempts below exemplify how (different) ideas of Sustainability Hacks can be obtained through this process.

Attempt with Archetype 2: You believe the government is not providing refugees clear guidance on how to muddle through their bureaucratic machine. There should be an easier way: there is clearly a gap to be filled. You may then be able to explore traits of Archetype 2.

Can you think of a mechanism to simply enhance the performance (i.e. Trait 2) of the bureaucratic institutions providing work permits? Or, alternatively, can you think of a way of guiding refugees through the bureaucratic system that is foreign to them so they will not unnecessarily lose time?

You start exploring Trait 4, looking at the parts of the system, and realised there are multiple documents and processes that need to be fulfilled in tandem. After talking to some refugees, you realise that a bottleneck to speed up the process is indeed the lack of information.

Since the problem is lack of information, tapping into information and communication technologies (i.e. Trait 9) seems a promising path forward.

You may then have the following early stage idea: developing a gamified app that walks refugees through what they have to do next to obtain a work permit, as if in levels of a fictional game.

Attempt with Archetype 3: Can you think of a loophole in the system (i.e. Trait 1)? Something that can be exploited to bypass the bureaucratic constraints imposed by the government?

You believe this is a promising and rather exciting route, but you still do not know how. You read Case C of Chapter 5, for inspiration. This case describes that women were provided safe abortions in international waters, bypassing the undesired regulations of countries where abortion is illegal. Inspired by this case, you examine the parts of the system you want to act upon (i.e. Trait 4), asking yourself: can I redefine the boundaries of work, so they will not have to abide to German bureaucracy despite being in German soil?

Bringing them to international waters, like Case C, does not seem to you as a viable option. So you start exploring alternatives. After talking to a group of refugees, you realised many of them have received coding training while in their home countries (i.e. Trait 9).

You start exploring ideas to address only this subgroup: What if they work as freelancers for organisations needing web developers? Do they still need work permits, even if the hiring organisations are from abroad? After delving into the law, you realise this approach might imply in liabilities: it seems they cannot legally receive salaries or remunerations without a work permit.

Then you have the following early stage idea: creating a non-profit organisation that will deliver freelancing coding jobs. It would charge hiring organisations, but would only use unpaid work from volunteering refugees. The revenues obtained will be then wired to the refugees as *donations* through a pre-paid credit card: they cannot receive salaries or remuneration, but they can receive donations.

6.4. Grey Areas for Future Research

The previous Section has pinpointed numerous possibilities of using the Archetypes of Sustainability Hacking as frames of reference to contribute to future studies and practice. This Section also investigates research avenues identified as possessing great potential for developing the understanding of Sustainability Hacking further. However, differently from the previous section, it focuses on 3 broad research questions to which the researcher has only a few inconclusive observations.

These questions have surfaced throughout the analysis of the datasets presented in Chapter 5. The data provides insights on them, although not with the accuracy and thoroughness needed for asserting strong claims. Despite recognising their importance, my database was, therefore, not enough to elicit robust observations. Furthermore, differently from the cross-sectional research approach of this thesis, answering some of these questions may require longitudinal datasets, i.e. that tracks the same sample at different points in time to obtain methodologically rigorous inferences. For these reasons, in this Section the researcher briefly contemplates these Grey Areas, describing observations that should be interpreted with care, but may be used as starting points for future studies.

6.4.1. What problems are best addressed by Sustainability Hacks, as opposed to governance mechanisms?

The researcher has not found evidence either of problems that cannot be addressed by a Hack or of a sociotechnical system that is not Hackable. Therefore, my inductive approach allows inferring that ‘every system is Hackable’ and ‘every problem can be addressed by a Hack’, unless proven the contrary. That does not provide, however, a clear indication of the *kinds of problems* that are best addressed by Sustainability Hacks. A few reflections addressing this matter are listed below.

First, this research has pioneered the concept of Sustainability Hacking, which refers to ‘unconventional’ mechanisms for addressing sustainability problems of sociotechnical systems in situations where information is limited, resources are scarce, stakes are high, and decision-making, urgent. They consist of immediate and scalable solutions. Therefore, the very definition of the concept already signalises circumstances in which Sustainability Hacks may be appropriate. These tend to consist of pressing socioenvironmental problems. ‘Pressing’ is a subjective adjective, but its subjectivity is precisely where its strength lies. It is because it can be interpreted differently that Sustainability Hacks can be so diverse, covering a wide spectrum

of problems. Therefore, an indication of the kinds of problems best addressed by Hacks cannot be fully dissociated of the ontological perceptions, expectations and aspirations of agents.

Second, it would be very naïve to claim that a Sustainability Hack is always preferable to other change drivers of sociotechnical systems. That would undermine the essentially complex nature of system change and the multiple forms of exerting agency. What seems clear, however, is that Sustainability Hacks are somehow bypassing governance. They tend to be deployed when governance disappoints, either because the problem is contentiously disputed (e.g. abortion rights) or due to agency failures (e.g. delivery of medicines in remote regions of Zambia). Furthermore, Sustainability Hacks are just good-enough. It is hard to imagine a person claiming that the ideal solution for abortion rights is to provide abortion services in international waters (i.e. Case C). However, governance mechanisms may systematically fail to address these problems because they have to abide to the rules of the game and rely on careful design, planning and coordination of agents. Since Hackers are not passively complying with rules – but, instead, bypassing them to pursue immediate, good-enough solutions – Sustainability Hacks may be best, precisely, for the kinds of problems that mainstream means are struggling to address. In other words, if a problem is very persistent, if governance has attempted and failed systematically, or if governance has not addressed it at all, then the problem may be a good one for Hacking. Sustainability Hacks can, thus, be interpreted as good change drivers not only for problems of pressing nature, but also to fill gaps within governance portfolios, complementing what governance is not properly delivering.

Third, the definition and dominant characteristics of Sustainability Hacking do not constrain the kinds of problems that need addressed, but instead the kinds of solutions to those problems. For example, there may be many unconventional ways of addressing death due to malaria in Sub-Saharan countries. This problem can probably be addressed by a Sustainability Hack. However, the solution of inventing a vaccine cannot be a Sustainability Hack, given that this solution goes against the very definition of the concept (i.e. it is not 'unconventional') and many of its dominant characteristics (e.g. 'Distributed Ownership', 'Urgency' and 'Practicality').

Fourth, Sustainability Hacks are driven by agents who are *external* to the system. They have no ownership, or accountability over the sociotechnical system they are acting upon. They are often driven by a feeling of distrust in authority and by a sentiment of disenfranchisement. Problems of these nature may be particularly well addressed by Sustainability Hacks: the ones related not only to socioeconomic marginalization, but to the marginalization of agency (i.e. the desire of taking a more active role in system change). Interestingly, similar feelings may

have recently impacted politics for the worse[49]. The world has recently seen the rise of populism, nativism, nationalism, and conservativism combined with the political discourse of the '*outsider*'[50]. This has happened in multiple countries (e.g., with the elections of Donald Trump, in the United States, and Jair Bolsonaro, in Brazil) and is strongly associated to a distrust in the political establishment. Sustainability Hacking may be related to a similar feeling of disenfranchisement and distrust in the establishment, but one that can drive positive results instead.

6.4.2. When does a Sustainability Hack stop being a Hack to become something else?

This is a particularly challenging question to answer without longitudinal data of multiple cases. Cases of Sustainability Hacking in this research have, at most, been accompanied for a period of 2 years, ranging from the first engagement until the moment of concluding this work. Even for cases that occurred decades ago, it was particularly challenging – and outside the scope of this work – to obtain data that could be objectively and systematically contrasted over time. This section can only provide conjectures and indications of what was observed from cases that were facing transformations throughout data collection, i.e. in the process of evolving from a Sustainability Hack into something else.

First, it is first important to highlight that a Sustainability Hack is an 'unconventional' solution. If, for some reason it becomes the mainstream approach towards the problem, then, in principle, it will no longer be a Sustainability Hack. This may happen if the solution becomes widely disseminated and, as a result, changes the 'rules of the game'. For example, Bitcoin – i.e. cryptocurrency that uses decentralised control, based on blockchain technology – opposes centralised currencies and central banking systems and may be interpreted as a Sustainability Hack. It is clearly an unconventional solution to what is seen by many as a problem: i.e. the centralization of financial transactions within the hands of a few powerful organisations. The movement Occupy Wall Street, among many, claimed this contributes to amplify the divide of the rich and the poor[51]. If countries fully substitute their currencies for Bitcoin, then what may

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[49] Here the researcher recognises his analytical bias, given his abhorrence towards the political phenomena described in this paragraph – including in his home country, Brazil.

[50] E.g. https://www.washingtonpost.com/world/the_americas/just-like-trump-bolsonaro-leads-brazils-presidential-race-with-right-wing-populist-pitch/2018/10/04/c4ba3728-c65c-11e8-9c0f-2ffaf6d422aa_story.html?utm_term=.63b234ef8a29 [Accessed 10 December 2018]

[51] The Occupy Wall Street was a protest that began on September 2011, in New York City's Wall Street financial district. It received global attention and bolstered movements against economic inequality worldwide. Many – including WikiLeaks's founder Julian Assange – have claimed that Bitcoin and other cryptocurrencies are powerful mechanisms of (unconventionally) addressing the problem (e.g. see: https://www.marketwatch.com/story/wikileaks-founder-julian-assange-bitcoin-is-the-real-occupy-wall-street-2017-12-15) [Accessed 10 December 2018]

be interpreted as a Sustainability Hack will be undoubtedly converted into a mainstream solution, changing the rules of the game.

Second, it seems that, so long as it remains 'unconventional', a Sustainability Hack can be replicated or adapted to other contexts, without necessarily becoming something else. For example, resulting from my Action Research with ColaLife (Case A) is a report, described in richer details in a previous section, that aims to serve as an intervention model portraying a stepwise process on how to implement a similar Sustainability Hack in other contexts. Therefore, even if requiring a high level of adaptation to be implemented elsewhere, it would likely remain as a Sustainability Hack.

Third, there is an important and rather subjective caveat to be taken into account: Sustainability Hacks also present dominant features. Chapter 5 has, in fact, listed and explained 15 similarities identified across cases. They are not 'must-have' features. However, once a Sustainability Hack evolves and start progressively missing out some of these features, they may start progressively looking like 'something else'. For example, Goats for Water (Case I) has clearly started as a Sustainability Hack. The only exception it had, from its inception, was 'horizontal governance': it presented all other 14 features. They are invested in scaling up within Pakistan and, throughout the process, began to miss out some of its original features: e.g. ownership is no longer distributed. The more they miss out these features, the more likely they may be described as a social enterprise, or 'something else', instead of as a Sustainability Hack.

6.4.3. How to scale up a Sustainability Hack? What is its impact in the long-term?

Investigating possibilities of scaling up Sustainability Hacks was one of the most challenging tasks the researcher faced during his PhD. This question can deeply contribute not only to theory but also to practice, with immediate results to pressing sustainability problems. For this reason, the researcher has been directly involved – with different time requirements and scope – with the scaling up processes of a few cases, obtaining insights that may provide valuable starting points for future research endeavours.

The data presented in Chapter 5 clearly indicates that these possibilities can be placed within a spectrum, ranging from replicability to adaptability. However, the specificities across cases and mechanisms available to purposefully bolster their expansion have not been fully explored to draw robust conclusions.

The most intense involvement was with Case A, ColaLife, as described in a previous section. The analysis has identified several possibilities for scaling up the principles and design of this Sustainability Hack; most of which would require a high level of contextual adaptation

and efforts. These prospects to scale-up vary according to the settings and intended goals for expansion and can be summarized as follows: 1) organic expansion of emulated value chains within Zambia; 2) systematic efforts for scaling up to other countries; and 3) systematic efforts promoting access to other healthcare products. However, since an intervention model of this nature was only created for Case A, the inferences are not robust enough to pinpoint what is specific to this case and what traits are shared by others. Furthermore, the model has not yet been used in other contexts and, therefore, the analysis may have not foreseen important traits factoring in the likelihood of the Sustainability Hack successfully expanding.

Also within the spectrum, but tending to replicability, is Case B, OSA. The analysis of this case, scrutinised in Chapter 5, has identified different possibilities of scaling up, based on plans of the Sustainability Hackers themselves. The initiative is essentially anchored on the principle of 'open access' – and it is intended to scale up as such. Using AI in similar contexts and purposes would simply require replication of the initiative: scope here lies mostly in applying or modifying the robots to an analogous scenario that has not yet been contemplated. The more the context and the purpose change, the more the initiative would have to be adapted, instead of simply replicated. Finally, the project also has a capacity of spilling-over practices of governments, in case these organisations, that are not 'external' to the system, start deploying AI internally to audit public expenses and enhance their investigative capacity.

Similar to the previous subsection, understanding long-term impact will likely require longitudinal data of multiple cases, obtaining data entries that can be systematically contrasted and accompanying their evolution over time. As a way of working around this limitation, future studies can draw upon analogous domains, such as innovation prizes and strategic niches, which may provide a richer dataset to infer about long-term impacts of Sustainability Hacks.

6.5. Final Reflections and Concluding Remarks

The major contribution of this work consists of exploring a largely ignored change driver of sociotechnical systems. The phenomena of Sustainability Hacking, conceptualised in this work, is particularly promising for situations where information is limited, resources are scarce, stakes are high, and decision-making, urgent.

This chapter has evidenced how the researcher has met the research objectives, paving the way for future research endeavours. It highlights the main contributions of this work and discusses a diverse set of opportunities both for research and practice on Sustainability Hacking. This section openly reflects on the strengths and weaknesses of this research, before concluding this work by contemplating a rather subjective question: 'can a Hack save the world'?

6.5.1. Weaknesses

All methodological choices inevitably carry limitations. In this research, methods were means to an end, not an end in themselves. They were chosen for being the most appropriate to address specific sets of questions. Their particular weaknesses have been recognised from the outset of the research design, and, when possible, their impacts on the quality and robustness of the findings were rigorously minimized. The limitations of each research stage have been scrutinised in Chapter 2 (i.e. Research Design), but are briefly reassessed now that the outcomes of this work have been fully presented.

The 1st research stage consisted of a systematic literature review, with data initially collected from the Web of Science database, and subsequently expanded through snowballing. This is a limitation, given that relevant publications that are not within that database may not have configured within the initial sample, and snowballing only addresses publications cited by, and consequently published before, the papers within the sample. The impact was minimized with the inclusion of articles recommended by experts and on underrepresented topics identified by the researcher.

The 2nd stage adopted a Phenomenon-Driven approach, exploring multiple perspectives composing the 'whole', instead of validating parts for generalisability or for causality. The main limitation thus consists of its rather descriptive nature. In fact, the traits found were not treated as 'must-haves' in the following research stage, but rather as dominant traits to be further investigated with cases of Sustainability Hacking.

The 3rd stage employed an inductive and exploratory approach, combining Action Research and Case Study. Similar to the 2nd, it did not aim at validating or testing results for generalisability. Furthermore, since this research was investigating a rather unexplored phenomenon, i.e. 'Sustainability Hacking', data collection relied on finding cases through online searches and recommendations from others. Data collection, as a result, has an unintended selection bias, against which the researcher could not do much.

Cutting across all research stages is the limitation of subjectively interpreting content from documents and, most importantly, interviews. Triangulation with other researchers was sporadically used to cope with subjectivity, and the process of coding was deployed in a very structured and systematic manner. However, this is undoubtedly the most critical limitation of this study; and, consequently, also an opportunity for future studies aiming at elaborating further on this research topic. Furthermore, due not only to subjectivity, but also the richness of datasets and novelty of the investigated topic, important features may have unintendedly

passed unnoticed. All contents presented in this thesis were, nonetheless, rigorously analysed and transparently reported – and can, therefore, be tested by future research.

Besides limitations associated to the employed methods, there are two major limitations of content that have not been explored in subsection 6.5 (i.e. Grey Areas of this Research). That is because they are more than Grey Areas in this thesis: they are murky.

First, the researcher attempted to contact all identified cases of Sustainability Hacking, during the 3rd research stage. For an unknown reason, cases motivated by social goals were not only easier to find, but also more responsive to my approaches. The researcher has speculated on the reasons for this seemingly (and rather unintended) selection bias, including: 'the existence of more social cases'; 'social cases receiving more publicity than environmental ones, hence influencing my ability of finding them'; 'environmental cases being led by individuals/organisations that are more sceptical towards the value of engaging with academics'; and 'the researcher feeling more motivated to investigate social cases and, consequently, unconsciously biasing the sample'. Although they seem plausible, the researcher has no evidence for these conjectures. Second, due to the cross-sectional nature of the datasets, the researcher could not rigorously investigate – not even speculate on – the unintended consequences of Sustainability Hacking: a very important aspect to analyse if a system change has, in fact, been as sustainable as it initially seems.

The researcher would, therefore, particularly urge future studies to investigate cases motivated solely by environmental goal to contrast to the findings of Chapter 5, as well as longitudinal studies capable of fully investigating the cascading effects of Sustainability Hacking, including but not restricted to the unintended ones. That would be extremely valuable not only to test if the findings of this research are widely applicable, but also to obtain novel insights to contribute to furthering the understanding of Sustainability Hacking.

6.5.2. Strengths

From the outset, the researcher aimed to develop an original, bold piece of work. In 2015, I had a research proposal that got me a fully funded PhD offer at Cambridge. Its relevance to theory was evident, but I thought it was too vanilla. Something that would simply fill a gap in theory. I decided to investigate new ways of contributing to theory beyond gap filling and, after conducting the systematic literature review portrayed in Chapter 3, many research avenues were identified. Many of them were safe choices: they were definitely PhDable. Pursuing the route of 'Hacking' was definitely a riskier route. But this was too intriguing, too itchy. When discussing these possibilities with my supervisor, he said: "if you have an itch, you should scratch it". I scratched and I am very grateful for this piece of advice.

Resembling mothers that think their babies are the cutest – even when they barely look human – many PhD students believe their work is super original. I may be blinded by the excitement of something new. If the concept of Sustainability Hacking is indeed original, only others can tell. Yet, inspiration from its apparent originality and motivation by its practical implications for sustainability got me moving throughout the past 3 years. That was what made me excited to collect and analyse data, to engage with multiple agents, to reflect on the implications of the findings to theory and practice, and to brew extra doses of coffee to bolster my writing. If not a distinctive strength of this work, originality was at least critical for its conclusion.

Interestingly, two academics introduced to my research told me I should write 'a book to be sold at airports'. When I first heard that, I did not know if I could take that as a compliment. I have been appalled many times by the sheer number of self-help and motivational leadership books taking the front shelves of bookshops at airports. I had the impression travellers had bad taste. When a second academic gave me the same remark, I saw a pattern – and, well, researchers love patterns! I had to explore that further. For my contentment, he said my work was not only thought-provoking, but also accessible to different audiences. Now, towards its completion, I believe accessibility is one of this work's main virtues; one that I hope the academia will value progressively more.

Whereas originality and accessibility are subjective to interpretation, other traits are less so. Readers will likely acknowledge methodological rigor as a merit of this research, besides the large quantity, richness and transparency of my datasets. This work has, indeed, involved a lot of sweat – and, believe me, no tears! The 1st research stage involved the systematic review of over 200 documents. The 2nd included over 14 hours of transcribed interviews. The 3rd, and most far-reaching research stage, counts with approximately 89 hours of interviews of 19 cases, based in 9 different countries. Besides the satisfaction of helping initiatives I admired, my Action Research with some cases allowed me to gain valuable insights that were only possible due to an active engagement. Furthermore, beyond the large quantity and richness of primary data, the diversity within the dataset, and the combination of multiple research methods have been responsible for the multiple findings, transparently shared with the readers in Chapters 3, 4 and 5.

6.5.3. Can a Hack save the world?

The reader may be wondering, at this stage, if a Sustainability Hack can save the world from the most intractable socioenvironmental challenges of our times. Can a Hack, for example, save us from climate change? Unfortunately, my answer is: I do not think so. Believing in the

existence of an elixir for intra and intergenerational prosperity would be extremely naïve for the following reasons.

First, there is no single change driver of sociotechnical systems that can save the world from its greatest challenges. For example, climate change will not be fully tackled by the wide diffusion of a single technical solution, such as hybrid cars, neither by a massive change in social behaviour, such as veganism. Likewise, no president, CEO or Hacker will be fully responsible for the complex and interconnected changes required to address problems of grand magnitude. Hope lies on a diverse portfolio of change drivers pursued through coordinated action of multiple stakeholders, which may include but will unlikely be limited to Hacking.

Second, the empirical exploration has indicated that the possibility of Hacking a system empowers the disenfranchised of traditional power structures to take agency over socioenvironmental problems. Nothing, in principle, impedes them from targeting intractable challenges. Yet, taking agency over such challenges may seem impractical or unfeasible: they focus instead on problems that can be immediately and autonomously addressed, with the resources that are widely available. That naturally sets the most intractable problems of our times apart from their ambitions. For example, Case A emulates Coca-Cola's value chain to make diarrhoea treatment available in the Last Mile, but it does not directly target the bottlenecks preventing medicines to reach remote regions. Likewise, Case C focuses on providing safe abortion services for women residing in countries where abortion is illegal, instead of directly tackling the roots of institutionalised gender inequality.

Third, the cases studied in this research happened at the margins of sociotechnical systems, but they have also signalized the potential of impacting beyond what was originally intended. Can a Sustainability Hack (intentionally or not) move from the margins to the mainstream and radically change a system? Unfortunately, this research does not have strong evidence to accurately discuss the scale of these cascading impacts. This would require longitudinal studies and larger datasets. I, nevertheless, suppose that a Sustainability Hack may be able to trigger a transformation of sociotechnical regimes only if the initial disturbance in the system is subsequently accompanied by the emergence and diffusion of other systemic changes, driven by multiple stakeholders. For example, Case B has used Artificial Intelligence to identify and report suspicious public expenses. Despite clearly promoting direct participation of citizens in the public administration, it is hard to envision this solution replacing electoral systems for political representation if not accompanied by the subsequent mobilization of other agents and resources.

Lastly, this work contributes by revealing and exploring a change driver that has been largely ignored by the literature on sociotechnical system change for sustainability. By

recognizing its existence and identifying how it can be pursued, this research explores one of the multiple mechanisms capable of steering much-needed system change towards more sustainable directions. It is nonetheless important to recognize that Sustainability Hacking is one, not *the* one. Solutions to the world's most challenging problems will likely occur both outside and within the established power structures – even if we have to Hack these power structures first!

REFERENCES

Abernathy, W. & Utterback, J. 1978. Patterns of Industrial Innovation. *Technology Review*, 80(7) pp.41–47.

Abramovitz, M. 1986. Catching Up, Forging Ahead, and Falling Behind. *The Journal of Economic History*, 46(2), pp.385–406.

Ackoff, R. 1974. Systems, Messes and Interactive Planning. *Planning and Policy*, 3, pp.417–438.

Ahn, J.M., Minshall, T. & Mortara, L. 2014. Open Innovation: A New Classification and Its Impact on Firm Performance in Innovative SMEs. *Ssrn*, 2, pp.33–54.

Alvesson, M. & Sandberg, J. 2011. Generating Research Questions Through Problematization. *Academy of Management Review*, 38(2), pp.247–271.

Amsden, A. 2002. The Rise of "The Rest": Challenges to the West from Late-Industrializing Economies, *Oxford University Press.*

Arrow, K.J. 1972. Economic Welfare and the Allocation of Resources for Invention. *Readings in Industrial Economics*, pp.219–236.

Arthur, W.B. 1989. Competing Technologies, Increasing Returns, and Lock-in By Historical Events. *The Economic Journal*, 99(March), pp.116–131.

Bailey, C.A. 1996. A guide to qualitative field research. *Thousand Oaks: Pine Forge*.

Baker, T., Miner, A.S. & Eesley, D.T. 2003. Improvising firms: Bricolage, account giving and improvisational competencies in the founding process. *Research Policy*, 32(2 SPEC.), pp.255–276.

Banks, L., Pim, D. & Thomas, M. 2003. Viruses and the 26S proteasome: hacking into destruction. *Trends in Biochemical Sciences*, 28(8), pp.452–459.

Baqui, A.H. *et al.* 2002. Effect of zinc supplementation started during diarrhoea on morbidity and mortality in Bangladeshi children: community randomised trial. *BMJ (Clinical research ed.)*, 325(7372), p.1059.

Barras, R. 1986. Towards a theory of innovation in services. *Research Policy*, 15(4), pp.161–173.

Basu, R., Banerjee, P. & Sweeny, E. 2013. Frugal Innovation: Core Competencies to Address Global Sustainability. *Journal of Management for Global Sustainability*, 1(2), pp.63–82.

Beck, U. 1999. *World Risk Society*, Cambridge: Polity Press.

Berkhout, F., Stirling, A. & Smith, A. 2004. Socio-technological regimes and transition contexts. *System innovation and the transition to sustainability: Theory, evidence and*

policy, 44(106), pp.48–75.

Bhandari, N. *et al.* 2008. Effectiveness of zinc supplementation plus oral rehydration salts compared with oral rehydration salts alone as a treatment for acute diarrhea in a primary care setting: a cluster randomized trial. *Pediatrics*, 121(5), pp.e1279-85.

Bhatti, Y.A. 2012. What is Frugal, What is Innovation? Towards a Theory of Frugal Innovation. *SSRN Electronic Journal*.

Bhutta, Z.A. *et al*., 2000. Therapeutic effects of oral zinc in acute and persistent diarrhea in children in developing countries: pooled analysis of randomized controlled trials. *The American journal of clinical nutrition*, 72(6), pp.1516–22.

Bijker, W. 1995. *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change*, Cambridge, Massachusetts: The MIT Press.

Birtchnell, T. 2011. *Jugaad* as systemic risk and disruptive innovation in India. *Contemporary South Asia*, 19(4), pp.357–372.

Blanchflower, D. & Oswald, A. 1998. What Makes an Entrepreneur? *Journal of Labor Economics*, 16(1), pp.26–60.

Blizzard, J.L. & Klotz, L.E. 2012. A framework for sustainable whole systems design. *Design Studies*, 33(5), pp.456–479.

Borrás, S. and Edler, J. (2015) *The governance of socio-technical systems: explaining change*. Edited by S. Borrás and J. Edler. Edward Elgar Publishing.

Bower, J. & Christensen, C. 1995. Disruptive Technologies: Catching the Wave. *Harvard Business Review*, (January-February), pp.43-53.

Brass, E., Searle, D. & Poklewski Koziell, S. 1997. *G*athering force : DIY culture : radical action for those tired of waiting. *Big Issue Writers.*

Brennan, G. & Tennant, M. 2018. Sustainable value and trade-offs: Exploring situational logics and power relations in a UK brewery's malt supply network business model. *Business Strategy and the Environment*, 27(5), pp.621–630.

Brundtland, G.H. 1987. Our Common Future: Report of the World Commission on Environment and Development. *Medicine, Conflict and Survival*, 4(1), p.300.

Burns, L.R. *et al.* 2002. The Wharton School Study of the Health Care Value Chain. In *Health Care Value Chain: producers, purchasers, and providers*. John Wiley & Sons.

Cabrera, D. 2006. *Systems thinking*. Cornell University.

Cahnman, W.J. *et al.* 2016. Ideal Type Theory: Max Weber's Concept and Some of Its Derivations. *The Sociological Quarterly*, 6(3), pp.268–280.

Capra, F. 1983. The turning point: science, society, and the rising culture. *Bantam Books.*

Carlsson, B. *et al.* 2002. Innovation systems: analytical and methodological issues. *Research*

Policy, 31, pp.233–245.

Ceschin, F. & Gaziulusoy, I. 2016. Evolution of design for sustainability: From product design to design for system innovations and transitions. *Design Studies*, 47, pp.118–163.

Chang, H.-J. 2002. Kicking away the ladder: development strategy in historical perspective. *Anthem.*

Chankova, S. & Sulzbach, S. 2006. Zambia Health Services and Systems Program. *Bethesda, MD.*

Charnley, F., Lemon, M. & Evans, S. 2011. Exploring the process of whole system design. *Design Studies*, 32(2), pp.156–179.

Chesbrough, H. 2010. Business model innovation: Opportunities and barriers. *Long Range Planning*, 43(2–3), pp.354–363.

Chesbrough, H.W. 2003. Open innovation: the new imperative for creating and profiting from technology. *Harvard Business School Press*.

Christensen, C., Raynor, M. & McDonald, R. 2015. What Is Disruptive Innovation? *Harvard Business Review*, (December).

Christensen, C.M. 2013. The innovator's dilemma: when new technologies cause great firms to fail. *Harvard Business Review Press.*

Ciborra, C. 2004. The labyrinths of Information: challenging the wisdom of systems. *Oxford University Press.*

Clark, K. & Fujimoto, T. 1991. Product development performance: strategy, organization, and management in the world auto industry. *Harvard Business School Press.*

Clark, W. & Crutzen, P. 2005. Science for global sustainability: toward a new paradigm. *KSG Working Paper No.*, (120), pp.1–28.

Coenen, L., Benneworth, P. & Truffer, B. 2012. Toward a spatial perspective on sustainability transitions. *Research Policy*, 41(6), pp.968–979.

Cohen, M.J. 2006. Ecological modernization and its discontents: The American environmental movement's resistance to an innovation-driven future. *Futures*, 38(5), pp.528–547.

Cohen, M.J. 1997. Risk society and ecological modernisation alternative visions for post-industrial nations. *Futures*, 29(2), pp.105–119.

Cohen, W.M. & Levinthal, D.A. 1990. A new perspective on learning and innovation. *Administrative Science Quarterly*, 35(1), pp.128–152.

Cooke, P., Gomez Uranga, M. & Etxebarria, G. 1997. Regional innovation systems: Institutional and organisational dimensions. *Research Policy*, 26(4–5), pp.475–491.

Cooperrider, D. 2008. Sustainable Innovation. *BizEd*, 7(4), pp.32–38.

Coriat, B. & Weinstein, O. 2002. Organizations, firms and institutions in the generation of

innovation. *Research Policy*, 31(2), pp.273–290.

Crane, A. *et al*. 2014. Contesting the Value "Creating Shared Value" Concept. *California Management Review*, 56(2), pp.130–154.

Daly, H.E. 1991. *Steady-state economics*, Island Press.

Daly, H.E. & Townsend, K.N. (Kenneth N., 1993. *Valuing the earth: economics, ecology, ethics*, MIT Press.

de Bellis, N. 2009. Bibliometrics and Citation Analysis. *The Scarecrow Press*.

de Haan, F.J. *et al.* 2014. The needs of society: A new understanding of transitions, sustainability and liveability. *Technological Forecasting and Social Change*, 85, pp.121–132.

Denzin, N.K. & Lincoln, Y.S., 2008. Strategies of qualitative inquiry. *Thousand Oaks: Sage Publications.*

Derissen, S., Quaas, M.F. & Baumgärtner, S. 2011. The relationship between resilience and sustainability of ecological-economic systems. *Ecological Economics*, 70(6), pp.1121–1128.

Dewey, J. 1938. Logic: the theory of inquiry. *New York: Holt, Rinehart & Winston*.

Doloreux, D. & Parto, S. 2005. Regional innovation systems: Current discourse and unresolved issues. *Technology in Society*, 27(2), pp.133–153.

Dorst, K. 2011. The core of "design thinking" and its application. *Design Studies*, 32(6), pp.521–532.

Dosi, G. 1982. Technological paradigms and technological trajectories. A suggested interpretation of the determinants and directions of technical change. *Research Policy*, 11(3), pp.147–162.

Dosi, G., Nelson, R.R. & Winter, S.G. 2000. The nature and dynamics of organizational capabilities. *Oxford University Press.*

Dovers, S.R. & Handmer, J.W. 1993. Contradictions in Sustainability. *Environmental Conservation*, 20(3), pp.217–222.

Dreborg, K.H. 1996. Essence of backcasting. *Futures*, 28(9), pp.813–828.

Durance, P. & Godet, M. 2010. Scenario building: Uses and abuses. *Technological Forecasting and Social Change*, 77(9), pp.1488–1492.

Eames, M. & McDowall, W. 2010. Sustainability, foresight and contested futures: exploring visions and pathways in the transition to a hydrogen economy. *Technology Analysis & Strategic Management*, 22(6), pp.671–692.

Easterby-Smith, M., Thorpe, R. & Jackson, P. 2015. *Management and Business Research* 5th ed., London: Sage.

Eden, C. & Huxham, C. 1996. Action Research for Management Research. *British Journal of Management*, 7(1), pp.75–86.

Edmondson, A.C. & Mcmanus, S.E. 2007. Methodological fit in management field research. *Academy of Management Review*, 32(4), pp.1155–1179.

Eisenhardt, K.M., 1989. Building Theories from Case Study Research. *The Academy of Management Review*, 14(4), pp.532–550.

Eisenhardt, K.M. & Graebner, M.E. 2007. Theory building from cases: Opportunities and challenges. *Academy of Management Journal*, 50(1), pp.25–32.

Eisenhardt, K.M. & Tabrizi, B.N. 1995. Accelerating Adaptive Processes: Product Innovation in the Global Computer Industry. *Administrative Science Quarterly*, 40(1), pp.84–110.

Ekins, P. 2011. System Innovation for Environmental Sustainability: Concepts, Policies and Political Economy. In *International Economics of Resource Efficiency*. Heidelberg: Physica-Verlag HD, pp. 51–88.

Elkington, J. 1999. Cannibals with forks: the triple bottom line of 21st century business. *Capstone.*

Elzen, B., Geels, F.W. & Green, K. 2004. System innovation and the transition to sustainability: theory, evidence and policy. *Edward Elgar.*

England, R. 2007. Are we spending too much on HIV? *British Medical Journal (Clinical research ed.)*, 334(7589), p.344.

Esty, D.C. & Winston, A.S. 2009. Green to gold: how smart companies use environmental strategy to innovate, create value, and build competitive advantage. *Wiley.*

Ettlie, J.E. & Reza, E.M. 1992. Organizational Integration and Process Innovation. *Academy of Management Journal*, 35(4), pp.795–827.

Evans, S. *et al.* 2009. Towards a sustainable industrial system. *International Manufacturing Professors Symposium in Cambridge UK*, pp.1–25.

Ezrahi, Y. 1990. The Descent of Icarus: Science and the Transformation of Contemporary Democracy. *Harvard University Press.*

Fagerberg, J. 1994. Technology and international differences in growth rates. *Journal of Economic Literature*, 32(3), pp.1147–1175.

Farla, J. *et al.* 2012. Sustainability transitions in the making: A closer look at actors, strategies and resources. *Technological Forecasting and Social Change*, 79(6), pp.991–998.

FIESP, 2010. Área de Competitividade Relatório Corrupção: custos econômicos e propostas de combate. pp.7–35.

Forrester, J.W. 1961. *Industrial dynamics* Reprinted., Martino Publ.

Fowke, R. & Prasad, D. 1996. Sustainable Development, Cities and Local Government.

Australian Planner, 33(2), pp.61–66.

Fox, S., Ulgado, R.R. & Rosner, D. 2015. Hacking Culture, Not Devices. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing - CSCW '15*. New York, USA: ACM Press, pp. 56–68.

Freeman, C. 1991. Innovation, Changes of Techno-Economic Paradigm and Biological Analogies in Economics. *Revue Économique*, 42(2), p.211.

Freeman, C., 1995. The 'National System of Innovation' in historical perspective. *Cambridge Journal of Economics*, 19, pp.5–24.

Freeman, C. & Louçã, F. 2001. As time goes by: from the industrial revolutions to the information revolution. *Oxford University Press.*

Freeman, C. & Perez, C. 1988. Structural crises of adjustment, business cycles and investment behaviour. In G. et al Dosi, ed. *Technical Change and Economic Theory*. pp. 38–66.

Freeman, C. & Soete, L. 2000. The Economics of Industrial Innovation. *Routledge*, p.470.

Funtowicz, S.O. & Ravetz, J.R. 1995. Science for the Post Normal Age. In L. Westra & J. Lemons, eds. *Perspectives on Ecological Integrity*. Dordrecht: Springer Netherlands, pp. 146–161.

Funtowicz, S.O. & Ravetz, J.R., 1990. *Uncertainty and Quality in Science for Policy*, Dordrecht: Springer Netherlands.

Furman, J.L., Porter, M.E. & Stern, S. 2002. The determinants of national innovative capacity. *Research Policy*, 31, pp.899–933.

Gallouj, F. & Weinstein, O. 1997. Innovation in services. *Research Policy*, 26, pp.537–556.

Ganatra, B. *et al.* 2017. Global, regional, and subregional classification of abortions by safety, 2010–14: estimates from a Bayesian hierarchical model. *The Lancet*, 390(10110), pp.2372–2381.

Garud, R. & Karnøe, P. 2003. Bricolage versus breakthrough: distributed and embedded agency in technology entrepreneurship. *Research Policy*, 32, pp.277–300.

Gaziulusoy, A.I. & Brezet, H. 2015. Design for system innovations and transitions: A conceptual framework integrating insights from sustainability science and theories of system innovations and transitions. *Journal of Cleaner Production*, 108, pp.1–11.

Geels, F.W. 2004. From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory. *Research Policy*, 33(6–7), pp.897–920.

Geels, F.W. 2004. From sectoral systems of innovation to socio-technical systems Insights about dynamics and change from sociology and institutional theory. *Research Policy*, 33,

pp.897–920.

Geels, F.W. 2010. Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. *Research Policy*, 39(4), pp.495–510.

Geels, F.W. 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy*, 31(8–9), pp.1257–1274.

Geels, F.W. 2005. The Dynamics of Transitions in Socio-technical Systems: A Multi-level Analysis of the Transition Pathway from Horse-drawn Carriages to Automobiles (1860–1930). *Technology Analysis & Strategic Management*, 17(4), pp.445–476.

Geels, F.W. & Schot, J. 2007. Typology of sociotechnical transition pathways. *Research Policy*, 36(3), pp.399–417.

Geissdoerfer, M. *et al.* 2017. The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, 143, pp.757–768.

Geissdoerfer, M. *et al.* 2016. The Cambridge Sustainable Business Model Innovation Process. *14th Global Conference on Sustainable Manufacturing*, 00(October), pp.262–269.

George, G., Mcgahan, A.M. & Prabhu, J. 2012. Innovation for Inclusive Growth: Towards a Theoretical Framework and a Research Agenda. *Journal of Management Studies*, 49(4), pp.661–683.

Gerschenkron, A. 1962. Economic backwardness in historical perspective: a book of essays. *Harvard University Press.*

Giacomin, J. 2014. What Is Human Centred Design? *The Design Journal*, 17(4), pp.606–623.

Gill, C.J. *et al.* 2013. Bottlenecks, barriers, and solutions: Results from multicountry consultations focused on reduction of childhood pneumonia and diarrhoea deaths. *The Lancet*, 381(9876), pp.1487–1498.

Gill, J. & Johnson, P. 2002. Research methods for managers. *London: Sage Publications*, 3rd ed.

Glaser, B.G. & Strauss, A.L. 1967. The Discovery of Grounded Theory: Strategies for Qualitative Research. *Nursing Research,* 17(4), pp. 364.

Goffin, K. & Mitchell, R. 2010. Innovation management: strategy and implementation using the pentathlon framework. *Palgrave Macmillan.*

Graddy-Reed, A. & Feldman, M.P. 2015. Stepping up: an empirical analysis of the role of social innovation in response to an economic recession. *Cambridge Journal of Regions, Economy and Society,* 8(2), pp. 293-312.

Gregory, M.J. 1995. Technology management: a process approach. *Journal of Engineering Manufacture*, 209(5), pp.347–356.

Grey, W. 1993. Anthropocentrism and deep ecology. *Australasian Journal of Philosophy*,

71(4), pp.463–475.

Gupta, A. 2016. Grassroots Innovation: minds on the margin are not marginal minds. *Penguin Books*.

Hamilton, C. 2004. The Growth Fetish. *Pluto Press.*

Hardin, G. 1968. The Tragedy of the Commons. *Science*, 162(June), pp.1243–1248.

Hart, S.L. 2000. Beyond greening: Strategies for a Sustainable World. *Harvard Business Review*, 97015.

Hart, S.L. & Milstein, M.B. 2003. Creating sustainable value. *Academy of Management Executive*, 17(2), pp.56–67.

Hipp, C. & Grupp, H. 2005. Innovation in the service sector: The demand for service-specific innovation measurement concepts and typologies. *Research Policy*, 34(4), pp.517–535.

Von Hippel, E. 2001. Perspective: User toolkits for innovation. *Journal of Product Innovation Management*, 18(4), pp.247–257.

Hodgson, G. 2005. Institutions and Economic Development: Constraining, Enabling and Reconstituting. In G. Dymski & S. De Paula, eds. *Reimagining Growth: Towards a Renewal of Development Theory*. Zed Books, pp. 88–95.

Holmberg, J. & Robert, K.-H. 2000. Backcasting — a framework for strategic planning. *International Journal of Sustainable Development & World Ecology*, 7(4), pp.291–308.

Iglesias, D. 2017. Open Data and The Fight Against Corruption in Brazil. *Transparency International and World Wide Web Foundation*.

IHME. 2015. Access, Bottlenecks, Costs, and Equity: ABCE Project Cross-Country Protocol. *Institute for Health Metrics and Evaluation*. Seattle, WA: IHME, 2015

Jackson, T. 2009. Prosperity without Growth? The transition to a sustainable economy. *Sustainable Development Commission,* p.0-136.

Jänicke, M. & Jacob, K. 2006. Environmental governance in global perspective: new approaches to ecological modernisation. *Berlin.*

Jasanoff, S. 2010. A New Climate for Society. *Theory, Culture & Society*, 27(2–3), pp.233–253.

Jasanoff, S. 2009. Governing innovation. *Seminar 507*.

Jasanoff, S. & Kim, S.H. 2009. Containing the atom: Sociotechnical imaginaries and nuclear power in the United States and South Korea. *Minerva*, 47(2), pp.119–146.

Jewkes, J., Sawers, D. & Stillerman, R. 1969. The Development of Inventions. In *The Sources of Invention*. London: Palgrave Macmillan UK, pp. 152–168.

Jordan, A. & Lenschow, A. 2008. Innovation in environmental policy? Integrating the environment for sustainability. *Edward Elgar.*

Jørgensen, U. 2012. Mapping and navigating transitions - The multi-level perspective compared with arenas of development. *Research Policy*, 41(6), pp.996–1010.

De Jouvenel, H. 2000. A brief methodological guide to scenario building. *Technological Forecasting and Social Change*, 65(1), pp.37–48.

Kallis, G. 2011. In defence of degrowth. *Ecological Economics*, 70(5), pp.873–880.

Kaplan, A. 1964. The Conduct of Inquiry: methodology for behavioral science. *San Francisco: Chandler Publishing Company.*

Kaplinsky, R. *et al.* 2002. A Handbook for Value Chain Research. *International Development Research Centre* (*IDRC).*

Kates, R.W. & Parris, T.M. 2003. Long-term trends and a sustainability transition. *Proceedings of the National Academy of Sciences of the United States of America*, 100(14), pp.8062–8067.

Kates, R.W., Parris, T.M. & Leiserowitz, A.A. 2005. What Is Sustainable Development? Goals, Indicators, Values, and Practice. *Environment: Science and Policy*, 47(3), pp.8–21.

Kauffman, S.A., 1995. At home in the universe: the search for laws of self-organization and complexity. *Oxford University Press.*

Kemp, R. 1994. Technology and the transition to environmental sustainability. *Futures*, 26(10), pp.1023–1046.

Kemp, R. & Pearson, P. 2007. Final report MEI project about measuring eco-innovation. *UM Merit, Maastricht*, 10.

Kemp, R., Schot, J. & Hoogma, R. 1998. Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management. *Technology Analysis & Strategic Management*, 10(2), pp.175–195.

Kharrazi, A., Fath, D.B. & Katzmair, H. 2016. Advancing Empirical Approaches to the Concept of Resilience: A Critical Examination of Panarchy, Ecological Information, and Statistical Evidence. *Sustainability*, 8(9).

Kivimaa, P. & Kern, F. 2016. Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. *Research Policy*, 45(1), pp.205–217.

Knutas, A. *et al.* 2015. Cloud-based bibliometric analysis service for systematic mapping studies. *ACM International Conference Proceeding Series*, 1008(212), pp.184–191.

Kuhn, T.S. 1996. The structure of scientific revolutions. *University of Chicago Press.*

Kukk, P., Moors, E.H.M. & Hekkert, M.P. 2016. Institutional power play in innovation systems: The case of Herceptin®. *Research Policy*, 45(8), pp.1558–1569.

Lafferty, W. & Hovden, E. 2002. Environmental Policy Integration: Towards an Analytical Framework? *Environmental Politics,* 12(3), pp. 1-22.

Lanahan, L. & Feldman, M.P. 2015. Multilevel innovation policy mix: A closer look at state policies that augment the federal SBIR program. *Research Policy*, 44(7), pp.1387–1402.

Latour, B. & Woolgar, S. 1986. Laboratory Life: The Construction of Scientific Facts. *New Jersey 08540: Princeton University Press.*

Leach, M., Scoones, I. & Stirling, A. 2007. Pathways to Sustainability: an overview of the STEPS Centre approach. *Brighton: STEP Centre*, p.19.

Leach, M., Scoones, I. & Wynne, B. 2005. Science, citizenship and globalization. *Zed Press.*

Leonard-Barton, D. 1992. The Factory as the Learning Laboratory. *Sloan Management Review*, 34(1), pp.23–28.

Lévi-Strauss, C. 1962. The Savage Mind. *University of Chicago Press.*

Levy, S. 2010. Hackers: heroes of the computer revolution. *O'Reilly Media.*

Leydesdorff, L. 2000. The triple helix: an evolutionary model of innovations. *Research Policy*, 29(2), pp.243–255.

Lincoln, Y. & Guba, E. 1994. Competing Paradigms in Qualitative Research. In N. Denzin & Y. Lincoln, eds. *Handbook of Qualitative Research*. Thousand Oaks: SAGE.

Liu, L. *et al.* 2015. Global, regional, and national causes of child mortality in 2000-13, with projections to inform post-2015 priorities: an updated systematic analysis. *Lancet (London, England)*, 385(9966), pp.430–40.

Loorbach, D. 2010. Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework. *Governance*, 23(1), pp.161–183.

Loorbach, D.A. 2007. Transition Management: New Mode of Governance for Sustainable Development. *Erasmus University.*

Lundvall, B.A. *et al.* 2009. Handbook of innovation systems and developing countries: building domestic capabilities in a global setting. *Edward Elgar.*

Lundvall, B.-Å. *et al.* 2002. National systems of production, innovation and competence building. *Research Policy*, 31(2), pp.213–231.

MacKerron, G. & Berkhout, F. 2009. Learning to listen: institutional change and legitimation in UK radioactive waste policy. *Journal of Risk Research*, 12(7–8), pp.37–41.

Maclean, G. 2005. Dimension, Dynamics and Diversity: A 3D Approach to Appraising Global Maternal and Neonatal Health Initiatives. In R. Balin, ed. *Trends in Midwifery Research*. Nova Biomedical Books, pp. 299–300.

Makridakis, S. 2017. The forthcoming Artificial Intelligence (AI) revolution: Its impact on society and firms. *Futures*, 90, pp.46–60.

Malerba, F. 2006. Innovation, Industrial Dynamics and Industry Evolution: Progress and the Research Agendas. *Revue de l'OFCE*, 97 bis(5), p.21.

Malerba, F. 2004. Sectoral systems of innovation: concepts, issues and analyses of six major sectors in Europe. *Cambridge University Press.*

Malerba, F. 2002. Sectoral systems of innovation and production. *Research Policy*, 31(2), pp.247–264.

Malinowski, B. 1922. Argonauts of the Western Pacific. *Wolnelektury.pl.*

Manzini, E. 2015. Design, when everybody designs: an introduction to design for social innovation. *Cambridge, Massachusetts: MIT Press.*

Markard, J., Raven, R. & Truffer, B. 2012. Sustainability transitions: An emerging field of research and its prospects. *Research Policy*, 41(6), pp.955–967.

Markard, J., Wirth, S. & Truffer, B. 2016. Institutional dynamics and technology legitimacy - A framework and a case study on biogas technology. *Research Policy*, 45(1), pp.330–344.

Markides, C. 2006. Disruptive innovation: In need of better theory. *Journal of Product Innovation Management*, 23(1), pp.19–25.

Martin, B.R., Nightingale, P. & Yegros-Yegros, A. 2012. Science and technology studies: Exploring the knowledge base. *Research Policy*, 41(7), pp.1182–1204.

Mazzucato, M. 2013. The entrepreneurial state: debunking public vs. private sector myths. *Anthem Press.*

McDowall, W. 2012. Technology roadmaps for transition management: The case of hydrogen energy. *Technological Forecasting and Social Change*, 79(3), pp.530–542.

Mckelvey, B. 2002. Managing Coevolutionary Dynamics. *8th EGOS Colloquium*.

Mcwilliams, A. 2016. Corporate Social Responsibility: A Theory of the Firm. *The Academy of Management Review*, 26(1), pp. 117-127.

Meadows, D. 2002. Dancing with Systems. *Whole Earth,* 106, pp.58-63.

Meadows, D. *et al.* 1972. The Limits to Growth: A report for the Club of Rome's project on the predicament of mankind. *New York: Universe Books.*

Meadows, D. 2008. Thinking in Systems: A Primer. *Chelsea Green Publishing.*

Meroni, A. & Milano, P. 2015. A socio-technical approach to design for community resilience: A framework for analysis and design goal forming. *Design Studies*, 40(September), pp.60–84.

Meyer, M.H. & Utterback, J.M. 1993. The product family and the dynamics of core capability. *MIT Sloan Management Review*, 34(3), pp.29–47.

Middleton, N. & O'Keefe, P. 1993. Tears of the Crocodile: From Rio to Reality in the Developing World. *Pluto Press.*

Miller, C.A. 2005. New Civic Epistemologies of Quantification: Making Sense of Indicators of Local and Global Sustainability. *Science, Technology & Human Values*, 30(3), pp.403–

432.

Millstone, E. 2007. Can food safety policy-making be both scientifically and democratically legitimated? If so, how? *Journal of Agricultural and Environmental Ethics*, 20(5), pp.483–508.

Mingers, J. & White, L. 2009. A review of the recent contribution of systems thinking to operational research and management science. *European Journal of Operational Research*, 207(3), pp.1147–1161.

Ministry of Health, R. of Z. 2011. National Health Strategic Plan 2011-2015. Lusaka.

Minshall, T. *et al.* 2010. Making "Asymmetric" partnerships work. *Research Technology Management*, 53(3), pp.53–63.

Mokyr, J. 1990. The lever of riches: technological creativity and economic progress. *Oxford University Press.*

Moorman, C. & Miner, A.S. 1998. Organizational Improvisation and Organizational Memory. *Academy of Management Review*, 23(4), pp.698–723.

Mortara, L. & Minshall, T. 2011. How do large multinational companies implement open innovation? *Technovation*, 31(10), pp.586–597.

Morton, T. 2007. Ecology without nature: rethinking environmental aesthetics. *Harvard University Press.*

Moultrie, J., Clarkson, P.J. & Probert, D. 2007. Development of a Design Audit Tool for SMEs. *Journal of Product Innovation Management*, 24(4), pp.335–368.

Nakata, C. & Weidner, K. 2012. Enhancing new product adoption at the base of the pyramid: A contextualized model. *Journal of Product Innovation Management*, 29(1), pp.21–32.

National Research Council, 1999. Our common journey. *Washington, D.C: National Academies Press.*

Nelson, R.R. & Winter, S.G. 1982. An evolutionary theory of economic change. *Harvard University Press.*

Neuman, W.L. 2013. Social research methods: qualitative and quantitative approaches. *Pearson Education.*

North, D. 1990. Institutions, Institutional Change and Economic Performance. *Cambridge University Press.*

O'Riordan, 1993. The Politics of Sustainability. In K. Turner, ed. *Sustainable Environment Economics and Management: Principles and Practice*. London: Belhaven Press, pp. 37–69.

OECD, 2011. Better Policies to Support Eco-innovation. *OECD Publishing.*

OECD, 2016. Summary of the CDEP Technology Foresight Forum Economic and Social

Implications of Artificial Intelligence. *OECD Publishing*, pp.1–12.

Ostrom, E. 2000. Collective Action and the Evolution of Social Norms. *Journal of Economic Perspectives*, 14(3), pp.137–158.

Palafox, B. *et al.* 2012. ACTwatch 2009 Supply Chain Survey Results. *ACTwatch, Zambia*. Nairobi.

Partidário, P.J., Lambert, J. & Evans, S. 2007. Building more sustainable solutions in production-consumption systems: the case of food for people with reduced access. *Journal of Cleaner Production*, 15(6), pp.513–524.

Penna, C.C.R. & Geels, F.W. 2012. Multi-dimensional struggles in the greening of industry: A dialectic issue lifecycle model and case study. *Technological Forecasting and Social Change*, 79(6), pp.999–1020.

Penrose, E. 2013. The theory of the growth of the firm. *Martino Fine Books.*

Perez, C. 2012. Innovation systems and policy: not only for the rich? *The Other Canon Foundation Working Paper in Technology Governance and Economic Dynamics*, (42).

Perez, C. 2002. Technological revolutions and financial capital: the dynamics of bubbles and golden ages. *E. Elgar Pub.*

Pestre, D. 2008. Challenges for the Democratic Management of Technoscience: Governance, Participation and the Political Today. *Science as Culture*, 17(2), pp.101–119.

Phaal, R., Farrukh, C.J.P. & Probert, D.R. 2001. A framework for supporting the management of technological innovation. *Engineering Department, University of Cambridge*, pp.1–14.

Pincetl, S. *et al.* 2014. Enabling Future Sustainability Transitions: An Urban Metabolism Approach to Los Angeles. In Pincetl *et al.* Enabling Future Sustainability Transitions. *Journal of Industrial Ecology*, 18(6), pp.871–882.

Pisano, G.P. & Verganti, R. 2008. Which kind of collaboration is right for you? *Harvard Business Review*, 86(12), pp.1–7.

Pittaway, L. *et al.* 2004. Networking and innovation in the UK: a Systematic Review of the Literature. *International Journal of Management Reviews,* 5(3-4), pp.137-168.

Poole, M.S. & Van de Ven, A.H., 1989. Towards a general theory of innovation processes. In A. H. Van de Ven, H. L. Angle, & M. S. Poole, eds. *Research on the management of innovation: the Minnesota studies*. New York: Harper & Row Publishers, pp. 637– 662.

Porter, M.E. & Kramer, M.R. 2011. Creating Shared Value how to reinvent capitalism—and unleash a wave of innovation and growth. *Harvard business review*, Jan-Feb, p.17.

Porter, M.E. & Teisberg, E.O. 2006. Redefining health care: creating value-based competition on results. *Harvard Business School Press.*

Prabhu, J. & Jain, S. 2015. Innovation and entrepreneurship in India: Understanding jugaad.

Asia Pacific Journal of Management, 32(4), pp.843–868.

Prahalad, C.K. 2004. *The Fortune at the Bottom of the Pyramid: Eradicating Poverty Through Profits:* Wharton School Publishing.

Prahalad, C.K., Di Benedetto, A. & Nakata, C. 2012. Bottom of the pyramid as a source of breakthrough innovations. *Journal of Product Innovation Management*, 29(1), pp.6–12.

Prahalad, C.K. & Hart, S.L. 2002. The Fortune at the Bottom of the Pyramid. *Strategy+Business Magazine*, (26), p.273.

Radjou, N., Prabhu, J. & Ahuja, S. 2012. Jugaad innovation: Think frugal, be flexible, generate breakthrough growth. *John Wiley & Sons.*

Ramchandani, R. 2016. Emulating commercial, private-sector value-chains to improve access to ORS and zinc in rural Zambia: evaluation of the Colalife trial. *John Hopkins University.*

Raymond, E.S. 1996. The new hacker's dictionary.

Remenyi, D. *et al.* 1998. Doing research in business and management: an introduction to process and method. *SAGE*.

Rip, A. 2006. Reflexive governance for sustainable development. In J.-P. Voss, D. Bauknecht, & R. Kemp, eds. *Reflexive governance for sustainable development*. Edward Elgar, pp. 82–100.

Rip, A. & Schot, J. 1996. The Past and Future of Constructive Technology Assessment. *Technological Forecasting and Social Change*, 54, pp.251–268.

Robson, C. 2002. Real world research: a resource for users of social research methods in applied settings. *Oxford: Blackwell,* 2nds ed.

Rockfeller Foundation, 2008. Private sector role in health supply chains: Review of the role and potential for private sector engagement in developing country health supply chains. *World Health Organization*, Technical Partner Paper, 13, New York.

Rockström, J. *et al.* 2009. Planetary Boundaries: Exploring the safe operating space for humanity. *Ecology and Society*, 14(2).

Roijakkers, N. *et al.* 2018. How Do Entrepreneurial Leaders Promote Open Innovation Adoption in Small Firms? *Open Innovations in SMEs, World Scientific.*

Rotmans, J., Kemp, R. & van Asselt, M. 2001. More evolution than revolution: transition management in public policy. *Foresight*, 3(1), pp.15–31.

Roussel, P. a, Saad, K.N. & Erickson, T.J. 1991. Third-Generation R&D Management. *Harvard Business School Press*, p.6.

Sachs, J. 2015a. The Age of Sustainable Development. *Columbia University Press.*

Sachs, J. 2015b. The Age of Sustainable Development. *Columbia University Press.*

Saunders, M., Lewis, P. & Thornhill, A. 2009. Research Methods for Business Students.

Pearson Education, 5th ed.

Savaget, P. *et al.* 2019. The theoretical foundations of sociotechnical systems change for sustainability: A systematic literature review. *Journal of Cleaner Production*, 206, pp.878–892.

Savaget, P. & Acero, L. 2017. Plurality in understandings of innovation, sociotechnical progress and sustainable development: An analysis of OECD expert narratives. *Public Understanding of Science*, 27(5).

Savaget, P. & Carvalho, F. 2016. Investigating the regulatory-push of eco-innovations in Brazilian companies. *Sustainable Design and Manufacturing,* pp. 27-37.

Schatsky, D., Muraskin, C. & Gurumurthy, R. 2015. Demystifying artificial intelligence. *Deloitte University Press*, p.24.

Schiederig, T., Tietze, F. & Herstatt, C. 2012. Green Innovation in Technology and Innovation Management – an exploratory literature review. *R&D Management*, 42(2), pp.180–192.

Schmookler, J. 1966. Invention and Economic Growth. *Harvard University Press*.

Schot, J. & Geels, F.W. 2008. Strategic niche management and sustainable innovation journeys: theory, findings, research agenda, and policy. *Technology Analysis & Strategic Management*, 20(5), pp.537–554.

Schumpeter, J.A. 1997. Teoria Do Desenvolvimento Econômico - Uma Investigação Sobre Lucros, Capital, Crédito, Juro e O Ciclo Econômico. *São Paulo: Editora Nova Cultural.*

Schwarz, G. & Stensaker, I. 2014. Time to Take Off the Theoretical Straightjacket and (Re-) Introduce Research. *The Journal of Applied Behavioral Sciences,* 50 (4), pp. 478-501.

Sedgh, G. *et al.* 2012. Induced abortion: Incidence and trends worldwide from 1995 to 2008. *The Lancet*, 379(9816), pp.625–632.

Seiffert, M. & Loch, C. 2005. Systemic thinking in environmental management: support for sustainable development. *Journal of Cleaner Production*, 13(12), pp.1197–1202.

Senge, P.M. 1990. The fifth discipline: the art and practice of the learning organization. *Currency*.

Seyfang, G. & Smith, A. 2007. Grassroots innovations for sustainable development: Towards a new research and policy agenda. *Environmental Politics*, 16(4), pp.584–603.

Shaw, A. *et al*. 2014. Accelerating the sustainability transition: Exploring synergies between adaptation and mitigation in British Columbian communities. *Global Environmental Change*, 25(1), pp.41–51.

Shields, P.M. 1998. Pragmatism as Philosophy of Science: a tool for public administration. *Research in Public Administration*, 4, pp.195–225.

Shove, E. & Walker, G. 2010. Governing transitions in the sustainability of everyday life.

Research Policy, 39(4), pp.471–476.

Simon, H. 1996. The Sciences of the Artificial. *MIT Press*, 3rd ed.

Smith, A., Fressoli, M. & Thomas, H 2014. Grassroots innovation movements: challenges and contributions. *Journal of Cleaner Production*, 63, pp.114–124.

Smith, A. & Raven, R. 2012. What is protective space? Reconsidering niches in transitions to sustainability. *Research Policy*, 41(6), pp.1025–1036.

Smith, A. & Stirling, A. 2007. Moving Outside or Inside? Objectification and Reflexivity in the Governance of Socio-Technical Systems. *Journal of Environmental Policy & Planning*, 9(3–4), pp.351–373.

Smith, A., Stirling, A. & Berkhout, F. 2005. The governance of sustainable socio-technical transitions. *Research Policy*, 34(10), pp.1491–1510.

Smith, A., Voss, J.P. & Grin, J. 2010. Innovation studies and sustainability transitions: The allure of the multi-level perspective and its challenges. *Research Policy*, 39(4), pp.435–448.

Stegmaier, P., Kuhlmann, S. & Visser, V. 2014. The discontinuation of socio-technical systems as a governance problem. In Borrás, S et al, ed. *The Governance of Socio-technical Systems: Explaining Change*, pp.111–131.

Stirling, A. 2009. Direction, Distribution and Diversity! Pluralising Progress in Innovation, Sustainability and Development. *STEPS Working Paper 32*, pp.1–45.

Stirling, A. 2014. From Sustainability, through Diversity to Transformation: Towards More Reflexive Governance of Vulnerability. In A. Hommels, J. Mesman, W. Bijker (ed). *Vulnerability in Technological Cultures: New Directions in Research and Governance*. Cambridge, Massachusetts: MIT Press.

Stirling, A. 2008. Opening up and Closing down: Power, participation, and pluralism in the social appraisal of technology. *Science, Technology & Human Values*, 33(2), pp.262–294.

Stirling, A. 2007. Risk, precaution and science: towards a more constructive policy debate. *EMBO reports*, 8(4), pp.309–315.

Stirling, A. 2003. Risk, uncertainty and precaution: Some instrumental implications from the social sciences. In I. Berkhout, F., Leach, M., and Scoones, ed. *Negotiating Change: new perspectives from the social sciences*. Edward Elgar, pp. 33–76.

Strauss, A. & Corbin, J. 1990. Basics of Qualitative Research. *Basics of. Qualitative Research 2nd edition*, pp.3–14.

Stringer, E.T. 2007. Action research. *Sage Publications.*

STRN, 2010. A mission statement and research agenda for the Sustainability Transitions Research Network. *Steering Group of the Sustainability Transitions Research Network.*

Sull, D. & Eisenhardt, K. 2015. Simple rules: how to thrive in a complex world. *Houghton Mifflin.*

Sushandoyo, D. & Magnusson, T. 2014. Strategic niche management from a business perspective: Taking cleaner vehicle technologies from prototype to series production. *Journal of Cleaner Production*, 74, pp.17–26.

Teece, D.J., Pisano, G. & Shuen, A., 2008. Dynamic Capabilities and Strategic Management. *Strategic Management Journal*, 18(7), pp.509–533.

Teisman, G.R., van Buuren, A. & Gerrits, L. 2010. Managing complex governance systems. *Routledge.*

Tennant, M.G., 2015. Values-led entrepreneurship: Developing business models through the exercise of reflexivity. *Local Economy*, 30(5), pp.520–533.

Thaler, R.H. & Sunstein, C.R. 2009. Nudge: improving decisions about health, wealth and happiness. *Penguin Books.*

Tidd, J. 2001. Innovation management in context: environment, organization and performance. *International Journal of Management Reviews*, 3(3), pp.169–183.

Tranfield, D., Denyer, D. & Smart, P. 2003. Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British Journal of Management*, 14, pp.207–222.

Turner, B.L. *et al.* 2003. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Sciences*, 100(14), pp.8074–8079.

Turnheim, B. *et al.* 2015. Evaluating sustainability transitions pathways: Bridging analytical approaches to address governance challenges. *Global Environmental Change*, 35, pp.239–253.

UNAIDS, 2010. Unlocking the potential for social media. *UNAIDS Outlook Report*.

UNCED, 1992. *AGENDA 21*, Rio de Janeiro.

United Nations, 2015. Global Sustainable Development Report. *United Nations.*

Utterback, J.M. & Abernathy, W.J. 1975. A dynamic model of process and product innovation. *Omega*, 3(6), pp.639–656.

Van de Ven, A. *et al.* 1999. The innovation journey. *Oxford University Press.*

Van de Poel, I. 2000. On the Role of Outsiders in Technical Development. *Technology Analysis & Strategic Management*, 12(3), pp.383–397.

Van Fossen, K. 2018. Cultivating healthy food ventures: the business model perspective. *University of Cambridge*.

Van Zeijl-Rozema, A. *et al.* 2008. Governance for sustainable development. *Sustainable Development*, 421(October), pp.410–421.

Viotti, E.B. 2002. National learning systems: A new approach on technological change in late industrializing economies and evidences from the cases of Brazil and South Korea. *Technological Forecasting and Social Change*, 69(7), pp.653–680.

Von Krogh, G., Rossi-Lamastra, C. and Haefliger, S. (2012) 'Phenomenon-based research in management and organisation science: When is it rigorous and does it matter?', *Long Range Planning*, 45(4), pp. 277–298. doi: 10.1016/j.lrp.2012.05.001.

Von Tunzelmann, N. *et al.* 2008. Technological paradigms: Past, present and future. *Industrial and Corporate Change*, 17(3), pp.467–484.

Voß, J.P., Smith, A. & Grin, J. 2009. Designing long-term policy: Rethinking transition management. *Policy Sciences*, 42(4), pp.275–302.

Weber, R. 1990. Basic Content Analysis. *SAGE Publications.*

Webster, J. & Watson, R.T. 2002. Analyzing the Past to Prepare for the Future: Writing a Literature Review. *MIS Quarterly*, 26(2), pp.xiii–xxiii.

Webster, K. 2015. The Circular Economy: A Wealth of Flows. *Isle of Wight: Ellen MacArthur Foundation.*

Whetten, D. 1989. What Constitutes a Theoretical Contribution? *Academy of Management Review*, 14, pp.490–495.

White, L. 1967. The historical roots of our ecologic crisis. *Science,* 155(3767), pp.1203–1207.

WHO/UNICEF, 2001. Reduced osmolarity oral rehydration salts (ORS) formulation: report from a meeting of experts jointly organized by the World Health Organization and United Nations Children's Fund. *WHO-UNICEF, New York.*

WHO, 2001. Reduced osmolarity oral rehydration salts (ORS) formulation: report from a meeting of experts jointly organized by the World Health Organization and United Nations Children's Fund. *WHO, New York.*

Williams, C.C. & Millington, A.C. 2004. The diverse and contested meanings of sustainable development. *Geographical Journal*, 170(2), pp.99–104.

Wittmayer, J.M. & Schäpke, N. 2014. Action, research and participation: roles of researchers in sustainability transitions. *Sustainability Science*, 9(4), pp.483–496.

Wohlin, C. 2014. Guidelines for snowballing in systematic literature studies and a replication in software engineering. *EASE'14 Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering*.

World Bank, 2000. Overview of Rural Decentralization in India. *World Bank Report*. Washington.

Wynne, B. 1996. May the Sheep Safely Graze? A Reflexive View of the Expert-Lay Knowledge Divide. In B. Lash, Scott; Szerszynski, Bronislaw; Wynne, ed. *Risk,*

Environment and Modernity: Towards a New Ecology. London: SAGE Publications, pp. 44–83.

Wynne, B. 1992. Uncertainty and Environmental Learning - Reconceiving Science and Policy in the Preventive Paradigm. *Global Environmental Change-Human and Policy Dimensions*, 2(2), pp.111–127.

Yang, M. *et al.* 2014. Sustainable Value Analysis Tool for Value Creation. *Asian Journal of Management Science and Application*, 1(4), pp.312–332.

Yin, R.K. 2003. Case study research: design and methods. *Thousand Oaks: Sage Publications,* 3rd ed.

Zeschky, M., Widenmayer, B. & Gassmann, O. 2011. Frugal Innovation in Emerging Markets. *Research-Technology Management*, 54(4), pp.38–45.

Žižek, S., 2011. Living in the end times. *Verso*.

Zott, C., Amit, R. & Massa, L. 2011. The Business Model: Recent Developments and Future Research. *Journal of Management*, 37(4), pp.1019–1042.

Appendix A

Tables 25 and 26 provide details of the data recorded for Stages 2 and 3 of this (see Tables 25 and 26). These tables supplement, respectively, the contents of the sections 2.7.2 and 2.7.3.

Table 25: Detailed description of recorded data for Stage 2

Description of interviewee	Acronym	In-person or virtual	Location of the interview (or interviewee, in case of Skype)	Date(s)	Time of recorded audios (in min)
Self-declared hacker and cybersecurity expert	X1	In-person	Cambridge (United Kingdom)	October 2016	61,46
Self-declared hacker and cybersecurity expert	X2	In-person	Cambridge (United Kingdom)	October 2016	88,33
Self-declared hacker and cybersecurity expert	X3	In-person	Cambridge (United Kingdom)	October 2016	75,28
Cybersecurity expert	X4	In-person	Cambridge (United Kingdom)	October 2016	51,35
Self-declared hacker	X5	Skype	Rio de Janeiro (Brazil)	November 2016	88,2
Cybersecurity expert	X6	In-person	Cambridge (United Kingdom)	November 2016	61,42
Self-declared hacker	X7	In-person	Cambridge (United Kingdom)	November 2016	42,53
Self-declared hacker and cybersecurity expert	X8	In-person	Cambridge (United Kingdom)	November 2016	36,09
Cybersecurity expert	X9	In-person	Cambridge (United Kingdom)	November 2016	32,26
Self-declared hacker	X10	Skype	San Francisco (United States)	November 2016	62,02
Self-declared hacker	X11	Skype	Boston (United States)	November 2016	31,27
Self-declared hacker	X12	Skype	Amsterdam (Netherlands)	November 2016	19,13

Table 26: Detailed description of recorded data for Stage 3

Case	Method for data collection	Stakeholder Category	Agent(s)	Interviewees	Number of interviewees/ participants	Acronym	In-person or virtual	Location of the interview (or interviewee, in case of Skype)	Dates	Collective time of recorded audios (in min)
A	Semi-structured interview(s)	Sustainability Hacker	ColaLife	Founders and staff	3	A1-A3	In-person	London (United Kingdom), Lusaka and Chipata (Zambia)	December 2016 - July 2017	503,68
		Local Champion	Keepers Zambia Foundation	Staff	8	A4-A11		Lusaka and Chipata (Zambia)	May and June 2017	394,32
		Community-based Retailers	Rural and peri-urban shopkeepers	Shop owners or staff	16	A12-A27		Lusaka, Chipata, Lundazi, Chirundu, Kafue, Chilanga (Zambia)	May and June 2017	99,99
		Community members	Community Health Workers and Caregivers	Beneficiaries	2	A28-A29		Chipata, Chirundu (Zambia)	May and June 2017	31,22
		Public Health Officials	Administrative staff, Doctors, Midwives, Nurses and Technicians of Clinics, Hospitals and Health posts	Staff	11	A30-A40		Lusaka, Chipata, Lundazi, Chirundu, Kafue, and Chilanga (Zambia)	May and June 2017	98,2
		Wholesalers and large retailers	Pharmacies, Supermarkets and Wholesalers	Staff	10	A41-A50		Lusaka, Chipata, Chirundu and Kafue (Zambia)	May and June 2017	107,41
		Governmental organizations	Ministry of Health, Zambian Regulatory Agency, Centre for Infections Disease Research in Zambia, and Medical Stores Limited	Staff	4	A51-A54		Lusaka and Chipata (Zambia)	May and June 2017	271,77
		Pharmaceutical company	Pharmanova	Staff	2	A55-A56		Lusaka (Zambia)	June 2017	43,53
	Participant observation (group meetings)	Hacking organisation + local champion	ColaLife + Keepers Zambia Foundation	n/a	8	n/a		Lusaka	June 2017	487,84
		Pharmaceutical company + hacking organisation	ColaLife + Pharmanova	n/a	4	n/a		Lusaka (Zambia)	June 2017	48,34
		Pharmaceutical company + hacking organisation + local chamption	ColaLife + Keepers Zambia Foundation + Pharmanova	n/a	6	n/a		Lusaka (Zambia)	June 2017	50,55
		International Organization + hacking organization + local champion	UK Department for International Development and ColaLife	n/a	4	n/a		Lusaka (Zambia)	June 2017	n/a – not recorded for privacy reasons
		International Organization + hacking organization + local champion	USAID, ColaLife and Keepers Zambia Foundation	n/a	5	n/a		Lusaka (Zambia)	June 2017	n/a – not recorded for privacy reasons

B	Semi-structured interview(s)	Sustainability Hacker	Operação Serenata de Amor (OSA)	Founders and active members	6	B1-B6	Skype	n/a	November 2016 - January 2017	454,98
C	Semi-structured interview(s)	Sustainability Hacker	Women on Waves and Women on Web	Founder and staff	4	C1-C4	In-person and Skype	Amsterdam (Netherlands)	February and March 2018	322,94
D	Semi-structured interview(s)	Sustainability Hacker	Tribe Guarani-Kaiowá	Tribe leader	1	D1	In-person	Dourados (Brazil)	March 2017	47,44
		Governmental agency	Fundação Nacional do Índio (Funai)	Staff	1	D-2		Dourados (Brazil)	March 2017	107,23
E	Semi-structured interview(s)	Sustainability Hacker	Shoot the Shit	Founder	1	E1	In-person	Rio de Janeiro (Brazil)	March 2017	88,2
F	Semi-structured interview(s)	Sustainability Hacker	Vigie Aqui	Staff	2	F1-F2	Skype	n/a	March 2017	54,52
G	Semi-structured interview(s)	Sustainability Hacker	Sugata Mitra (the hacker is an individual)	Sugata Mitra (the hacker is an individual)	1	G1	In-person	Newcastle (United Kingdom)	October 2017	86,07
H	Semi-structured interview(s)	Sustainability Hacker	Social Finance	Staff	1	H1	In-person	Cambridge (United Kingdom)	November 2017	34,21
I	Semi-structured interview(s)	Sustainability Hacker	Goats for Water	Founder	1	I1	Skype	n/a	February - May 2018	83,42
J	Semi-structured interview(s)	Sustainability Hacker	Elango (the hacker is an individual)	Elango (the hacker is an individual)	1	J1	In-person	Kuthambakkam (India)	April 2018	204,64
		Academia	Expert (case of Deity Tiles)	Expert (case of Deity Tiles)	1	J2	In-person	Kozhikode (India)	April 2018	49,38

K	Semi-structured interview(s)	Academia	Individual	Expert	1	K1	In-person	Hyderabad (India)	April 2018	85,13
L	Semi-structured interview(s)	Sustainability Hacker	Ugly Indian	Volunteer	1	L1	In-person	Hyderabad (India)	April 2018	29,26
M	Semi-structured interview(s)	Sustainability Hacker	Dharma Rao (the hacker is an individual)	Dharma Rao (the hacker is an individual)	1	M1	In-person	Hyderabad (India)	April 2018	47,04
N	Semi-structured interview(s)	Sustainability Hacker	Kalpana Srivastava (the hacker is an individual)	Kalpana Srivastava (the hacker is an individual)	1	N1	Skype	n/a	April 2018	50,71
		Academia	Individual	Expert	1	N2	In-person	Hyderabad (India)	April 2018	132,08
O	Semi-structured interview(s)	Sustainability Hacker	Mod Skool	Team member and idealizer	1	O1	In-person	Delhi (India)	April 2018	68,25
P	Semi-structured interview(s)	Sustainability Hacker	Field Ready	Staff member	1	P1	In-person	Kathmandu (Nepal)	April 2018	120,88
Q	Semi-structured interview(s)	Sustainability Hacker	Sikka	Staff members	2	Q1-Q2	In-person	Kathmandu (Nepal)	April 2018	122,48
R	Semi-structured interview(s)	Sustainability Hacker	Honey Bee Network, Gian, Sristi and Palle Srujana	Founder and staff	4	R1-R7	In-person	Hyderabad and Ahmedabad (India)	April - May 2018	755,69
		Grassroots innovators	Individuals	Beneficiaries	3	R8-R10	In-person	Ahmedabad (India)	May 2018	164,43
S	Semi-structured interview(s)	Sustainability Hacker	Four Thieves Vinegar	Founder	1	S1	Skype	n/a	May 2018	94,39

Appendix B

The 3 boxes in this appendix illustrate the open-ended questions used to initiate the semi-structured interviews. The first two boxes demonstrate the initial set of questions used in the 2nd research stage: with cybersecurity experts (Box 10) and self-declared Hackers (Box 11). Box 12 illustrates – with the example of Case G – how questions were jotted down prior to interviews with the 19 cases of Stage 3, based on secondary data on each of these cases. These questions were only used to initiate conversations, since the approach was essentially exploratory.

Box 10: Initial Set of Questions for Cybersecurity Experts

1. How would you describe a Hack? (e.g. Is it an action? A process? An intervention? An attitude? A mind-set? What characteristics must a hack present to be framed as a hack instead of any other term?)
2. What is aimed at changing? (e.g. A system? An IT component? An undesired feature of a system?)
3. What are the motivations of hacks? What kinds of problems does a hack aim at solving? Why are hacks suitable options to deal with such problems?
4. Who has the power and ability to hack?
5. What are the consequences of a hack? What is the magnitude of its impact? What kinds of changes can a hack attain and what is not attainable?
6. What is the timeframe of a hack? How does it vary? When does it start when does it end? What about the consequences unravelling from a hack?
7. How different is a hack from other IT interventions that are not considered hacks?
8. How does a hacker assess opportunities for hacking? What is predictable and what is not? What changes are controllable and what aren't? What are the levels of uncertainty involved?
9. What happens in the process, between identifying the opportunity for change until the actual intervention?
10. How do expectations differ from results? Can you learn to hack? How does learning influence outcomes over time?
11. What conditions enable or constrain a hack to happen?
12. Is a hacker accountable for the desired change?
13. Does a hacker own the outcomes of a hack? To what extent?
14. How would you describe a hacker? What is the mind-set? How is a hacker different from an innovator or inventor?
15. How does all of that relate to your work? Tell me a bit about your experiences with hacking.
16. What I'm interested is understanding the use of the term "hack" and applying it to the analysis of interventions with sustainability purposes. The term is already being used in non-IT contexts (e.g. Hacking Food, Urban Hack, Biohack). Why do you think this is happening? Why are people using this word? What do they have in common? How do they differ?
17. What would you understand as a hack for sustainability? Why?

Box 11: Initial Set of Questions for self-declared hackers

1. How would you describe a Hack? (e.g. Is it an action? A process? An intervention? An attitude? A mind-set? What characteristics must a hack present to be framed as a hack instead of any other term?)
2. Why are you using the term Hack instead of any other term? Is there any synonym you could use to express the same idea?
3. How similar is it in comparison to the IT use of the term? Why are people increasingly using this word in different contexts? What do they all have in common? How do they differ?
4. In your case, what is aimed at changing?
5. What are the motivations of your hacks? What kinds of problems does a hack aim at solving? And what kinds of problems does your hack aim at solving? Why are your kinds of hacks suitable options to deal with such problems?
6. Who has the power and ability to conduct your kinds of hack?
7. What are the consequences of your hacks? What is the magnitude of their impacts? What kinds of changes can your hack attain and what is not attainable?
8. What is the timeframe of your hack? How does it vary? When does it start when does it end? What about the consequences unravelling from a hack?
9. Do you consider yourself a hacker? How would you describe a hacker? What is the mind-set? How is a hacker different from an innovator or inventor?
10. How do you assess opportunities for hacking? What is predictable and what is not? What changes are controllable and what aren't? What are the levels of uncertainty involved?
11. What happens in the process, between identifying the opportunity for change until the actual intervention?
12. How do your expectations differ from results? Can you learn to hack? How does learning influence outcomes over time?
13. What conditions enable or constrain a hack to happen?
14. Are you accountable for the desired change caused by your hacks?
15. Do you own the outcomes of a hack? To what extent?
16. What I'm interested is understanding the use of the term "hack" to apply this to the analysis of interventions in sociotechnical systems with sustainability purposes. What would you indicate as a hack for sustainability? Why?

Box 12: Example of Initial Questions for Case G

1. What is the main problem you deal with? What are the bottlenecks to solving them?
2. What is the standard approach to tackling the problem? Do you think the performance both of the Hole in the Wall and School in the Cloud is better when compared to traditional schooling or does it aim at being as similar as possible but addressing people are disenfranchised?
3. Why are you interested in this and not in something else?
4. What is your proposed change? Why do you think you should be the agent leading this change?
5. What are the characteristics and the functioning of the system you're dealing with? (Ps: explore social, cultural, political, environmental and economic characteristics of the system). What are the main constrains, bottlenecks or challenges of this system to achieve what you considered to be the desired change?
6. Did you have to circumvent the status-quo of the system? What did you circumvent? How?
7. How did you start? Where did you get the idea from? Did you need funding? How did you get it? What other kinds of support did you need to make that happen?
8. How was the unravelling of the process, from having the idea to actually carrying out the desired change? What were your expectations back then? What did this process entail? What boundaries have you set? How has all of this changed over time?
9. What were the stakeholders and networks involved? How did you engage them? Who was involved from the beginning and who is involved now? How do they participate? What are their roles and how do they benefit?
10. What methods have you used? Can you explain how this actually happens?
11. What impact has it had so far? What impacts do you expect it to have? Do you think the scope will change through time?
12. Do you think you own the outcomes? Are you accountable for outcomes? In that case, what are you accountable for?
13. What have been the main constraints to your operation? Is there anyone against you? Who's in your favour?
14. What would you do differently if you could go back in time?
15. What are your goals for the future?
16. Discuss my observations and test them
17. Ask for recommendations of other cases + experiences in India