Perspectives and Impacts of Modern Technology on the Environment and Society

Master thesis

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Abstract

Much of the effort and hope for the challenges and aspirations of today and tomorrow, such as the climate crisis and the Sustainable Development Goals (SDGs), rely on technological progress. The idea that technology will provide a better future seems embedded in the present collective mindset. Although technology is a comprehensive concept with various perspectives and a plethora of materializations, it has barely been studied in its broader sense. Most of the empirical studies focus on specific technologies while those who address the concept at large do it in a rather abstract manner. Considering the high environmental and social expectations placed on technology, addressing it comprehensively through both theoretical and empirical approaches is necessary. This study aims, first, to grasp the concept of technology and, second, to assess its material impacts, both concerning the environment and society. For the first aim, a conceptual domain analysis through the philosophy of technology took place. This analysis narrowed the focus to the concept of 'modern technology' and urged to consider three different theories under the framework of modernity. For the second aim, a systematic literature review (SLR) on modern technology's environmental and social impacts took place. The SLR showed that most of the empirical research is focused on specific technologies' environmental impact and seems biased by the ideological framework in which the studies occur. As a result of the reductionist perspective throughout the SLR, a system analysis in a causal loop diagram was constructed. Together, the domain analysis, the SLR, and the system analysis give a broader view of technology's implications and perspectives while urging the need to address technology in a systematic and interdisciplinary way.

Table of Contents

List of Figures

List of Tables

1. Introduction

Technology has earned such an immanent role in human life that its presence seems to be hidden in plain sight. From the daily routine of communication, transportation, and transaction to public speech and political goals, its presence is so ubiquitous that questioning it hardly appears necessary and defining it merely redundant. Regardless of its apparent triviality, technology is increasingly filled with hopes and expectations that it seems condemned to hold up humanity as Atlas the heavens.

Amid the current climate crisis and the warnings on Earth's limitations towards human development, technology appears to be the Promethean fire that will outsmart the human needs and challenges ahead. The titanic role of technology has permeated the world's expectations across the public and private dimensions, from international frameworks like the United Nations' *Agenda 2030* and its Sustainable Development Goals (SDGs) *(United Nations 2015),* which heavily relies on technology for their fulfilment (Sætra 2023), to the mainstream media and businesses claims on artificial intelligence as a global game changer. It appears that now more than ever, technological and scientific progress have become undeniable ideals for everyone to pursue. The general idea of progress has taken a major role in today's grand narrative and the common political speech where technology has become the means to its realisation.

Simultaneously, technology's benefits brought by industrialisation, mass production and consumption, have been causing today's environmental degradation and opening the gap between countries and persons in terms of development and wealth. Technology has been a major cause of changes in human history and the planet's ecosystem since the Industrial Revolution, from the increase in life expectancy and population to the current climate crisis.

Recognizing the double-edged status of technology, this study initially aimed to critically reflect on technology's ambivalent promise by conducting a domain analysis of the concept of technology and its relationship with the environment and society through perspectives given by the philosophy of technology and comparing it with empirical data on its impacts. However, while doing the domain analysis, it became clear that the distinction between non-modern and modern technology was necessary, and that relationships and impacts of these are conditioned by its context and socioeconomic structures, and thus, all this had to be considered.

Most of the authors in the domain analysis, being Western philosophers, identify modernity, brought by the Age of Enlightenment and the Industrial Revolution, as technology's main condition, and see modern technology as the most impactful form of technology. This insight narrowed the focus to modern technology while it pushed the notion of modernity and today's widely debated theories under its umbrella to be included in the study. After analysing such theories' claims on modern technology, the need to evaluate the reported impacts of modern technology became even more necessary. Therefore, the aims of the study were further developed as follows:

(I) *To understand the perspectives of the philosophy of technology and the main theories, within the framework of modernity, regarding the relationship between modern technology with the environment and society.*

(II) *To evaluate and compare these perspectives with the reported impacts of modern technology on the environment and society, as reported in scientific publications.*

In line with these aims and considering the interdisciplinary nature of the study, different research questions arose, and two research methods were adopted, a domain analysis for the first aim and a systematic literature review for the second. Both research methods including their specific research questions are presented throughout the text and listed in the **Appendix** (Table 10).

In the next chapter, the domain analysis is presented, first, it focuses on the concept of technology according to the philosophy of technology, analysis which is consequentially narrowed to the concept of modern technology and the relationships of this with the environment and society. Later, as mentioned before, the domain analysis expands to different theories and their perspective on modern technology's relationship with the environment and society. These theories are neoliberalism, ecological modernisation theory, and degrowth since they are the most widely debated theories under the framework of modernity in the present day. As a matter of synthesis and through a process of abstraction, each perspective on modern technology's relationship with the environment and society is given a characteristic descriptor and presented throughout different tables.

Afterwards, in Chapter 3, a systematic literature review (SLR) on the reported impacts and causes of technology on the environment and society is described. The SLR is based on scientific publications, specifically journal articles, of the last ten years considering the increasing importance of the topic. Out of the SLR's findings, which are presented graphically and reflected upon, a system analysis approach appeared to be necessary to further understand the impacts and relationship of modern technology towards the environment and society. The system analysis is developed and presented as a causal loop diagram in Chapter 4.

Finally, the discussion of the main and overall findings of both research methods and their developments is presented in Chapter 5. The conclusions of the study and possible further research are presented in Chapter 6.

2. Domain Analysis

To assess the impacts and relationship of technology towards the environment and society, is essential to first establish a clear conceptual understanding of technology (Section 2.1). For this purpose, a domain analysis of technology is performed through the review of a vast literature that covers handbooks, readers, books, articles, and all sorts of publications from major authors on the philosophy of technology. Throughout the analysis, the distinction made by Mitcham (1994) between two branches of the philosophy of technology, engineering and humanities, is described and adopted with the latter becoming the main reference for this study.

Similarly, the distinction between non-modern or ancient technology and modern technology became apparent. Since most of the authors on the humanities philosophy of technology are mainly concerned with the second type of technology and this has a greater impact on both the environment and society, the analysis is narrowed to modern technology which is further described in Section 2.2.

Later, in Section 2.3, since the analysed authors see modern technology's relationships with the environment and society as a consequence of the paradigm of modernity, the main theories under its umbrella are described according to their main scholars and publications.

For the humanities philosophy of technology and the three theories within modernity, a characteristic descriptor for the relationship of modern technology with the environment and society was developed through a process of abstraction. These are individually presented for each perspective throughout the text and altogether in Table 5.

2.1. Technology

The use of tools has been argued to be part of human nature since hands became free due to bipedalism (Ko 2015). The exertion of control over a freely manipulable external object to alter the physical properties or mediate the flow of information of another object or surrounding via dynamic interaction has been part of human existence since primaeval times (St Amant and Horton 2008).

If the view on technology is – partially - taken as an extension of the usage of tools, the development between humans' history and their technology can be seen side to side (Aunger 2010) but not necessarily in parallel. From the archaeological findings such as the Acheulean hand axe spanning 1.7 – 0.1 million years ago (De la Torre 2016), to later religious and mythical scriptures and spoken tales from all around the globe in which humans are given the knowledge, capacity, and right to transform their surrounding and the objects and creatures within, such as in judaea-christian tradition (Genesis I), the notion, or pre-notion, of technology has been always there, developing with its internal logic while taking part in the big picture of history.

Regardless of its constant presence, technology and its appearance have been changing ever since, but it was not until the last centuries that the concept started to be reflected upon. For instance, the word technology itself is a recent term that came into common use after the Second World War. Its etymology can be tracked to the Greek-Sanskrit stem, *tekhn-*, meaning "woodwork" or "carpentry", later turned into the Greek *tecné* – *τέχνη* – commonly defined as "skill, craft, or art", that combined with the Greek *logos* – *λόγος* – "study or knowledge" gave origin to the word. In Ancient Greece the word *tecné* already implied *logos* and the combination of both is recent deliberation. What is called nowadays technology was previously referred to in most European languages as technique, or in some cases, industrial arts. It was only after WWII with the American and English language hegemony that the word technology became the norm (Mitcham and Schatzberg 2009).

Like the word, the concept of technology has not been static, especially in the last two centuries. Before the 1800 little or no reflection at all took place around technology or technique despite its undeniable presence. The term 'philosophy of technology' was coined by Ernst Kapp for the first time in 1877 in his book *Eine Philosophie der Technik* (Franssen, Lokhorst et al. 2022). Contemporary to Kapp, Karl Marx is also recognized as one of the first philosophers to reflect upon technology and its implications, even to be considered by many as the founder of technological determinism (Winner 1983). Before that, in the XVII century, Francis Bacon is regarded to be the first modern author to reflect on the human impact on the world through technological means (Franssen, Lokhorst et al. 2022).

After Kapp's publication during an ongoing second industrial revolution, the discussion around technology became a subject of increasing interest and philosophical debate. Carl Mitcham (1994) synthesizes the development from Kapp's book until the late twentieth century between two main perspectives, which he defines as 'engineering philosophy of technology' and 'humanities philosophy of technology'. The first, best represented by thinkers like Mario Bunge, Juan David García Bacca, Friedrich Dessauer, and Ernst Kapp himself, argues for technology's moral neutrality and its tool-wise nature as an applied science that gradually evolves on top of itself (Mitcham 1994). For the engineering philosophy of technology, technology is a phenomenon that should be studied from an analytic perspective that pays attention to the details of *what* it can produce (Franssen, Lokhorst et al. 2022). This focus on productivity ought to address the endeavours on what technology can provide or facilitate for human existence whereas the 'how' refers to the efficiency of production.

On the other hand, the humanities philosophy of technology focuses on the implications of technology, on how humans attempt to control their lives and environment through an instrumental approach (Franssen, Lokhorst et al. 2022). Technology is seen as a result of human ambitions and vices and as such, it is incapable of being morally neutral, it always has moral agency projecting and reflecting human nature in the social, cultural, political and aesthetical dimensions (Mitcham 1994). It is sometimes treated as a 'black box', an unescapable phenomenon (Franssen, Lokhorst et al. 2022), that needs to be studied through its intentions and repercussions. Major contributors to the early humanities philosophy of technology are Lewis Mumford, José Ortega y Gasset, Martin Heidegger, Jacques Ellul, and members of the Frankfurt School such as Theodore Adorno, Max Horkheimer, and Hebert Marcuse, to mention a few.

With a few exemptions like the Luddite movement in England during the XVIII and XIX centuries, technology was popularly conceived as a neutral phenomenon of tool development and applied science before 1945. By the end of WWII and the reflection on its atrocities, the humanities philosophy of technology became the primary standpoint towards technology (Mitcham 1994).

Although both traditions, engineering and humanities philosophy of technology, are still widely present, the latter focuses on the impact of technology on human life and its context which coincides with the aim of this study, thus, the readings of these authors and the ones that followed this tradition such as Hans Jonas, Andrew Feenberg, Langdon Winner, Don Ihde, Albert

Borgmann, among others are researched. This, of course, is an incomplete list and it is far from doing justice to the many and valuable thinkers who have scrutinized technology. From these readings, the following research questions arise:

RQ1: What is modern technology?

RQ2: What are the perspectives of modern technology in relationship to the environment and society according to the main authors of the humanities philosophy of technology?

Not all authors address the two spheres on the second question, the environmental and social, explicitly in their work, but all deal with modern technology and its implications. After carefully reading these authors and through a process of abstraction, a table with a characteristic descriptor for each relationship of modern technology is constructed (Table 1). The intention of constructing this table is to develop a tool that helps to apprehend, not what technology is, but what it has seemed to be according to the major figures that are found and mentioned throughout a vast collection of readings, handbooks, and all kinds of publications on the humanities philosophy of technology. Afterwards, recognizing that most, if not all, of these authors see the relationships of modern technology and its implications as a consequence of the dominant ideological context in which these relationships are formed, this tool is further developed by adding the major theories currently debated under the paradigm of modernity. These are neoliberalism, its socioenvironmental alternative ecological modernisation theory (EMT), and degrowth. The complete table (Table 5), presented in Section 2.4, gives a descriptive comparison of how these theories, including the humanities philosophy of technology, perceive the relationship of technology with the environment and society.

Later, this abstract tool is compared to scientific research output on what has been reported as the impact of technology on the environment and society through a systematic literature review (SLR) of the last ten years. For visualisation and additional assessment, recognizing the complexity of the subject, the SLR is further developed into a system analysis (Chapter 4).

Finally, under the hypothesis that the climate crisis is an environmental and social phenomenon partially caused by the impacts of modern technology and that these are a consequence of its relationship with the two spheres, the system analysis and the complete abstract tool, help to understand the role that modern technology can play in the environmental and social challenges the world is facing, as well as what kind of policy should be considered. From this point onwards in the text, when referring to ‘philosophy of technology’ it means the humanities philosophy of technology.

2.2. Modern Technology

Whereas the term ‘modern’ technology implies a difference from an ‘old’ or ‘ancient’ technology, this distinction is rather abstract and not universally agreed in or outside the philosophical realm. However, even though there is no standard taxonomy, technology has been commonly divided into ‘low’ and ‘high’ tech according to its intensity or degree of complexity and requirements (Kostakis, Pazaitis et al. 2023). *Low* tech are tools and modest machines that usually operate on mechanical, often human, power, that are simple in composition and purpose (i.e., hammers, levers, bicycles, etc.); *high* tech is often characterized by its complexity, level of sophistication, and its requirements such as scarce materials, high demand of energy, and/or specialized knowledge and components (i.e., computers, cars, DNA tests, electricity plants, etc.).

The concept of *mid* tech, also known as appropriate technology, was first proposed by Schumacher in 1973 and has been used to refer to a synthesis of both low and high tech, usually balancing capacity with accessibility (Kostakis, Pazaitis et al. 2023).

Simultaneously technology has been categorized by its sector of use and production, i.e., agriculture, electric, transportation, communication, medical, etc. (Pavitt 1984, Peneder 2010) in which each sector includes one or more types of technology (low, mid, and high). Regardless of the sector, the definition of low tech approximates the concept of ancient technology as the concept of modern technology is approximated by the definition of high tech. The first, low tech/ancient technology is, to some extent, not exclusive to humans, while high tech/modern technology is (Aunger 2010). Still, it is important to mention that whereas the term low and high tech usually refers to the products or artefacts of technology, most of the authors mentioned include within their analysis of technology all non-tangible variables (i.e., methodologies, imaginaries, attitudes, organisation, etc.) that have taken place in and become intrinsic to the production, consumption, and interaction with such products.

For this study, 'modern technology' is understood as all high-tech technology that has been developed since the first industrial revolution including the non-tangible variables that contribute to its existence. It differs from 'ancient technology' in its level of abstraction, complexity, and modus operandi. While ancient technology is developed and includes a skilled acquired artistic-like process, like carpentry, that turns into a low-tech product that resembles or is indistinguishable from the natural surroundings, for example, a canoe; modern technology is developed and includes an abstract and acquired scientific knowledge, like Maxwell's equations, that turns into a high tech product with a composition that disrupts the natural surroundings, for example, a transmission antenna.

In this sense and following the dominant modern - and Western - thought, authors point out that modern technology and science not only boost and rely on each other dynamically but are interwoven under the frame of rationalism and the restless liberal idea of progress or meliorism (Thorsen and Lie 2006, Gremmen 2009, Marcuse [1941] 2004). Science requires modern technology to measure, prove, and discover all kinds of phenomena, take radio telescopes and modern astronomy as an example, while simultaneously, modern technology relies on scientific knowledge to develop its products, for example, the laws of thermodynamics and combustion engines. Science and modern technology, just like entangled threads in a weave are relying and building on each other to fulfil their purpose (Ihde 2009). Some authors refer to this relationship as 'technoscience' with science instrumentally embodied by technology throughout industrial and research centres (Latour 1987, Ihde 2009, Haraway [1985] 2000).

Moreover, modern technology is distinguished from ancient technology by the intensity of transformation of the product from its initial source (Heidegger 1977, Feenberg 2008, Ortega y Gasset [1939] 2014), for instance, the energy given as light by an LED from the fossil fuel in which the energy was originally contained. This form of technology has been monumentally changing the world ever since, thus its importance. And so, it would be naïve to think that modern technology emerged out of the bloom as a mere invention of itself. Jacques Ellul (1954) argues that the technical phenomenon, the rise of modern technology, was initially made possible in the West due to five conditions 1) the fruition of a long technical experience; 2) population expansion; 3) the suitability of the economic environment; 4) the plasticity of the social milieu; and 5) the appearance of a clear technical intention (Ellul [1954] 2021).

In other words, it was not just the invention of the steam engine, whose early designs date back to Ancient Greece (see i.e., (Keyser 1992)), that unleashed the Industrial Revolution, but the social and economic conditions in which the inventions took place. They were the ideas of that time derived from the Scientific Revolution and the Enlightenment, such as rationalism, meliorism, liberalism, and individualism, together with the evolved versions of mercantilism which provided fertile soil for what is referred to as modernity and modern technology to sprout. In this sense, technology, including modern technology and its relationships, has always been conditioned by its context, a constructed concept by the paradigms in which it arises.

When interacting with the environment and society, modern technology touches on different layers of human existence by immersing itself into the humane and transforming how reality appears. Modernity (Delanty 2007) with modern technology (Ihde [1990] 2009) has changed how time and space are measured and experienced and has become part of language and everyday life (Winner 1983). Take transportation and telecommunication technologies as an example, they have not only changed the notion of distance but also the interaction of the subject with other subjects and the world. Modern technology in food production and medical practice has allowed the expansion of the human population (Roser, Ritchie et al. 2013) and its life expectancy (Roser, Ortiz-Ospina et al. 2013), mediating the most intimate part of human existence, the relationship with their bodies and with death (Elliott 2011), not to mention the relationship towards the natural environment and the landscape. The exploitation of resources, urbanisation, weather prediction, digital imaging, and genetic modification of crops, among others, are all examples of how modern technology has placed itself in between humans and the world they live in (Borgmann 2010, Ihde [1990] 2009). To quote the American film director, Godfrey Reggio, “Humans don’t live with technology but in technology”.

And so, if the relationship with modern technology has been mediative at the individual level, as an in-between, the relationship in the common and plural level, society, can be seen as a start and end. By using and adding value and direction to modern technology, society has developed an instrumental relationship with it (Feenberg 2008). Modern technology has been used by society as a means of ‘building’ to the ends of ‘inhabiting’ the world (Ortega y Gasset [1939] 2014). Inhabiting, in this sense, means to live as much as to transform, and re-create, the world according to aspirations defined and shaped by the ideals in which society has been immersed. For the Western world, these ideals are defined by the socio-economic structure that has developed from modernity’s ideas of individualism, rationalism, meliorism, and liberalism that came with the Enlightenment (Horkheimer and Adorno [1947] 2016) and the development of mercantilism into capitalism (Weber 1922, Wallerstein 1995).

In that regard, the instrumental relationship between society and modern technology permeates all aspects of the first. In the cultural aspect, the mechanic and digital reproduction of art and cultural works commodify these into potential particular acquisitions promoting the ideas of individualism and private property (Benjamin [1936] 2008, Horkheimer and Adorno [1947] 2016, Marcuse [1964] 2013). In the political and economic aspect, modern technology helps to ratify and reinforce the status quo and meliorism, by making the technological a part of society’s needs due to the advantages provided in terms of power dynamics (Jonas 1979, Winner 1980, Feenberg 1996, Marcuse [1941] 2004, Habermas [1970] 2010). In the institutional aspect, modern technology has served as a means for the hierarchical and stratified ways of organisation under the claims of production efficiency and safety while also promoting democratic participation by providing access to information and products (Winner 1980).

On the other hand, the environment contrary to society has no aspirations or agency, it follows natural and complex cycles and processes that have emerged over the past of time. Modern technology changes the environment by making use of its natural resources to produce and be produced in what can be considered an exploitative rather than instrumental relationship. The environment has been commodified by modern technology (Borgmann 2010) making it exchangeable and reducing it into potential products, or a 'standing reserve' waiting to be exploited (Heidegger 1977). The exploitative characteristic refers to the form in which this unbalanced relationship unfolds, it should not be understood from the moral perspective but through the objectiveness that the environment is always passive or intentionless against an intentionful and always active modern technology. The environment's natural phenomena only make use of modern technology as far as this is intentionally or accidentally designed for that, take the concrete and metal structures for coral reef restoration as an example (Rinkevich 2005).

To synthesize what has been described so far regarding the perspective of the authors of the philosophy of technology, Table 1 summarizes and abstracts the conceived relationships between modern technology with the environment and society.

Table 1. Relationships of modern technology according to the humanities philosophy of technology.

	Environment	**Society**
Modern Technology	Exploitative[1]	Instrumental[2]

[1] (Mumford 1934, Von Neumann 1955, Mumford 1966, Mumford 1970, Heidegger 1977, Jonas 1979, Glendinning 1990, Feenberg 1996, Feenberg 2008, Tiles 2009, Thompson 2017, Bacon [1626] 2016, Marx and Engels [1846] 1970, Ortega y Gasset [1939] 2014, Marcuse [1941] 2004, Horkheimer and Adorno [1947] 2016, Ellul [1954] 2021, Habermas [1970] 2010, Jonas [1973] 2009, Haraway [1985] 2000, Latour [1999] 2009)

[2] (Mumford 1934, Von Neumann 1955, Mumford 1966, Heilbroner 1967, Mumford 1970, Heidegger 1977, Jonas 1979, Winner 1980, Winner 1983, Glendinning 1990, Feenberg 1996, Feenberg 2008, Bijker 2009, Tiles 2009, Thompson 2017, Bacon [1626] 2016, Marx and Engels [1846] 1970, Benjamin [1936] 2008, Ortega y Gasset [1939] 2014, Marcuse [1941] 2004, Horkheimer and Adorno [1947] 2016, Ellul [1954] 2021, Marcuse [1964] 2013, Habermas [1970] 2010, Jonas [1973] 2009, Haraway [1985] 2000, Latour [1999] 2009)

Here, the environment can be seen, again, not morally, as the ultimate consequence of the sum of the relationships previously described. The environment, although often considered an externality in the philosophy of technology, is after all the quintessential means for life in the world, and thus, the attitudes of expansion, production, and comfort, given by the socio-economic structures and the ideals behind them described by the authors, has led to its unreflective and anthropocentric use, as they simultaneously promote the instrumentalization in and of society, and consequentially shaping human existence.

Furthermore, if modern technology and its relationships are rooted in the paradigm and theories behind, as the studied authors suggest, and the ongoing climate crisis is an ultimate consequence of such ideological frameworks, then a change or optimisation of technology would not be sufficient – or even possible – to mitigate it. Thus, a change of paradigm or framework that includes a different stand on technology is then needed.

Considering that CO2 emissions are a key driving factor of the current socioenvironmental crisis (IPCC 2023) and that the biggest emitters (Ritchie, Roser et al. 2020) are countries that have embraced the paradigm of modernity, which the consulted authors of the philosophy of technology inquire. It is relevant to, first, understand the position of neoliberalism, which is considered the hegemonic theory within modernity's umbrella (Harvey 2007), towards modern technology and its relationships, and second, the position of the main debated alternatives to neoliberalism, namely, ecological modernisation theory and degrowth. Thus, the following research question arises:

RQ3: What are the perspectives of modern technology in relationship to the environment and society according to modernity's main theories currently debated, namely, neoliberalism, ecological modernization theory (EMT), and degrowth?

This research question is further explored in the following sections.

2.3. Modernity and Theories

The term paradigm, which can be defined as a general theoretical standpoint, a common root of a certain collection of perspectives (Eckberg and Hill Jr 1979), was initially conceived by Thomas Kuhn in his publication *The Structure of Scientific Revolutions* (1962) exclusively for natural sciences. However, it has been adapted and used beyond Kuhn's intention for both natural and social sciences ever since. In this study, the term paradigm is used not in the strict Kuhnian sense but in the loose and broader sense as a set of basic principles that define the individuals' or objects' relationships with the world and its parts, explaining the nature of reality. Principles that, however well argued, are always ultimately accepted on faith as a set of beliefs (Guba and Lincoln 1994).

In this sense, progress and individuality can be defined as the set of beliefs that construct the 'modernity paradigm' (Delanty 1999), but do not necessarily define its totality. Defining a paradigm by the enumeration of its concrete characteristics is implausible, a paradigm is more than the sum of its parts, it also includes interactions and iterations. Trying to define a paradigm point by point would be an impossible endeavour, as Margaret Masterman points out, the question is not what a paradigm is but what it does (Masterman, Lakatos et al. 1970, Eckberg and Hill Jr 1979). Furthermore, it seems to be the obscure and manifold definitions that depict the paradigmatic character. In the case of Modernity, its foundational ideas of individualism, rationalism, and progress are obscure enough to be defined as an 'incomplete project' or an 'endless trial' (Delanty 2007), which gives room for different theories to develop under its umbrella.

Theories like neoliberalism, ecological modernisation theory, and degrowth, which occupy a big part of the current political and socioeconomic debate, are examples of conceptual frameworks that can develop within modernity's paradigm. In other words, the different *hows* of what modernity does.

2.3.1. Neoliberalism

The name's prefix 'neo' indicates either an origin from liberalism, the political ideology based on individual rights of equity, liberty, and private property, that stands for a free market and a minimal power of the state over the citizens' affairs, or that liberalism has gone under a process of birth, growth and decay, to be reborn into a new liberalism (Thorsen and Lie 2006). There is no concise definition of neoliberalism, on the contrary, since it shares the same principles as liberalism valuing individual freedom uttermost but differs in other key aspects, such as the role of the state, the definition of neoliberalism varies among proponents and is ill-defined.

Thorsen and Lie (2006) claim that even though neoliberalism has been claimed to be the dominant socioeconomic theory or political ideology of today, they could not find a clear definition of what neoliberalism is over an extensive literature review. However, they seem to agree that the definition given by David Harvey in his *A Brief History of Neoliberalism* (2005) hints closely at how neoliberalism unfolds:

"Neoliberalism is in the first instance a theory of political economic practices that proposes that human well-being can best be advanced by liberating individual entrepreneurial freedoms and skills within an institutional framework characterized by strong private property rights, free markets and free trade. The role of the state is to create and preserve an institutional framework appropriate to such practices. [...] It must also set up those military, defence, police and legal structures and functions required to secure private property rights and to guarantee, by force if need be, the proper functioning of markets. Furthermore, if markets do not exist (in areas such as land, water, education, health care, social security, or environmental pollution) then they must be created, by state action if necessary. But beyond these tasks the state should not venture. State interventions in markets (once created) must be kept to a bare minimum [...]" (Harvey 2007).

In other words, neoliberalism promotes and enhances a market-defined existence where private property and economic power are the main drivers of Modern social life with the state as a safeguarding promotor of such practices. Under this theory, modern technology is seen as a means to neoliberal ends since it enables the concentration of economic power by owning and controlling materials and processes from the extraction of resources to the distribution of products. Technological invention creates market competition and consumable needs for the sake of progress, individual emancipation, and economic liberation.

Considering neoliberalism as such, its stance towards modern technology is given by its ideals and goals. Table 2 approximates how the relationships of modern technology are according to the neoliberal approach.

Table 2. Relationships of modern technology under neoliberalism

	Environment	**Society**
Modern Technology	Utilitarian	Enabling

Under neoliberalism, modern technology should make use of the environment for the ends set by the ideals of growth, property, and progress under market dynamics. It takes a utilitarian approach driven mainly by the economic principles of free market and competitiveness, in other words, modern technology should use the environment's resources for the greatest good, which is often conceived as the highest return value that is achieved technically through efficiency and innovation.

When it comes to society, neoliberalism resonates with the non-neoliberal Hannah Arendt in the perception of modern technology as a means to liberate society from labour, the exhaustive effort for self-preservation, and provide it with work, a productive defined activity (Arendt [1958] 2013). Simultaneously to the relief of needs, modern technology enables the upscaling and creation of markets that through technification and mass production will ultimately enable the individuals to satisfy desires and improve their living.

2.3.2. Ecological Modernisation Theory (EMT)

The term 'ecological modernisation' was first coined and developed in Europe in the 1980s by Martin Jänicke and Joseph Huber and explicitly established into a social theory by Arthur Mol and Gert Spaargaren around 1990. It arises as an alternative to the ecological movements claims that a fundamental change of system, namely capitalism, neoliberalism included, is needed to avoid an environmental disaster (Mol, Sonnenfeld et al. 2020). The EMT argues that the environmental crisis can be avoided without a revolutionary system change but rather through the means of capitalism (Mol and Jänicke [2009] 2020), in this sense, it declares to be not a change of paradigm but a required adaptation for the survival of the existing one.

According to the EMT's first proponents, what distinguishes this theory from neoliberalism is the inclusion of the environment in the state-market-individual equation. For EMT the state's role is to ensure the environment's preservation and restoration through policies directed towards a greener market, one that maintains the principles of growth and competition but, while it does, promotes environmental restitution (Spaargaren and Mol 1992).

EMT claims that maintaining and improving the current life standards while restoring the environment is possible if technological innovation takes place. For this theory, technology occupies the first step in the ladder towards ecological modernisation (Huber [1991] 2020). In this sense, compared to the philosophy of technology and neoliberalism, EMT sees the relationship of modern technology with the environment as restorative, instead of exploitative or utilitarian. This theory, especially in its later and American version, rejects the notion that the growth nature of capitalism is environmentally unsustainable and claims that a decoupling between economic growth and harmful environmental impact is possible through technological and demographic trends (Asafu-Adjaye, Blomquist et al. 2015).

Even though EMT claims to not stand outside the modernity paradigm and maintains the Enlightenment liberal values, its perspective on modern technology's relationships differs from the others as shown in Table 3.

Table 3. Relationships of modern technology under EMT

	Environment	**Society**
Modern Technology	Restorative	Democratic

For EMT, modern technology will and already does restore the environment towards preindustrial times while maintaining the economic and productive prosperity of the contemporary ones by providing individuals with access to goods that favour ecological practices throughout the supply chain using efficient and ever more sustainable production (Spaargaren and Mol 1992). Simultaneously, the theory claims that modern technology reduces humanity's dependence on the environment's natural resources through efficiency, artificial environments such as greenhouses, and nuclear energy production, among other examples, thus, it gives room to the environment to restore (Asafu-Adjaye, Blomquist et al. 2015).

When it comes to society the relationship with modern technology is claimed to be democratic; EMT argues that modern technology enables society to be informed and empowered to participate in the decision-making process creating a consented movement towards sustainable practices (Spaargaren and Mol 1992) by providing access to goods and information to an increasing population under democratic values (Hajer [1996] 2020, Buttel [2000] 2020).

2.3.3. Degrowth

Degrowth has been variably defined as a movement, a socio-economic theory, an ideological posture, and a claim for environmental justice, among others (Demaria, Schneider et al. 2013). It was initially conceived in France (*décroissance)* as a proposal for radical change amid the context of neoliberal capitalism and the environmental degradation caused by a growing consumer society. It positions itself against the socio-technological narratives and can be seen as an opposition to the ecological modernisation theory (Grunwald 2018, Kerschner, Wächter et al. 2018).

Degrowth sees the pursuit of economic growth and increases in consumption and capital accumulation as the root cause of the climate crisis the world has been submerging itself into. For the degrowth theory the idea of 'sustainable development' is a contradiction that cannot be resolved by technological or any other means. Sustainability can only be achieved by the renunciation, or *releasement*, of the economic notion of development and by an ever-decreasing throughput of energy and matter (Heikkurinen 2018), and thus, degrowth represents a new theory in which human identity is disentangled from economic representations (Demaria, Schneider et al. 2013).

This emerging theory has been proposed in many forms and strategies for its achievement, all share a certain common picture that includes a large-scale redistribution of wealth including natural resources; the implementation of mechanisms that avoid inequality due to growth, i.e., setting a maximum income and wealth and eradicating borders between countries; diminishing production and consumption deliberatively; giving natural resources value in themselves beyond utilitarian gains; repairing past and present injustice caused by colonisation and extractivism; and global collaboration for collective benefit (Demaria, Schneider et al. 2013, Heikkurinen 2018, Kerschner, Wächter et al. 2018)

Setting aside further inquiry into the sociopolitical plausibility of the theory, when it comes to technology, degrowth has mixed perspectives and reservations, it sees in modern technology the potential for degrowth's goal but also its interdependency with resources usage and the current economic interests (Grunwald 2018). Some proponents argue that technology should be assessed according to its conviviality, appropriateness, feasibility, and viability (Kerschner, Wächter et al. 2018), some refer to Winner's (1978) methodological Luddism as a deliberate restraint of certain technologies (Garcia, Jerónimo et al. 2018), while others rather opt for a straight 'no' to technology (Heikkurinen 2018) or to further technological development (Samerski 2018).

Table 4. Relationships of modern technology under degrowth

	Environment	**Society**
Modern Technology	Compromising	Instrumental

In the realm of modern technology, it is evident that degrowth scholars acknowledge the necessity and significance of questioning technology thoroughly. However, they have divergent opinions and concur that additional research is needed (Kerschner, Wächter et al. 2018). Degrowth scholars often give a normative approach to modern technology, what it ought to be, together with a descriptive one, what it is. In Table 4 a synthesis of the latter analysis on modern technology's relationships is given.

Based on various authors of the philosophy of technology previously mentioned in this study, such as Jacques Ellul, Langdon Winner, Albert Borgmann, and others, degrowth also sees the current relationship of modern technology with society as instrumental, as a tool that serves particular ends. From a degrowth perspective, these ends have been defined so far under the faith and idealisation of economic growth (Samerski 2018). By following Ivan Illich's idea of tools for conviviality (Illich 1973), degrowth argues that modern technology's relationship with society should foster collaboration and interaction between humans and non-humans (Haucke 2018, Kerschner, Wächter et al. 2018, Samerski 2018). Modern technology according to degrowth, should pass from instrumental to convivial, meaning that instead of being a market-productive driven means that turns into a need, it should be a 'convivial tool' that fosters human creativity, autonomy and collaboration between peers (Illich 1973, Samerski 2018).

When it comes to the relationship between modern technology and the environment, degrowth takes a sceptical perspective towards modern technology as a solution to the environmental crisis and uses Jevons' paradox as the quintessential example of how hollow technological hopes are. The Jevons' paradox, first proposed in 1865 by William Stanley Jevons referring to carbon consumption, is the phenomenon in which technological gains in resource use efficiency increase instead of diminishing the overall resources' consumption (Alcott 2005). With this example, also known as the 'rebound effect', degrowth argues that modern technology always entails long-term and side effects on the environment (Ferrari and Chartier 2018, Grunwald 2018) and the use of resources, matter and energy, for its production and functioning (Heikkurinen 2018), in other words, it always compromise the environment. Even though within degrowth some scholars can be categorized as technological optimists (Samerski 2018) which promote either or both soft, low and mid-tech (Alexander and Yacoumis 2018, Sætra 2023) and/or technologies that favour public transport, education, and health (Demaria, Schneider et al. 2013, Kerschner, Wächter et al. 2018), both sceptical and optimists, see this compromising relationship of modern technology with the environment.

2.4. Overview and complete abstract tool

Table 5 presents the complete abstract tool of the different perspectives on modern technology and its relationships under the paradigm of Modernity. Excluding the philosophy of technology, the relationships identified in each theory not only talk about their perspective towards technology, but also shed light on the narrative in which they were conceived, their expectations, and their ideals. In this sense, technology reveals or *enframe* (*Gestell*) beyond the technological (Heidegger 1977). In other words, technology can be used as a point of reference that discloses the similitudes and differences between the theories and tests them, thus, it enframes them.

Table 5. Overview of relationships of modern technology

		Environment	Society
Modern Technology	***Philosophy of Technology***	Exploitative	Instrumental
	Neoliberalism	Utilitarian	Enabling
	EMT	Restorative	Democratic
	Degrowth	Compromising	Instrumental

Neoliberalism's narrative suggests the idea of individuals possessing land and resources, private property, arguing that the utilization of such possessions, through technological innovation, will bring progress and wealth to everyone (Harvey 2007). Simultaneously, neoliberalism argues that economic growth due to this innovation and the use of resources will enable individuals leading to the emancipation of society (Thorsen and Lie 2006).

The narrative of EMT starts from the premise that capitalism without environmental degradation is possible (Spaargaren and Mol 1992) by technological means (Huber [1991] 2020) and policy-making (Mol 1996), achieving a decoupling between economic growth and harmful environmental impact (Asafu-Adjaye, Blomquist et al. 2015). Thus, the relationship towards the environment is presented as one of restoration in which every individual democratically exercises their power through their decisions. Under EMT, the ideal is that independently every individual opts for the products that promote the restoration of the environment, that modern technology will enable the existence of such products, and this will allow socioenvironmental practices without a radical change of direction.

Starting as a reactionary movement, degrowth's narrative stands against the environmental degradation and social atomization caused by the neoliberal context in which the world has been submerged (Demaria, Schneider et al. 2013). It accuses the hunger for economic growth as the first motor of the environmental crisis and the social inequalities, while pointing out the long-term and side harmful effects that technological development has occasioned (Garcia, Jerónimo et al. 2018, Grunwald 2018, Kerschner, Wächter et al. 2018). Therefore, it calls for a reduction in the unreflective expansion of technology to avoid further unpredictable damage as has been observed in various examples of technological innovation (Kerschner, Wächter et al. 2018). Simultaneously degrowth stands for the need for technology that brings individuals closer to each other into a convivial society, one characterized by cooperation, solidarity, and mutual respect (Illich 1973). Degrowth aims to carefully consider and assess modern technology for its compromising risks towards the environment and its instrumental approach in society.

As mentioned before, the comparison provided in Table 5 is an abstract tool that helps to apprehend the relationships of modern technology towards the environment and society through different perspectives within modernity's paradigm. It helps to evaluate the feasibility and intention of the different claims and reveals the existing direction they aspire to take, as well as the role modern technology occupies and would occupy in each theory.

Even though these theories concern the mainstream academic debate, it would be naïve to consider them as the only possibilities or existing paths to take, or that the academic arena is unbiased and encapsulates all existing perspectives. These perspectives are an excerpt of what in this study is identified as the paradigm of Modernity, which stems mostly from a Western framework derived from the European ideas of the Enlightenment, namely the ideas of individualism, meliorism and rationalism (Horkheimer and Adorno [1947] 2016), same ideas from which the mainstream academia arose. However, it would be equally naïve to ignore the influence these ideas have had worldwide impact due to the history and influence of expansionism and colonialism, and more recently due to globalization, practices that were and are inherent to modernity in themselves (Giddens 1990, Robertson 1992).

Nevertheless, further study and appreciation of theories that diverged from modernity such as traditionalism, communitarianism or deep ecology (Naess 1973), and theories that have developed independently such as Ubuntu and perspectives within African philosophy (Ramose 2002, Coetzee and Roux 2004), indigenous knowledge, Eastern philosophies, and perspectives on intercultural philosophy (Kimmerle 2004), should be addressed and considered when it comes to technology, especially when technology bares global political expectations like the Agenda 2030 for Sustainable Development of the United Nations (United Nations 2015, Sætra 2023) and affects Earth's limitations and natural cycles.

In that sense, the theories under modernity's umbrella previously discussed are constrained by certain geopolitical and historical factors and certainly do not hold a universal truth. Therefore, considering that technological expansion has changed the world partially but not exclusively because of these and other theories, analysing technology through a more empirical approach is necessary. Simultaneously, contrasting the empirical with the theoretical perspectives discussed so far brings valuable light on the matter, thus, the following research questions appear:

RQ4: What have been the reported impacts and causes of modern technology on the environment and society?

RQ5: How do the reported impacts and causes relate to the perspectives of the philosophy of technology, neoliberalism, ecological modernisation theory, and degrowth?

In the next chapter, a systematic literature review to further explore these questions is developed.

3. Systematic Literature Review

To answer RQ4 and RQ5 on the reported impacts and causes related to modern technology and the theories, a systematic literature review (SLR) was conducted following the steps shown in Figure 1 based on the review framework of Krisnawijaya et al. (2022). Having the research questions defined, the next step was to define the search protocol including the database selection. Once the search protocol was executed, the selection criteria and delimitation were followed by a quality assessment. The selected studies were analysed thoroughly, and a data extraction form was utilized to answer the intended research questions. Lastly, a data synthesis and visualisation of the extracted data was performed.

Figure 1. SLR process used. Extracted from (Krisnawijaya, Tekinerdogan et al. 2022)

3.1. Search protocol

A systematic search method was utilized to find potential articles that would be used to understand and assess the impacts of modern technology on the environment and society and their causes. Among the different digital databases available, Scopus was chosen due to its extensive coverage of scientific articles in technology-related fields (Yang and Meho 2006, Aksnes and Sivertsen 2019). Bearing in mind the broad scope of this study, the range of publication years was ten years due to practical reasons and considering that technology and its environmental and social impacts are a topic that has been gaining popularity over the period defined (see i.e., the 2030 agenda of the UN (United Nations 2015)). The automated search was executed using a search string intended to retrieve both the positive and negative impacts of technology. The general syntax of the search string query can be seen as follows: (technology) AND (impact) AND (environment OR society). Where synonyms, plural and related terms were integrated.

To narrow the results, the search was limited to scientific articles on the environmental and social sciences domain, delivering 1076 results that were assessed according to the selection criteria (Table 6).

3.2. Selection criteria

From the retrieved results, the selection criteria presented in Table 6 were performed to identify the relevant studies. The selection criteria were first applied by reading the papers' titles and abstracts and then by reading the studies thoroughly. After applying these criteria, 78 articles of the 1076 were selected.

Table 6. Selection Criteria

No	Criteria
EC1	Papers that do not have full text available
EC2	Papers which not written in English
EC3	The duplicate publication found in multiple sources
EC4	Papers do not cover modern technology
EC5	Papers do not discuss the impacts of technology on the environment and/or society
EC6	Papers do not relate to the environment or society directly
EC7	Conference, experience, book series, and survey papers
EC8	Papers do not validate the proposed study

3.3. Quality assessment

Before synthesizing the data, a quality assessment was performed as part of the data extraction according to the quality criteria presented in Table 7 based on Krisnawijaya et al. (2022). Using a three-point scale (yes, partial, no) for each criterion, every article proved to have a satisfactory mark, above 4.5, as seen in Figure 2. Thus, all 78 selected studies were included in the data extraction and synthesis process.

Table 7. Quality assessment criteria

No	Question	Yes (1)	Partial (0.5)	No (0)
Q1	Aims clearly stated			
Q2	Scope and Context clearly defined			
Q3	Variables valid and reliable			
Q4	The research process documented adequately			
Q5	All study questions answered			
Q6	Impacts clearly defined			
Q7	Causes clearly defined			
Q8	The main findings clearly stated			
Q9	Conclusions relate to the aim of the purpose of the study			

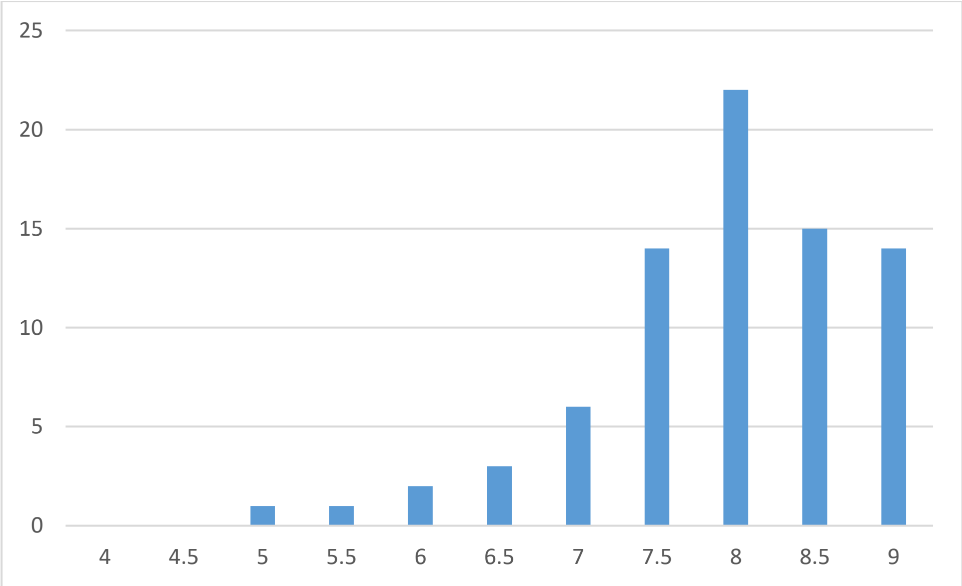

Figure 2. Quality assessment score distribution of selected articles

3.4. Data extraction

By reading thoroughly the 78 studies, the research questions RQ4 and RQ5 (see above or Table 10) should be answered. In addition, each read article was evaluated according to the previously studied perspectives (philosophy of technology, neoliberalism, ecological modernisation theory, and degrowth) according to the article's stance on modern technology, when the article's views did not fit any of the studied perspectives, it was labelled as "other" or "non-applicable". For this purpose, a data extraction form was developed to collect all relevant information for each study. This data extraction form was created by noting all relevant information that was found in several randomly selected studies which were read meticulously. This was an iterative process in which the data extraction form was constantly updated.

Eventually, the form included general information related to the publication itself, as well as more specific information that relates directly to the research questions and aim of this study. The final data extraction form is provided in the **Appendix**.

3.5. Data synthesis

The data synthesis was performed to apprehend the information obtained through data extraction and understand the underlying relationships of modern technology with the environment and society across the different studies. Information such as the type of technology, the main focus of study, variables in terms of impacts and causes, targeted domain, location, and perspective, was synthesized and it is presented graphically in the next section.

3.6. Results

The first sub-section gives a general overview of the 78 reviewed studies, and the next sub-sections dive into answering the research questions on the reported impacts and causes of modern technology and providing insights related to the purpose of this study.

3.6.1. General Statistics

Figure 3 provides the year distribution of the reviewed studies ranging from 2014 to 2023, more than 70 per cent of the selected articles were published during the last three years. This data shows the increasing importance given to the impacts of technology in academic literature, confirming the relevance of this study. Nevertheless, out of the two selected articles from 2015, the one published by Liu, Zhou et al. is the most cited followed by Elsaid, Kamil et al. (2020). The top ten cited papers can be found in Figure 4 and all 78 studies are given in Table 8 with the complete list provided in the **Appendix**.

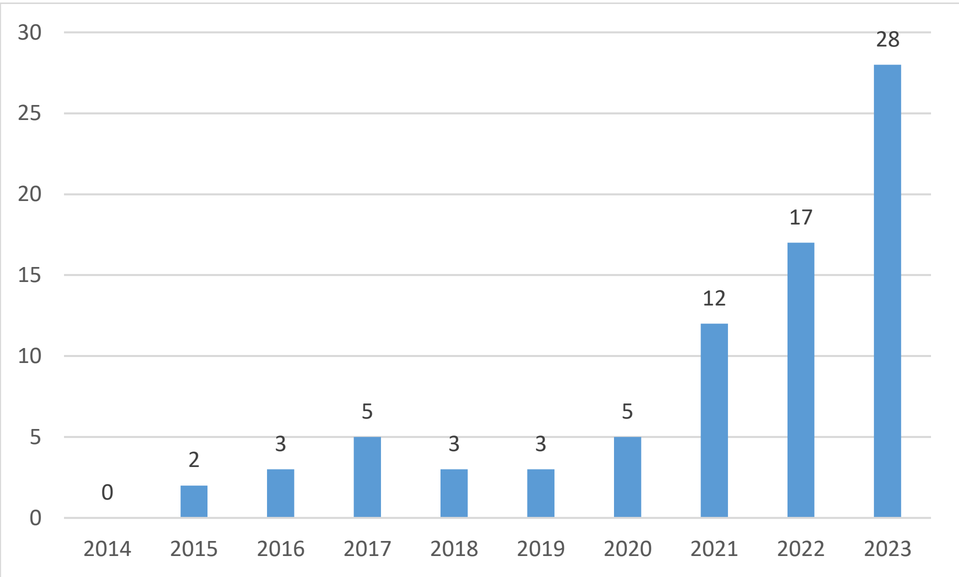

Figure 3. Year publication of studies

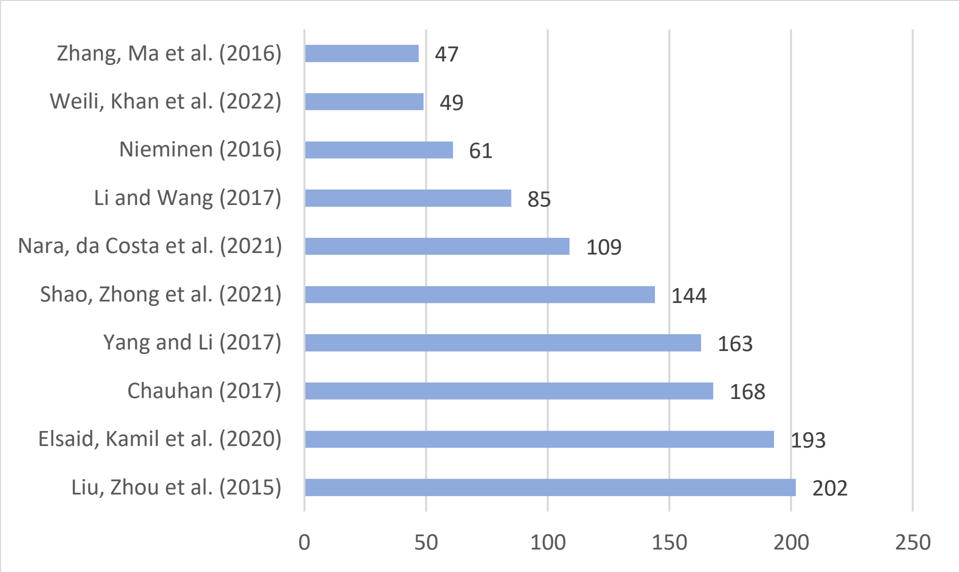

Figure 4. Top ten cited studies

When analysing the publication venues, around half of the articles, 40 in total, were published in unique journals, while the other half shared a venue with one or more articles. The *Environmental Science and Pollution Research* journal outbalances the others with 14 publications, almost four times more than the *International Journal of Environmental Research and Public Health* and the *Journal of Cleaner Production*, both in second position with 4 publications each (Table 9).

Table 8. Reviewed 78 studies.

Study	Year	Study	Year	Study	Year
Liu, Zhou et al.	2015	Mensah, Asiamah et al.	2021	Awad	2023
Chowdhury and Shanmugan	2015	Mirzaei Abbasabadi and Soleimani	2021	Behera, Haldar et al.	2023
Li and Lin	2016	Nara, da Costa et al.	2021	Burholt, Percival et al.	2023
Nieminen	2016	Shao, Zhong et al.	2021	Campero, Bennett et al.	2023
Zhang, Ma et al.	2016	Shobande	2021	Chien, Chau et al.	2023
Chauhan	2017	White, Viana et al.	2021	Gunnarsson, Lalander et al.	2023
Gerhart	2017	Ziebland, Hyde et al.	2021	Gyamfi, Agozie et al.	2023
Li and Wang	2017	Appiah-Otoo, Acheampong et al.	2022	Habiba, Xinbang et al.	2023
Qi and Zhang	2017	Buchmayr, Verhofstadt et al.	2022	Huo, Zaman et al.	2023
Yang and Li	2017	Chen, Mao et al.	2022	Hupli	2023
Dylko, Dolgov et al.	2018	Hu, Chen et al.	2022	Kuang, Liang et al.	2023
Mejame, Kim et al.	2018	Huang, Kong et al.	2022	Li, Chen et al.	2023
Yeom, Jung et al.	2018	John, Wesseling et al.	2022	Liu and Wan	2023
Cheng, Li et al.	2019	Khan, Weili et al.	2022	Mensah, Quansah et al.	2023
Macgregor, Pocock et al.	2019	Khattak and Ahmad	2022	Moghayedi, Hübner et al.	2023
Wang and Feng	2019	Li, Shi et al.	2022	Shen, Yang et al.	2023
Bacenetti, Paleari et al. 2020	2020	Munir and Ameer	2022	Timotheou, Miliou et al.	2023
Biru, Zeller et al. 2020	2020	Ronaghi and Mosakhani	2022	Verma, Bhatt et al.	2023
Elsaid, Kamil et al. 2020	2020	Shehzad, Zaman et al.	2022	Wang and Zhang	2023
Mirza, Ansar et al. 2020	2020	Weili, Khan et al.	2022	Xu, Ge et al.	2023
van der Hulst, Huijbregts et al. 2020	2020	Wen, Shabbir et al.	2022	Yang, Luan et al.	2023
Alhassan and Adam	2021	You, Khattak et al.	2022	Yuan, Qin et al.	2023
Altinoz, Vasbieva et al.	2021	Zhang and Wei	2022	Žani, Mileti et al.	2023
Brahmana and Kontesa	2021	Zhong, Xia et al.	2022	Zhang, Yang et al.	2023
Habtewoldh	2021	Albakjaji and Almarzoqi	2023	Zhang, Li et al.	2023
Hu, Zhang et al.	2021	Andati, Majiwa et al.	2023	Zhengxia, Batool et al.	2023

Table 9. Top publication venues.

Journal	No. articles
Environmental Science and Pollution Research	14
International Journal of Environmental Research and Public Health	4
Journal of Cleaner Production	4
Applied Energy	3
Environment, Development and Sustainability	3
Resources Policy	3
Sustainability	3
Business Strategy and the Environment	2
Science of the Total Environment	2

Another outbalance comes into sight when analysing the studied location of each paper, out of the 78 studies, 23 focus on China and 22 worldwide (Figure 5). The worldwide category was assigned when either the article mentioned an n number of countries without further specification or when a location was not mentioned at all. Contrarywise, countries that are mentioned individually in articles that focus on one or more countries were listed independently. An exception applied for groups of countries commonly addressed in literature such as BRICS (Brazil, Russia, India, China, and South Africa), the Belt and Road Initiative (1B1R) (over 155 countries), or MINT (Mexico, Indonesia, Nigeria, and Turkey), which had 3, 2, and 1 article, correspondingly. A map of the countries mentioned throughout the systematic literature review (SLR) can be seen in Figure 6.

Even without considering that China is part of BRICS and the 1B1R, not to mention the worldwide category, the country occupies almost a third of the SLR proving its academic interest in the impacts of technology, mainly on the environment, compared to the rest of the world.

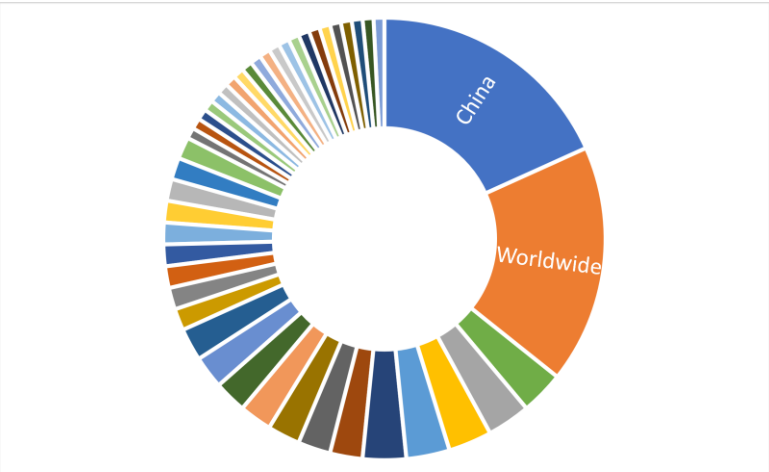

Figure 5. Studied location distribution.

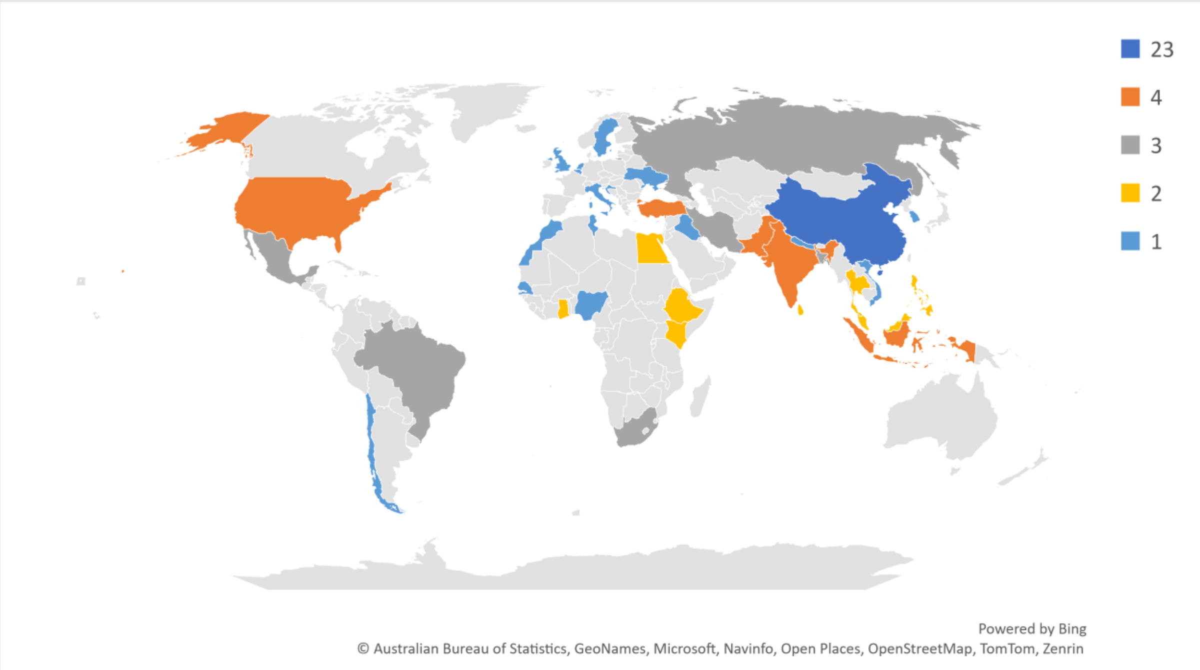

Figure 6. Map of studied locations by number of articles.

3.6.2. Focus of the studies

Although when performing the search protocol (Section 3.1) it was intended to equally address the impacts of modern technology on the environment and society, the number of selected articles focused on the first almost triples the latter. 52 articles were mainly on the environment's domain, 18 were on society, and 8 were on both (see Figure 7). The domain of focus was identified according to the main variables and the intention of each study, for example, if a study was about identifying the impacts of ICT on CO2 emissions, it was categorized under the environmental domain.

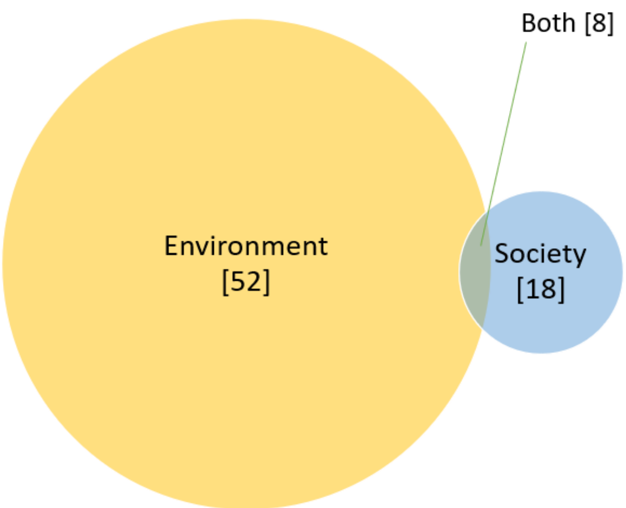

Figure 7. Distribution of studies' focus.

Within the domain, each article's particular focus was identified and categorized according to the main variable studied. For articles that had two or more main variables, i.e., economic growth and carbon emissions, they were counted and grouped independently. Figure 8 shows the categories created for each study's primary focus(es). Some categories, such as 'environmental impact,' 'energy,' or 'sustainable development', are formed by the same focus variable, in this case, environmental impact, energy consumption, and sustainable development, respectively. Other categories such as 'pollution', 'economic', or 'other' are formed by various focus variables. For example, industrial pollution, waste, and water, soil, heavy metals, and air pollution, are all considered under the umbrella of the 'pollution' category. The category 'other' is formed by foci that are not related to each other, i.e., addiction to social media, pollination, or political polarization. Furthermore, some articles' main focus was the technology in itself and its implications. A decomposition of all the categories can be found in the **Appendix**.

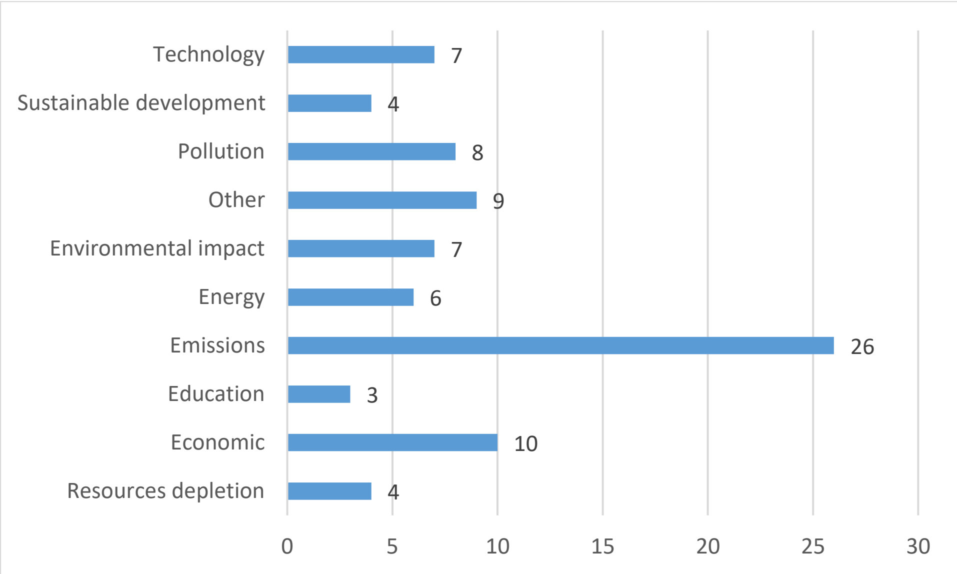

Figure 8. Studies main foci categories.

As shown in the previous figure, the category of emissions is by far the most popular among the selected studies. This category is formed by carbon or CO2 (24 articles) and greenhouse gases (GHG) (2 articles) emissions. In other words, half of the 52 studies of the environmental domain are focused on this subject, with carbon or CO2 emissions as the main focus variable to research. This is no surprise considering that carbon and CO2 emissions are the major point of discussion on the international agenda regarding the climate crisis (IPCC 2023). Thus, there is great interest in research about it.

3.6.3. Types of modern technology

In the 78 studies, different types of modern technology are mentioned. Sometimes as umbrella concepts such as ICT (information and communication technologies) or green technology, sometimes as specific technologies like genetically modified seeds or blockchain which can be grouped under bigger categories or not, like the case of artificial light, and robots which found no relatable partner. And other times, the articles will just mention technology or technological innovation in the broad sense, in these cases, the label 'general' was assigned. In Figure 9 the number of articles per type of modern technology are shown. Like the focus categories mentioned above, some articles discuss two or more types of technology which were categorised independently if they belong to different categories i.e., photovoltaic panels (renewable energy) and construction materials (materials).

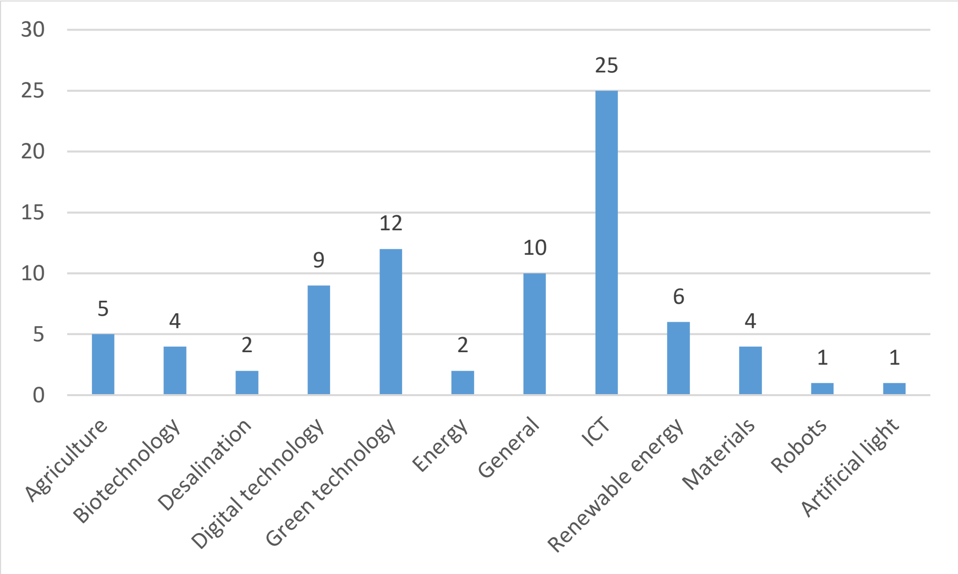

Figure 9. Types of modern technology.

The categories for the types of modern technology were developed based on the overall technologies mentioned, according to their purpose, sector, and how they were commonly addressed throughout the studies. Although, this categorization is not perfect and may encounter overlaps between each other, for example, genetic modification of seeds was categorized as 'biotechnology' even when this technology is most likely to be applied in the agricultural sector. For this and similar cases, the technology was compared to the other technologies in each category and placed in which it found the most similitude, like genetically engineered microbes instead of crop irrigation systems in the previous example. It was also considered relevant to differentiate between digital technology and ICT due to how these were separately referred to throughout the literature, even though digital technologies are commonly considered part of ICT. A similar argument was used for the differentiation between energy and renewable energy and of this latter one with green technology. In this last case, green technology is defined as an umbrella concept that includes all technology focused on diminishing harmful environmental impact. It could be argued renewable energy technologies fit in, but due to the differentiation given throughout the literature, it was kept separate.

Overall, ICT is by far the most mentioned type of technology throughout the literature. This can be attributed to ICT's wide spectrum and relevance in both environmental and social impacts, and the interest of international frameworks on these technologies (Sætra 2023), a characteristic that also applies to digital technology which is the fourth most mentioned. The second most popular type is green technology which, as mentioned before, is a broad term that includes all technologies intended to reduce, or restore, environmental damage, thus, its popularity and versatile use. Regarding technology in general terms, it is usually mentioned throughout the literature by referring to technological innovation or measuring it by number of patents, no specific sector or purpose of technology is named besides the variable itself.

3.6.4. Impacts and causes of modern technology

To answer the research questions, the impacts and causes reported throughout the different articles included in the systematic literature review (SLR) were identified as variables that correlate either positively or negatively to modern technology. As shown below, the number of reported impacts surpasses the number of reported causes by far, which is aligned with the SLR search protocol (see Section 3.1).

4.6.4a. Impacts

One of the main interests of this study is to identify the reported impacts of technology found in a vast collection of scientific journals. Throughout the extensive literature, 309 impacts were independently reported from which many are repeated across different articles. Figure 10 presents a word cloud of the reported impacts where the size of the word is proportional to the frequency in which they are mentioned. In this word cloud, 'emissions' and 'carbon' are identified as the bulkiest words in the cloud resembling the main focus of the articles as previously discussed. Followed by 'waste', 'economic', and 'growth', 'energy' and 'consumption' occupy second in the impacts reported, although, both words are frequently presented together as 'energy consumption'. However, some articles also report on energy efficiency or resource consumption, thus the differentiation in the cloud.

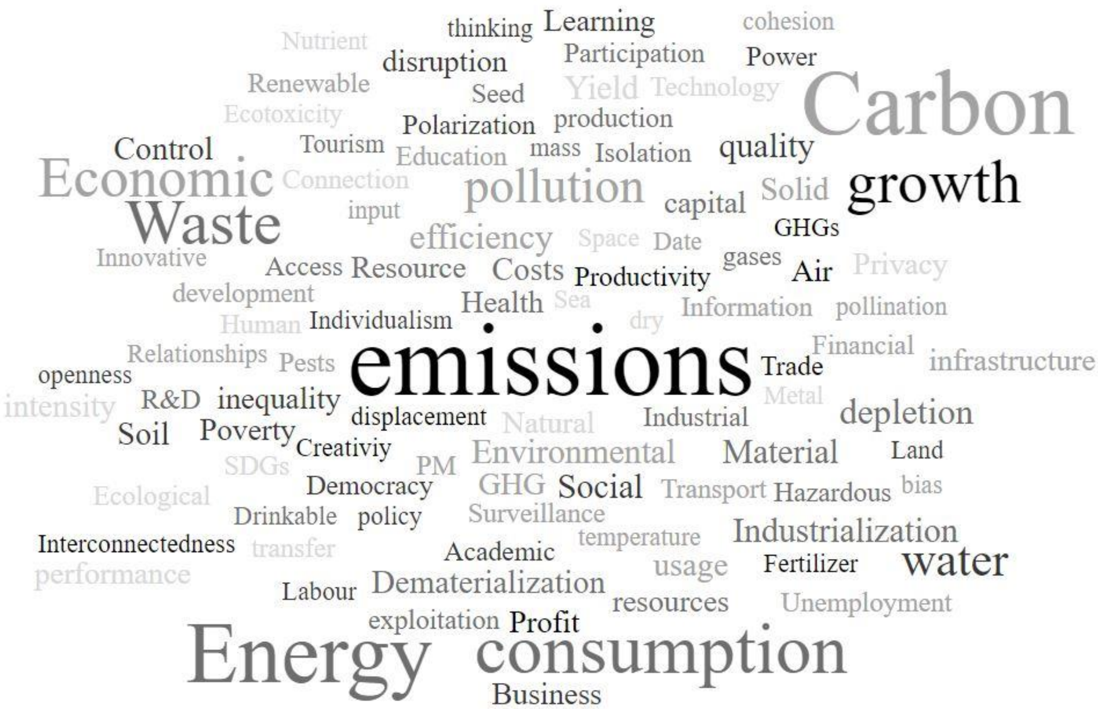

Figure 10. Word cloud of impacts reported.

Out of the reported impacts, studies differ on the correlation between them and modern technology, some argue that carbon emissions are reduced as modern technology increases, this is to say they have a negative correlation, while others argue the opposite, that they have a positive correlation. Figure 11 shows the number of articles that mention each impact and how they correlate. Out of the 29 articles that mention carbon emissions as an impact of modern technology, 20 reported these having a negative correlation. Out of 21, 12 articles reported that the increase in modern technology reduces energy consumption. Similarly, 3 out of 4 articles that report on GHG emissions, argued that these are reduced by an increase in modern technology.

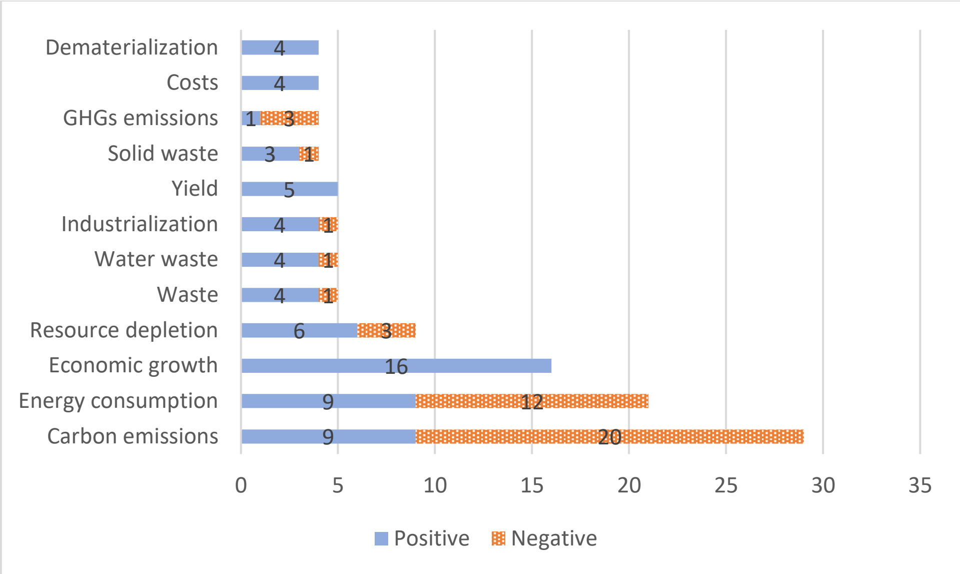

Figure 11. Most reported impacts and their correlation.

All 16 and 5 articles respectively reported that economic growth and yield have a positive correlation with modern technology which is aligned with the neoliberal and EMT ideas on which more modern technology brings more economic prosperity. Costs are also reported to increase with the increment of modern technology which is also aligned with classical economic theories under which neoliberalism and EMT have developed. Contrary to the so far beneficial impacts reported, modern technology is pointed out to have mostly a positive correlation with the increase of resource depletion and general waste, water waste, and solid waste, but also with dematerialization, which in theory reduces the depletion of resources and, by extension, waste, showing the complexity and interrelation between variables.

A greater example of the complexity of the impacts of modern technology is observed when the three major reported impacts, namely, carbon emissions, energy consumption, and economic growth, are analysed further. Figure 12 shows the reported correlation that modern technology and economic growth have on carbon emissions in the 16 articles that include both economic growth and carbon emissions as variables. In this figure, is shown that economic growth has been reported to be positively correlated with carbon emissions, thus, even though carbon emissions are reduced by modern technology, this reduction is intermediated by the simultaneous increase that modern technology has on economic growth. This challenges the assumption of EMT that a decoupling of economic growth and harmful environmental impact is possible by means of modern technology (Asafu-Adjaye, Blomquist et al. 2015).

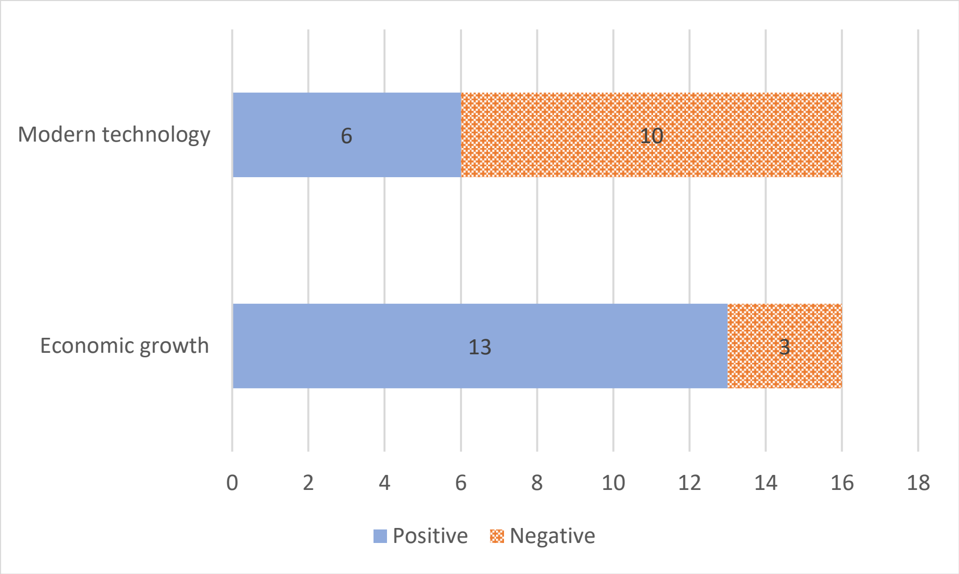

Figure 12. Correlation and impacts on carbon emissions.

Like the figure above, Figure 13 shows the correlation found in the articles that mention the impacts of both modern technology and economic growth on energy consumption. Considering that none of the studies found a negative correlation between economic growth to energy consumption, meaning that economic growth has a direct and indirect positive correlation with carbon emissions both by itself and through an increase in energy consumption. Simultaneously, energy consumption has been reported to have a direct positive correlation with economic growth, creating a positive reinforcing loop between the two (see Figure 14). This observation supports Degrowth's criticism of economic growth as a cause of the climate crisis (see Section 2.3.3).

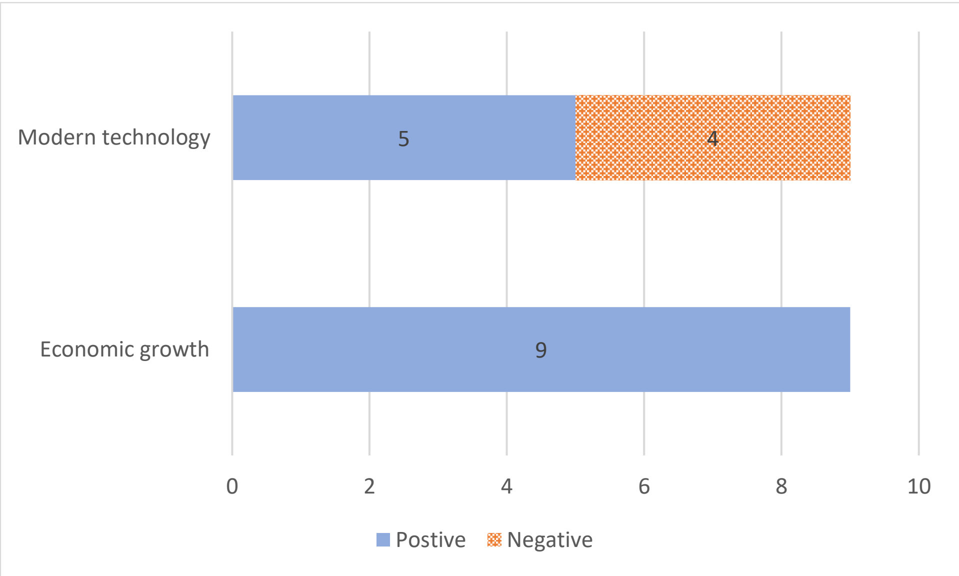

Figure 13. Correlation and impacts on energy consumption.

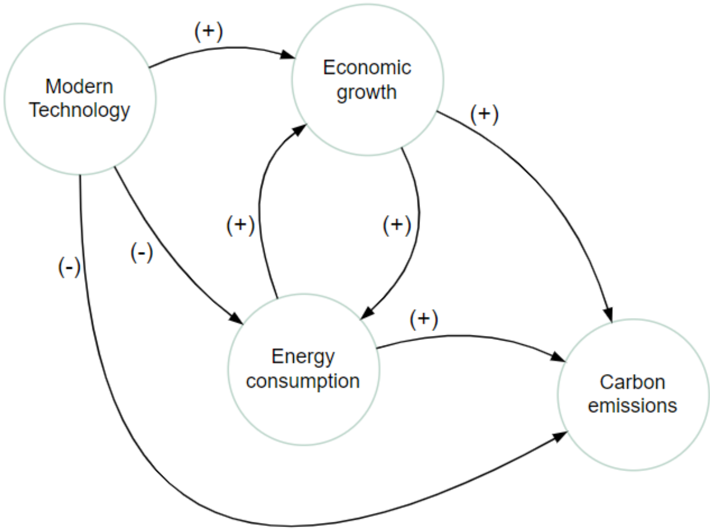

Figure 14. Correlations between modern technology, economic growth, energy consumption, and carbon emissions.

While being an example and a simplification, the figure above gives insight into the intertwined and complex nature of modern technology's impacts. Later in this study, in Section 4, a complete system analysis diagram is developed based on the SLR findings.

4.6.4b. Causes

Throughout the SLR, 51 causes of modern technology were reported and are presented in Figure 15 as a word cloud. Here, the words 'economic', 'growth', and 'financial' are the first to catch the eye followed by the words 'green' and 'technology'. Across the 78 studies, the major causes for the increase in modern technology are, as shown in Figure 16. Here, economic growth appears to be positively correlated to modern technology revealing a reinforcing loop between them. Curiously enough, green technology and renewable energy consumption, which both are a type or a product of modern technology, are a direct cause of modern technology in itself. This resembles Hans Jonas and other philosophers of technology analysis on technology as an end in itself (Jonas 1979)(see Chapter 2), in which modern technology behaves as an Ouroboros in an eternal reinforcing loop with itself.

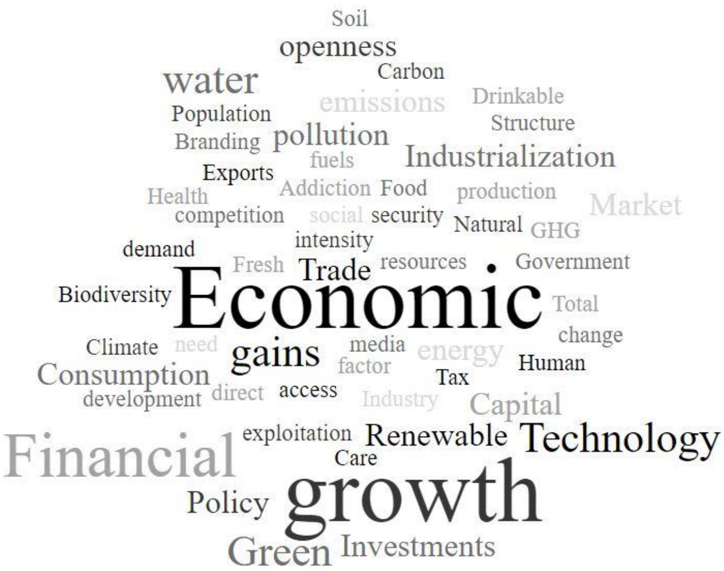

Figure 15. Word cloud of causes reported.

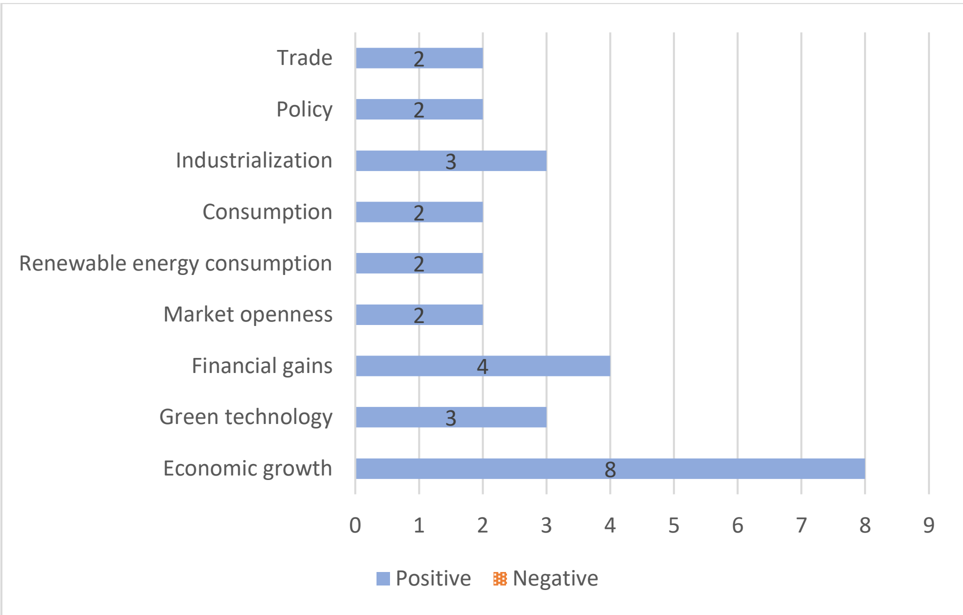

Figure 16. Most reported causes and their correlation.

Market openness and trade are also identified to have a positive correlation to modern technology, this seems logical considering that both bring the possibility for new products and technologies to reach places where they were unknown before, creating a market for new businesses and industries to arise, resonating with the neoliberal thought. In the same line of thought, consumption and industrialization are also identified as positively correlated causes, the latter having a reinforcing loop with modern technology. On the other hand, the policy identified as a positively correlated cause is described in two articles as government legislation that promotes technological innovation.

3.7. Perspectives

Each article was carefully reviewed and scrutinized to identify if they presented any resemblance with the theories discussed in Section 2.3. This was mainly done by looking at the introduction and conclusion of each article, analysing what is their study purpose and how, according to their findings, the role of modern technology is discussed. If an article, for example, wants to prove the mitigating effect of ICT on carbon emissions and finds that ICT has a minor effect on diminishing carbon emissions but in the conclusion insists that more investment in these and other technologies is necessary to achieve carbon neutrality and restore the environmental footprint, then the article would fall into the perspective of EMT. If the conclusion from another article is the need to regulate how the technologies are used due to the potential of increasing unequal opportunities or widening the social gap, the article would be categorized in the philosophy of technology/degrowth perspective.

So on and so forth, every article was labelled with a perspective according to what they said and how they expressed about technology. Sometimes, the article would not be aligned with any of the described perspectives, for those cases, a label of 'Other' was given. At the same time, it was evaluated if the article had a positive, negative, or neutral stance towards technology, this was easily done according to their conclusions and, in some cases, their policy advice.

Of the 60 studies that cover the environment focus (see Figure 7), 9 had a degrowth perspective, 26 had an EMT one, 16 resembled neoliberalism, and 9 were identified as 'other', none of the articles perceives modern technology as exploitative leaving the philosophy of technology (PoT) aside (see Figure 17). Figure 18 shows the stance towards technology according to each perspective which, as expected, shows that most of the articles with an EMT or neoliberal perspective have a positive stance towards modern technology, whereas for degrowth a neutral or negative stance. In the case of 'other' is mostly neutral but has both positive and negative as well.

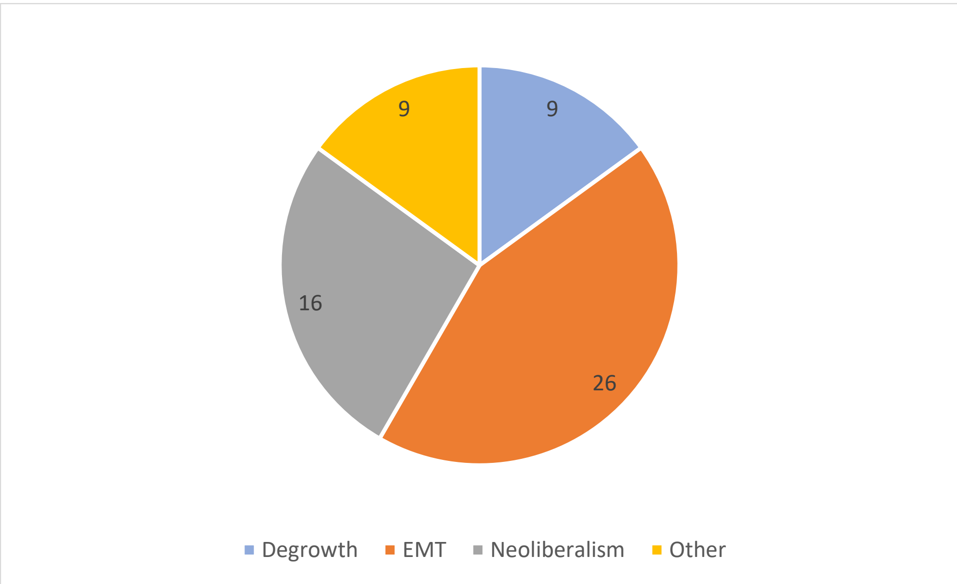

Figure 17. Perspective distribution on the environment focus.

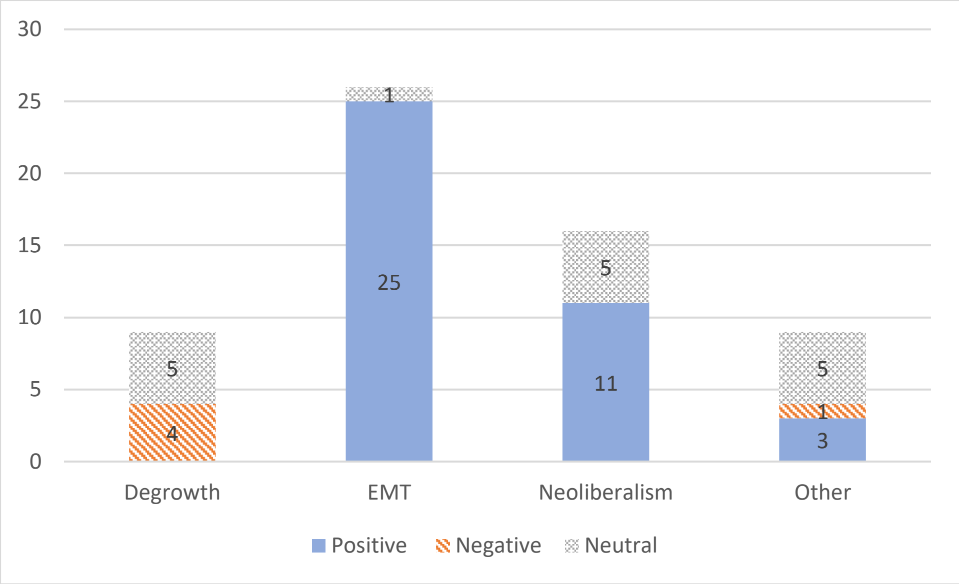

Figure 18. Stance distribution of each perspective on environment.

Of the 26 studies that include society (Figure 7), half of them perceive the instrumental aspect that modern technology has on society while almost the other half the enabling characteristics that modern technology entails (see Figure 19). Only one article was identified with EMT's democratic perspective on modern technology, and another one was not identified with any of the studied theories.

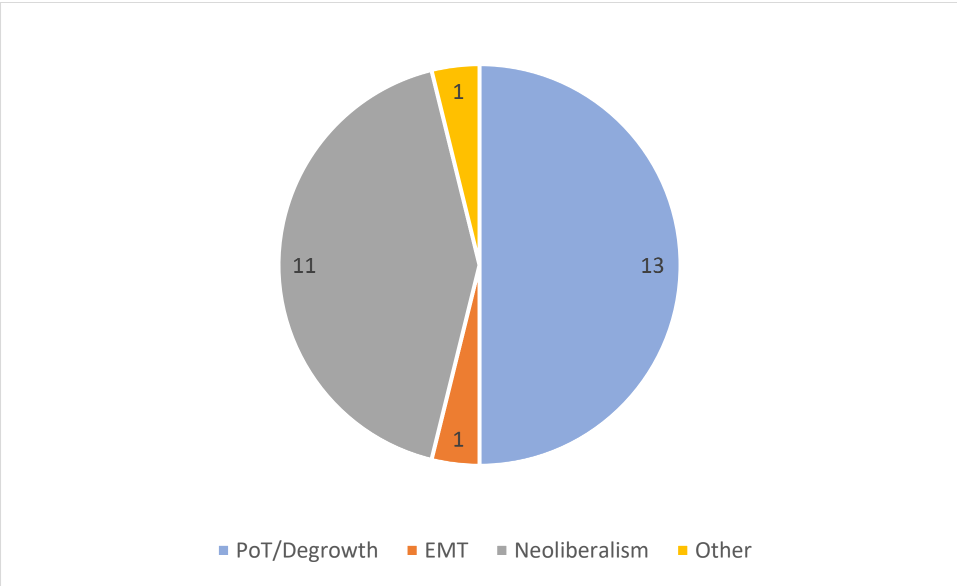

Figure 19. Perspective distribution on the society focus.

Figure 20 presents the stance distribution of each perspective on society showing that more than half, 14 in total, have a positive stance towards modern technology while only two presented a negative one. In the case of the philosophy of technology and degrowth (PoT/degrowth), most of the articles were identified from a neutral standpoint.

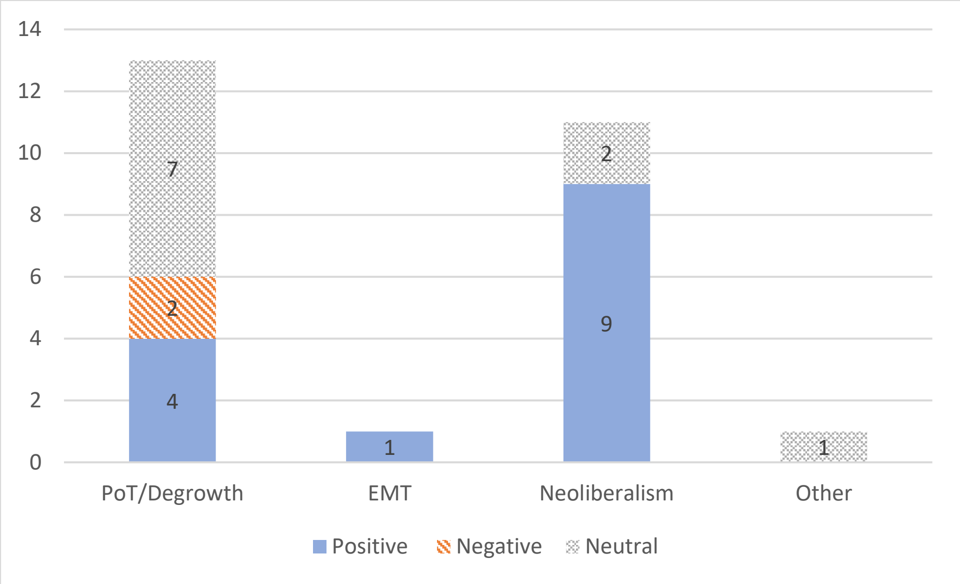

Figure 20. Stance distribution of each perspective on society.

3.8. Discussion on the SLR

3.8.1. General Discussion

The echo of Thomas Kuhn's definition of 'normal science' (Kuhn [1962] 2012) resonated throughout the reviewed 78 studies. Most of the articles appeared to be a puzzle-solving routine of statistical manipulation where uncertainties and complexities were uncritically dismissed to find an answer that, presented in the narrowest scope possible, appears to be conclusive: that technology, no matter what is desirable. None of the six articles that were identified to have a negative stance towards technology, not to mention the ones with neutral or positive stance, were against technology. Even when technology seemed to be, in the authors' own terms and statistical jargon, the cause of the studied undesirable outputs, CO2 emissions for example, technology was never rejected but rather embraced and advisable to increase with certain precautions.

Throughout the literature, an overall conflict of interests, namely, between the idea of progress and Earth's limitations on human development, appeared to be latent. A conflict that was often disclosed in the policy advice of articles that, no matter the results, argue for more technology while advising that all the negative consequences that more technology would entail – waste, water pollution, resource depletion, etc. – should be somehow diminished by, for example, greener technology or renewable energy sources, while all the positive ones – economic growth, emission reduction, dematerialization, etc. – are kept. Advise that without further question of its unintended consequences, is given by dissecting technology's effects into smaller pieces implied to be solvable one by one. A euphemism for the conviction that the problems brought by technology are to be solved with not less but more technology.

While diving into the studies that focus on China as a location, the assertion that technology is the path towards a greener and brighter future seems to be indeed biased by prior beliefs and goals. Being the preferred location of the 78 studies in the SLR, the articles in China are the best possible case study to further investigate what in the overall abstraction seems to be a bias towards a framework that sees socioeconomic and technological progress as the solution to all problems.

Out of the 23 articles with China as a location, 22 are focused on the environment and 1 on both the environment and society, suggesting China's great interest in studying the environmental impacts of technology. With most of the articles published in 2021 onwards and mainly focused on carbon emissions, the resemblance with China's fourteenth five-year plan aims at emissions reduction and non-fossil sourced energy (UNDP 2021) cannot be ignored. While investigating that 16 of the 23 articles show to have an ecological modernisation theory (EMT) perspective, Mol (2006) describes how China has been since 1970, especially after 1979 with Deng Xiaoping's economic reforms, restructuring its governance along the EMT's lines (Mol 2006). Lines that can be traced to the present day while looking at China's last five-year plan, and the investments in green technology, pollution reduction, and renewable energy that have been taking place in the last decades (Hepburn, Qi et al. 2021, Zhang, Shao et al. 2022). The 19 articles with a positive stance towards technology, and the overall advice for more technology, further reaffirm the alignment between scientific research and the political agenda.

Is this alignment caused by the increasing inclusion of scientific research in policymaking? Is it caused by how public funding for research is granted? Is it that the researchers, and authors of these papers, are initially biased by the paradigm of modernity, the notion of progress, technological optimism, and/or the political agenda of the studied countries? Or is it a combination of all? In that same line of thought, this study is also biased by the research output and the ideals and frameworks behind it. By representing almost a third of the reviewed articles, the perspective of technology in a Chinese context highly influences the overall results of the systematic literature review.

Another important question to ask is if it is not the ideological bias but that when studying modern technology by dissecting its interactions into singular pieces, the benefits and need for more technology become self-evident. If this is answered positively, would similar conclusions arise when having a more systemic approach? This question is further explored in the following chapter this last question is furtherly explored.

3.8.2. Threats to validity

To guarantee that the findings of the SLR are rigorous, the threats to construct, internal, external, and conclusion validity (Zhou, Jin et al. 2016) were considered throughout the different stages of the process. The planification of the SLR was meticulously developed by specifying the setting and ensuring sufficient details. The research questions and research objectives were extensively discussed and adjusted to narrow the gap between the two. The exclusion of non-peer-reviewed articles was deliberately intended to use high-quality publications only, with most of the articles retrieved being published in journals with high standards.

Furthermore, the search query was defined after several iterations of trial, error, and refinement to retrieve the most relevant studies. In the same repetitive way, the data extraction form was updated back and forth to ensure that all significant information was collected. This form included a diagram to draw all mentioned variables and their interactions according to each study, allowing to visualize and synthesize the information properly. In this way, the construct, internal, and external validity was ensured. For the conclusion validity, while conducting the SLR they were carefully read and discussed to minimize interpretation bias, while simultaneously, the protocol and criteria were strictly followed. Along these lines, the potential threats to this study's validity were tackled.

4. System Analysis

Considering the previous reflection on the reductionist approach most of the studies in the systematic literature review have on modern technology's effects, a systemic analysis was made with the main impacts (Figure 11) and causes (Figure 16) identified in the studies as a starting point. First, for each impact and cause reported, their other non-modern technology causes and impacts were listed. When there was more than one article identifying the same other cause and/or impact on the same variable, these were considered in the system. Then, an assortment of similar variables such as waste, wastewater, and solid waste, into one term, waste, in this case, was made. Finally, the positive and negative identified correlations between variables were assessed, keeping the one with an absolute majority (i.e., modern technology and energy consumption: 9 (+) < 12 (-) = (-) correlation). The result of this tracking led to the elaboration of a causal loop diagram shown in Figure 21.

This diagram helps to identify the main correlations of modern technology according to the 78 studies included in the SLR and how they relate to each other and to other variables that do not appear in plain sight. It shows the complexity surrounding modern technology's self-development, its relationship with other variables, and how they reinforce and mediate each other directly and indirectly. In other words, it shows that the interactions of modern technology cannot be isolated from each other, as most of the studies in the SLR do. For example, the diagram shows that modern technology's direct negative correlation with carbon emissions might not be as negative as it appears in the first instance since most of the other impacts of modern technology can be drawn to a positive correlation with carbon emissions, mediating or exceeding the direct effect initial claimed. For the scope of this study, the correlations between variables are not weighted, but the links and loops are analysed.

Figure 21 shows that modern technology has 22 direct links of which 10 are positively correlated causes, 9 are positively correlated impacts and 3 are negatively correlated impacts. Simultaneously, 6 direct loops are found of which 5 are reinforcing loops, these are with economic growth, resource depletion, trade, industrialization, and consumption; and one, with energy consumption, is a balancing loop. This indicates that out of these variables, only the last one directly decreases as modern technology increases, but not the opposite, meaning that if these two variables were only dependent on each other they would reach a steady state at a given moment in time. Meanwhile, the other variables would theoretically increase or decrease reciprocally with modern technology ad infinitum.

In total, modern technology has 161 loops with a length range of 1 to 8 variables, from which, around 80 per cent are reinforcing loops, suggesting that through its impacts, modern technology continuously adds on top of itself. Resembling the observations of Ellul, Illich, Jonas (Illich 1973, Jonas 1979, Ellul [1954] 2021) and other philosophers of technology as discussed before for which modern technology is a self-enforcing phenomenon that becomes an end in itself, feeding on its impacts.

After modern technology, economic growth has the highest leverage with 148 loops of 1 to 8 variables length range. All impacts and all causes except for 'government intervention' are positively correlated, and most of its loops are reinforcing loops, suggesting that economic growth will enhance economic growth. Carbon emissions, on the other hand, are only reported as a cause of economic growth, with a positive correlation in a reinforcing loop, of renewable energy consumption, with a negative correlation in a balancing loop, and of GHG emissions, which is redundant since carbon emissions are considered greenhouse gases. It has 124 loops of 1 to 8 variables length range and is the most common impact in all the diagram with 11 direct causes from which only two are negatively correlated, modern technology and renewable energy consumption. This reflects the SLR findings with carbon emissions as the main output variable when studying the impacts of modern technology.

After carbon emissions, energy consumption is the variable with the most connections and loops, 10 and 95 respectively. Out of the 6 causes, only modern technology has a negative correlation, meanwhile, all 4 impacts are positively correlated. For energy consumption as well most of the loops are reinforcing, suggesting that energy consumption will promote more energy consumption. Another variable that plays a major role in the analysis is 'industrialization' which is also an obvious guess given that modern technology's first great expansion, namely, the Industrial Revolution, was due to its manufacturing purposes and potential. In Figure 21, industrialization shows a positively correlated cause with consumption and with modern technology, all other links, 6 out of 8, are positively correlated impacts including economic growth, energy consumption, carbon emissions, pollution, waste, and, of course, modern technology, creating a reinforcing loop with it.

An interesting observation that Figure 21 provides is concerning the variable of 'consumption' which, even though it has only 5 links, 3 causes and 2 impacts, all positive, presents 81 loops mostly reinforcing, making it the fifth variable with the most leverage, even though it is barely mentioned throughout the SLR. This observation hints at the important role this variable plays in a system where modern technology, economic growth, carbon emissions, and energy consumption are involved. Considering that consumption is the largest component of a country's economic growth and the main contributor to carbon and other GHG emissions (IPCC 2023), this observation may appear logical, nevertheless, it is overlooked throughout the reviewed studies and it strengthens the need for a system analysis.

Overall, the causal loop diagram presents modern technology's interaction with the social dimension through concepts, like economic growth, industrialisation, trade, and variables that are a consequence of social activities and structures. The environmental dimension is mostly through ecologically harmful outcomes, reflecting how the research included in the SLR is composed. It displays the complexity of those interactions and the importance of assessing modern technology systematically. A complete assessment of this system would require further study of each variable, the correlation coefficients between them, and their relative weighting factor. Moreover, variables that were mentioned in the literature but not fully explored, like dematerialization and resource depletion, may provide deeper insight into modern technology's role in the climate crisis. Variables, like consumption, may also provide a more profound understanding of humans' relationship with modern technology. Nevertheless, the added value and insight provided by such a systemic approach is undeniable and confirms the wicked problem nature that technology, especially modern technology, may entail.

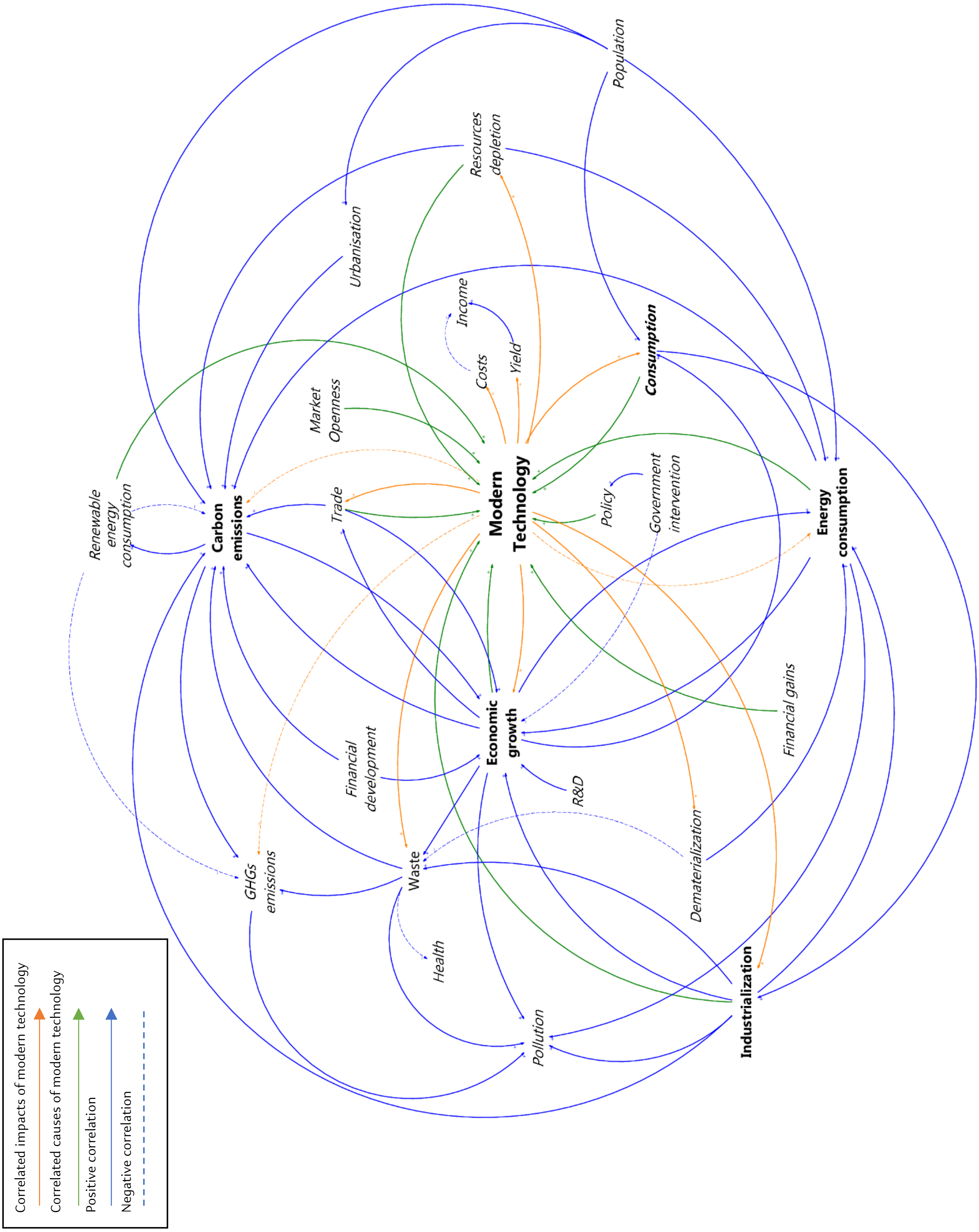

Figure 21. Diagram of reported impacts and causes of Modern Technology.

5. Discussion

Looking back on the relationship of modern technology with the environment and society described by the philosophy of technology, neoliberalism, EMT, and degrowth (Table 5) while considering the findings of the SLR and the system analysis, the need for reflection arises as some interesting observations appear.

First, the mismatch between the philosophers and the researchers of technology. While the first have been mostly interested in analysing modern technology's impacts on the human condition and society with the environment as an externality, the latter have been interested in the impacts towards the environment in contrast with macroeconomic indicators leaving the human condition aside. This reflects what some philosophers of technology have claimed in the first place, that modern technology is a phenomenon that goes beyond the technological (Heidegger 1977, Ellul [1954] 2021), technifying, reducing to numbers and problems to be solved, everything its way. In the case of the reviewed research articles, the climate crisis and society's well-being, are reduced to a matter of quantifiable variables, that as far as they can be measured, they can be tweaked to achieve desirable outputs. Here, modern technology is not only the means to tweak but also to measure inputs and outputs. Thus, modern technology encloses scientific research and its interpretation, including this study.

Second, the diaphanous presence of the paradigm of modernity along the SLR, especially in the conclusions given. The notion of progress as a one-way street where there is no return to technological development but rather the hope that its constant occurrence will bring a better future was present throughout most of the studies reviewed. The idea of progress seems to be taken for granted, with technical advancement and human condition improvement unquestionably linked. This resembles what Langdon Winner (1983) calls 'technological somnambulism', the idea that humanity is sleepwalking with modern technology, realizing what has been done after being executed (Winner 1983).

This somnambulism takes part in scientific research as much as in global political agendas. International programmes such as the United Nation's Sustainable Development Goals (SDGs) or more local as China's five-year plan, are charged with unquestioned expectations towards modern technology's role in an improved future. These political agendas influence and are influenced by the scientific research around them creating a reinforcing loop of technological optimism, and, consequently, technological promotion.

Third, the modern perspectives that were considered while performing the systematic literature review (Table 5), were most of the time surprisingly present in the selected studies, this was either a cognitive bias or the actual context in which these theories are immersed in the public sphere including the academia. While doing the review, a critical thinking standpoint was sought, striving to avoid any sort of motivated reasoning, this, nevertheless, can never be guaranteed in its totality. On more than one occasion, mixed conclusions were reached when assigning the perspective to an article, it is worth noticing that these perspectives – philosophy of technology, neoliberalism, EMT, and degrowth – are not mutually exclusive, but nuances within modernity's relentless predisposition to see technology – and science – as a source for answers. When mixed conclusions were reached, the article was read over and over, looking for fine distinctions between lines until the perspective, usually at the conclusion or policy advice, clearly appeared.

From these perspectives and their example publications, it seems that the glasses of EMT and neoliberalism occupy a predominant role in academia when looking at modern technology and its problems to solve. Meanwhile, degrowth and philosophy of technology, seem to be present in the literature for their more balanced and grounded perspective, but, the rejection of modern technology, often present in the work of these perspectives' scholars, was completely absent throughout the research papers. Other non-studied perspectives appeared mostly in non-Western located studies, which opens an invitation to investigate theories that may be outside of modernity's umbrella.

Lastly, the reductionist approach that most, if not all, studies had on modern technology's interactions reflects on what some philosophers of technology, like Mumford and Ellul, have pointed out on modern technology's tendency to technifying everything, including seeing the world's phenomena as an isolated problem to solve, a line of production where every segment is assembled independently. Even though, the studied theories postulate a more or less holistic approach to modern technology, the empirical studies seem to simplify it, failing to address the systematic nature of modern technology's interactions.

This simplification becomes problematic when policy advice is given out of it. Considering the complex and intertwined nature of modern technology's implications, as the diagram in this study shows (Figure 21), policy should not proceed based on reductionist factual predictions as if it were a singular and linear problem. Modern technology due to its high system uncertainties and high decision stakes should be better considered within what is defined as 'post-normal science', a scientific discipline that recognizes the complexity and multiplicity of perspectives a system has, and for which 'normal science', in the Kuhnian sense, is not enough to address (Funtowicz and Ravetz 1993).

Addressing modern technology within post-normal science would mean recognizing it as a system that permeates every aspect of reality entailing multiple and sometimes opposite effects on the environment and society. It would imply that modern technology is not studied as an isolated variable correlated with carbon emissions or economic growth, but as a phenomenon holistically embedded in the world with systematic repercussions. Thus, the claims and policy advice on modern technology would not be given on a factual reductionist base but accepting the uncertainty and pointing out all dangers and promises that modern technology entails.

6. Conclusion

This study aims to understand the perspectives of the philosophy of technology and the main theories, within the framework of modernity, regarding the relationship between modern technology, the environment, and society, was carried out by performing a vast domain analysis of literature from different authors and scholars. First, on the concept of technology and then, narrowed to the concept of modern technology and focusing on the humanities philosophy of technology, to later explore the theories of neoliberalism, ecological modernisation theory, and degrowth. From these readings, the concept of modern technology was approximated and an abstract summary of its identified relationships with the environment and society according to each theoretical frame was created (Table 5) and described. This domain analysis, including the development of the abstract tool, answered the first three research questions of the study (Table 10).

To satisfy the second aim of this study of evaluating and comparing the perspectives with the reported impacts of modern technology on the environment and society in scientific publications, a systematic literature review (SLR) was performed following selection criteria (Table 6), 78 scientific papers were included and reviewed thoroughly. Out of this SLR presented in Chapter 3, the main reported impacts and causes of modern technology were identified, answering the fourth research question. Simultaneously, throughout the SLR the studied perspectives were considered, and each article was categorized accordingly answering the last research question.

While performing the SLR interesting unexpected findings came out such as the distribution of publication focus between the environment and society (Figure 7), the studied locations distribution (Figure 5 and Figure 6), and the overall positive stance towards modern technology (Figure 18 and Figure 20), all these gave room for deeper reflection and provided insights that were further explored by using the studies focused on China as a case study, and expanding the research on impacts and causes through a system analysis presented in a causal loop diagram (Figure 21). With the system analysis, further reflection took place and proved the need for a non-reductionist approach to modern technology.

Throughout the study, the temptation to list arguments against and in favour of modern technology was latent. However, these arguments were implicitly addressed and deliberately not given. The reasoning behind it is that, as the study unfolded, it became clear that modern technology, as previously discussed, should not be reduced to a binary list of arguments that could further support one position or the other, but rather be recognized as a systemic subject, a wicked problem, to be studied and considered according to its complex and uncertain nature. To address this issue, this study briefly mentioned the possibility of using a post-normal science approach, acknowledging that technology as a solution will always bring unintended consequences.

In conclusion, this study is an approximation that broadens the ontological and phenomenological understanding of modern technology and how has been studied. It is a novel and broad interdisciplinary study that opens a window for future research, including the extension of the SLR and the system analysis to add weighted variables and correlation factors that could enable tweaking and running simulations of the system under different scenarios or theoretical perspectives; and the exploration of different theories, especially non-Western, and their perspectives towards technology, this could enrich greatly and bring a more holistic understanding to address the role of technology in the present and future global challenges.

7. Appendix

Table 10. List of research questions

No	Research Method	Research question
RQ1	Domain Analysis	What is modern technology?
RQ2	Domain Analysis	What are the perspectives of modern technology in relationship to the environment and society according to the main authors of the humanities philosophy of technology?
RQ3	Domain Analysis	What are the perspectives of modern technology in relationship to the environment and society according to modernity's main theories currently debated, namely, neoliberalism, ecological modernization theory (EMT), and degrowth?
RQ4	Systematic Literature Review	What have been the reported impacts and causes of modern technology on the environment and society?
RQ5	Systematic Literature Review	How do the reported impacts and causes relate to the perspectives of the philosophy of technology, neoliberalism, EMT, and degrowth?

Extraction Form							
General Information							
1	ID						
2	Title						
3	Year						
4	Authors						
5	Authors Affiliation						
6	Authors Organization						
7	Repository						
8	Publication Venue						
9	Date of extraction						
10	SLR Category						
Description							
11	Domain of Impacts		Environment		Society		Both
12	Main Focus						
13	Main Focus Causes						
14	Main Focus Impacts						
15	Technology described						
16	Identified Impacts of technology						
18	Identified Causes						
17	Environmental Kuznets		Classic		Inverted		NA
19	Related perspective (environment)						
20	Related perspective (society)						
21	Stance towards technology		Possitive		Negative		Neutral
22	Policy advise/risk mitigation						
23	Location						
24	Diagram						
Evaluation							
24	Personal Note						
25	Additional Note						
26	Quality Assessment						

Figure 22. Data extraction form.

List of complete references included in the Systematic Literature Review

Albakjaji, M. and R. Almarzoqi (2023). "The impact of digital technology on international relations: The case of the war between Russia and Ukraine." Access to Justice in Eastern Europe 6(2).

Altinoz, B., et al. (2021). "The effect of information and communication technologies and total factor productivity on CO2 emissions in top 10 emerging market economies." Environmental Science and Pollution Research 28(45): 9.

Andati, P., et al. (2023). "Effect of climate smart agriculture technologies on crop yields: Evidence from potato production in Kenya." Climate Risk Management 41.

Appiah-Otoo, I., et al. (2022). "The impact of information and communication technology (ICT) on carbon dioxide emissions: Evidence from heterogeneous ICT countries." Energy and Environment.

Awad, A. (2023). "Information and communication technologies role in alleviating poverty in Sub-Saharan Africa: Impacts and transmission channels." Sustainable Development 31(2): 16.

Behera, B., et al. (2023). "Investigating the direct and indirect effects of Information and Communication Technology on economic growth in the emerging economies: role of financial development, foreign direct investment, innovation, and institutional quality." Information Technology for Development.

Brahmana, R. K. and M. Kontesa (2021). "Does clean technology weaken the environmental impact on the financial performance? Insight from global oil and gas companies." Business Strategy and the Environment 30(7): 12.

Buchmayr, A., et al. (2022). "Exploring the global and local social sustainability of wind energy technologies: An application of a social impact assessment framework." Applied Energy 312.

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Category	**Pollution**						**Economic related**					
Focus	Waste	Heavy metals	Industrial	Air	Water	Soil	Economic growth	Financial Performance	Income	Profit	Poverty	Unemployment
No articles	1	1	1	3	1	1	3	1	1	1	3	1

Category	**Other**									**Emissions**	
Focus	Addiction to social media	Dispossession	Loneliness	Political polarization	Pollination	Agricultural yield	Primary care system	Sense of community	Urban Land Intensive Use	Carbon emissions	GHGs emissions
No articles	1	1	1	1	1	1	1	1	1	24	2

Category						
Focus	Energy	Environmental impact	Technology	Resources depletion	Education	Sustainable development
No articles	6	7	7	4	3	4

Figure 23. Categories of studies' main foci.

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