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HOW GREEN AND DIGITAL TRANSFORMATION SHAPES INDUSTRIES – TWIN TRANSITION TO A GREEN AND DIGITAL FUTURE

A ZÖLD ÉS DIGITÁLIS TRANSZFORMÁCIÓ HATÁSA AZ EGYES IPARÁGAKRA – ÁTÁLLÁS A ZÖLD ÉS DIGITÁLIS JÖVŐBE

Digital transformation creates challenges in nearly all industries and business sectors. In this article we provide a targeted multidisciplinary and horizontal overview of the extensive yet diverse and fragmented literature on digital transformation, clarifying the boundary conditions for investigating the phenomenon from the point of view of GreenTech and sustainability. There is a clear shift in the decisions of all actors toward sustainability, on which GreenTech solutions are built around. Recent studies highlighted the importance of green digitalization solutions, emphasizing the importance of (digital) technology in addressing sustainability challenges as well as in business and consumer use. Consequently, the authors found, the acceleration of the expansion of digital transformation and the role of GreenTech solutions within its ambit should assume greater prominence in the near future given that ultimately there is no energy transition without digitalization.

Keywords: **digital transformation, FinTech, EverythingTech, GreenTech, green digitalization**

A digitális átalakulás minden iparágban és üzleti szektorban kihívást jelent. Jelen cikkben a digitális átalakulás kiterjedt, sokrétű és szigetszerű szakirodalmának célzott multidiszciplináris és horizontális áttekintését nyújtják át a szerzők, tisztázva a jelenségnek a GreenTech és a fenntarthatóság szempontjából történő vizsgálati peremfeltételeit. Ugyanis egyértelmű elmozdulás tapasztalható a gazdasági döntéshozatalban a fenntarthatóság irányába, amely köré a GreenTech megoldások épülnek. Közelmúltbeli tanulmányok rávilágítottak a zöld digitalizációs megoldások fontosságára, hangsúlyozva a (digitális) technológia jelentőségét a fenntarthatósági kihívások kezelésében, valamint az üzleti és lakossági felhasználásban. Következésképpen azt találták, hogy a digitális átalakulás terjedésének felgyorsulása és a GreenTech megoldások ebben betöltött szerepe a közeljövőben jelentősen növekedni fog. Nem létezik energiaátmenet digitalizáció nélkül.

Kulcsszavak: **digitális transzformáció, FinTech, EverythingTech, zöld technológia, zöld digitalizáció**

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The global adoption of digital transformation has drastically altered business operations in nearly all industries (Gökalp & Martinez, 2021), as well as solved (but also created) several problems regarding employees' way of work and living (Primecz et al., 2016). Digital transformation can thus enhance the economy. It is anticipated that by 2030, more than 70% of new economic value creation would be related to digital platforms (World Economic Forum, 2023), while digital solutions can reduce global emissions by up to 20% by 2050 (World Economic Forum, n.d.). However, digital transformation means exceptional opportunities and significant risks at the same time. According to Bughin & Zeebroeck (2017), firms which do not or just partly respond to digital disruption are likely to experience a large decline in revenues and profits (Bumann & Peter, 2019). Numerous conventional businesses are rendered obsolete by the presence of newer and more innovative businesses (Verhoef et al., 2021).

The topic of digital transformation has been addressed by a decent number of researchers in recent decades (Fitzgerald et al., 2013; Stolterman & Fors, 2004; Westerman et al., 2011), but the occurrence of digital transformation as a term in the literature emerged significantly after 2014, according to a quantitative literature review conducted by Reis et al. (2018). Digital transformation is defined variously from many perspectives (Teichert, 2019). According to Schallmo et al. (2017), the term "digital transformation" has no widely acknowledged definition. The term "transformation" describes significant organizational changes that have an impact mainly on strategy and structure. Digital transformation can therefore be viewed as the process of adopting an ever-changing digital landscape in order to satisfy the digital expectations of consumers and producers (Teichert, 2019). McKinsey & Company (2016) also argued that the term "digital" refers less to a single process rather than how businesses operate.

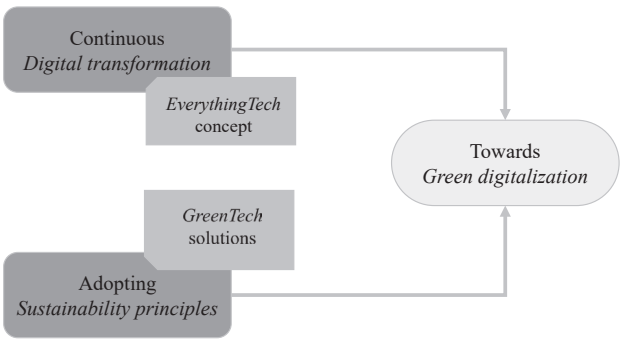
Gökalp and Martinez (2021) stated that digital transformation is described as the realization of disruptive technologies that introduce new business models and operations across all industries. Vial (2019, p. 118) through a quantitative literature review of 282 publications related to digital transformation, came across 23 different definitions, summarizing digital transformation as *"a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies"*. Although from this definition it can be assumed that digital transformation is organization-centric, in agreement with Legner et al. (2017), digital transformation can also be understood in a broader sense, such as by individuals and society. Thus, the consumer-centric digital transformation in our immediate environment and our daily lives is understandable. At the same time, from an organizational perspective, the question arises to what extent digital transformation serves real social interests, or is it just an organizational response driven by the constant growth constraint (Hidegh et al., 2014)? Digitalization must provide value for customers, the enterprise, and other key stakeholders (Schallmo et al., 2017). For an ordinary consumer, value is not necessarily created through radical innovation, but by meeting their expectations (Gelei & Kenesei, 2016), and according to Solis & Szymanski (2016), the transformation of technology and business models ultimately contributes to reaching digital consumers more effectively at any stage of their lifecycles.

The length and nature of digital transformation projects can vary depending on the age, size and type of the business and the industry in which it operates. According to Verhoef et al. (2021) and Kraus et al. (2021), digital transformation can take place in several phases, through affecting business processes, business models, the supply of products and services, organizational structures, or a combination of all these aspects. Although each may be powered by a different technology, the ultimate objective is the same: namely to keep up with the sectors' rapid shifts by utilizing new technical improvements to satisfy customers' demands for quick, smooth, and secure interactions (Dias et al., 2017). It is vital to stimulate the process through appropriate internal processes and by ensuring optimal conditions in the micro and macro environment of the given company to avoid being left behind (Bounfour, 2016). Consequently, digital transformation must be handled holistically since it has social, technical, technological, and management effects on enterprises (Gökalp & Martinez, 2021; McKinsey & Company, 2016; Verhoef et al., 2021).

It follows that digitalization can also be seen as embodying green oriented sustainability and vice versa. The ability to use digital technology to improve sustainability – known as green digitalization – is an essential tool to achieve a low-carbon or even carbon-neutral economy. However, it is important to be aware that digitalization is a two-sided sword as it is not always green. Although the energy consumption and wider adoption of new technologies – particularly in the ICT sector – is increasing in general, along with changes in user habits are often at odds with sustainability (e.g. replacing our electronic devices just to meet current trends and comply with new data protocols and transmission technologies), digitalization also makes production more efficient in many cases, thus sustainability could be measured in terms of replacing traditional systems. Demeter & Losonci (2020) pointed out that sustainability can be an angle to measure the impact of Industry 4.0, while sustainability is also an important aspect within the dimensions of Nick et al. (2023)'s Industry 4.0 maturity model. Ultimately, green digitalization has become one of the most important pathways toward attaining a sustainable future.

Figure 1

An approach to understanding the basis of green digitalization



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This paper proceeds, by presenting the methodological basis for a literature review, followed by introduction of the EverythingTech concept as a starting point with a focus on FinTech as its key pioneering element. This precedes a comprehensive comparison of digital transformation-specific themes and examples in various industries. Subsequently, when we discuss the conceptual approach of GreenTech, presenting its main characteristics and how it is interconnected to digital transformation. Lastly, we present the importance of green digitalization, the essen-

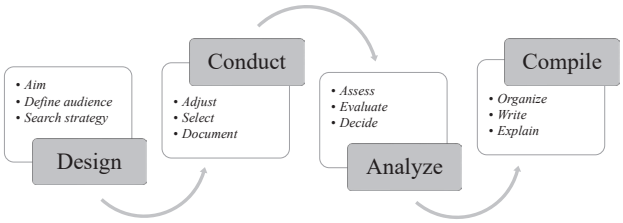
tial key in supporting energy transition in all industries, serving a sustainable solution for our economy, society, and our future. This approach could be summarized in Figure 1. This paper does not aim to analyze digital transformation or sustainability in detail, but rather the output of these processes and principles (the EverythingTech concept and GreenTech solutions) as well as their nexus.

Research Methodology

The process of conducting a literature review varies between the underlying approach and its goals (Booth et al., 2016; Wong et al., 2013), however, as Snyder (2019) points out, regardless of the chosen method, four main steps should be taken to fulfill the aim of a robust literature review process (Figure 2).

Figure 2

General guideline on what steps literature research should consist of



Source: own compilation based on Snyder (2019)

To identify relevant publications in this diversified topic, we conducted several systematic searches of literature databases such as Scopus, EBSCO, and ScienceDirect, as well as using the web search engine Google Scholar which forms an immense database due to its public form and contains many studies not only from indexed journals. Documents from relevant institutes such as statistical institutes, research and consulting firms were also included. Research tools encompassed horizon scanning of case studies and company reports as well as collecting available statistics. We did not define a start date, and the relevant language was set to either English or Hungarian. For each subtopic, we used partly different keywords ("Digital transformation", "EverythingTech", "FinTech", "GreenTech", and "Green digital*") and their Hungarian equivalents. When we filtered down the results, we also used combined search techniques ("AND") as well as predetermined focus areas (such as industry names in terms of the EverythingTech effect). Those publications were selected and incorporated into our paper which contributed to the broader understanding of each subtopic and not limited only to a specific aspect of the given subject. Therefore, literature exploring cause-and-effect relationships and discourse analyses formed the focus.

Our explorative research questions were set out as follows:

1. What are the practical manifestations of digital transformation among various industries?
2. Why is green technology playing an increasingly important role in sustainability goals, and what is the outlook of the segment?
3. How can digitalization facilitate green growth?

More than 60 research papers and studies were finally selected to support our work in answering research questions.

„EverythingTech" – the impact of a widespread technological development

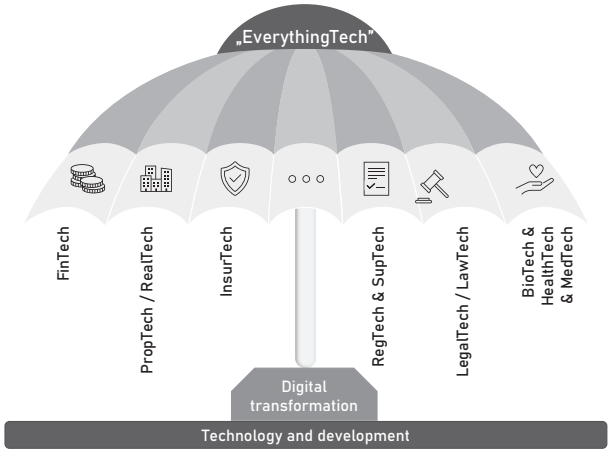
Digital transformation is based on continuous technological innovation, and therefore it is a never-ending process since in an ideal economic and social environment, there is no strict limit to technological development over time (Kraus et al., 2021). We are continuously moving further away on a smaller or larger scale from the leading technologies of the past while adapting new tools and technologies like mobile applications, automated manufacturing robots, artificial intelligence (AI) – such as VR technology, self-driving cars, automated decision-making, chatbots and digital assistants –, the Internet of Things (IoT) (e.g. smart home systems, wireless connectivity, biometric security access control) or cloud technology (e.g. SaaS services, virtual hosting) can support businesses taking a significant step towards their digital transformation.

Based on these and other innovative technologies, a transition has taken place in recent decades which is still in progress basically in all economic sectors. This is namely distinguishing traditional sectoral operating models from those which are continuously transformed by advanced technologies (Verhoef et al., 2021). This recognition of the latter indicates that the relevant business adds the term "tech" to the abbreviated name of its sector/field where it operates to demonstrate its active participation in the digital transformation (e.g. from a healthcare company to a "HealthTech" firm). From a certain point of view, it is a communication tool for social and economic players that the given organization is adopting some kind of digital transformation, and that by exploiting technological innovations it will theoretically be able to operate more economically, efficiently, and sustainably than its competitors (Beaumont, 2020). However, Beaumont also noted that there is – so far – no universally accepted measure of the indicator of how 'digital' a business model is. According to Hanelt et al. (2021), adopting digital technology solutions implies a move to a malleable organization model, where the impact varies on the level of acknowledgment and implementation. The digital maturity model tries to assess the stages of digital transformation impacting a given organization, how it reacts to digitalization purposes, and integrates the technology to achieve its goals and to respond to the digital competitive environment (Bumann & Peter, 2019; Haryanti et al., 2023; Ochoa-Urrego & Peña-Reyes, 2021). Haryanti et al. (2023) also compared dozens of existing maturity models to assess key interrelated dimensions for supporting the success of digital transformation, which could be served as one maturity measurement framework.

Figure 3 shows the most representative sectors in the digital transformation, without claiming completeness. These "end products" of digital transformation are also collectively referred to as "EverythingTech".

Figure 3

The EverythingTech phenomenon in various industries



Source: own compilation

The pioneer of this trend is FinTech, which is short for Financial Technology, a broad term that encompasses the creation, development and delivery of financial products and services to customers based on innovative technologies and digital solutions (Das, 2019; Schueffel, 2017). Suryono et al. (2020) and Barroso & Laborda (2022) classified the current challenges, trends, and regulations of FinTech based on their systematic literature review, mapping all relevant articles, while Siddiqui & Rivera (2022) gathered mainly the attributes, components, and benefits of FinTech in a similar manner. FinTech is used for many things these days at the intersection of finance and technology, which pushes the boundaries of the definition itself. The basis for the development of FinTech was essentially the emergence of the internet, and as the infrastructures (servers and networks) were continuously built, the available technology expanded (aforementioned AI, cloud, blockchain, big data, cybersecurity) and as financial service providers recognized and started to adopt various combinations of FinTech innovations, the number of FinTech solutions (e.g. mobile payments, digital wallets, community finance and trading platforms, robo-advisors, etc.) also increased (Pintér & Bagó, 2020). These solutions can achieve similar goals, but in different ways: to make the financial sector safer, faster, and more efficient, while meeting the needs of a new generation of consumers. With the emergence of FinTech, businesses have easier access to funds and other financial services, while cloud-based platforms and customer relationship management services help them to run their day-to-day business efficiently (Scardovi, 2017). Notwithstanding, these financial solutions are not only important for the corporate sector but also for the consumer society. Specifically, those who were born in the 2000s – the so-called "Generation Z" –, practically were raised in the world of digital technologies, a much higher proportion can be observed who use average Fintech solutions than those, who are in an older generation (Pintér et al., 2021).

Many FinTech studies (Arha & Jufri, 2020; Jutla & Sundararajan, 2016; Lee & Shin, 2018; Varga, 2017) explored the FinTech value drivers, ecosystem, and its elements, while Csepy & Aranyossy (2019) were focusing on the customer value creation power in the financial services industry. Although Phat Pham et al. (2021) categorized FinTech as "bank FinTech" (traditional financial institutions utilizing financial technologies) and as "FinTech-outside" (non-financial institutes using technology to provide financial services) – which viewpoint and sector-specific analysis also assessed by other authors (Gyüre, 2020; Horváth, 2019, 2020; Kerényi & Molnár, 2017) –, it can be concluded that the definition of FinTech is very versatile and can be approached from many sides. Another relevant angle is the importance of FinTech solutions in the field of green finance (MNB, 2022; Horvath, 2022), which can contribute to the aim of green financing and broadly, to GreenTech solutions – supporting green objectives and investments.

Overall, FinTech solutions have revolutionized many different markets, most notably the banking, retail, and insurance sectors. Yet the digital transformation and underlying hardware and software assets also impacted various other main industries by replacing traditional business models, such as the real estate ("PropTech"), education ("EdTech"), or healthcare ("MedTech") segments among others (Table 1).

This overview leads to the conclusion that while different technological solutions are implemented and further developed in each sector and industry under the EverythingTech concept, they are all based on the same foundations and serve similar aims, while each aspect (regulation, customer centricity, accessibility, etc.) must meet sector-specific requirements (Beaumont, 2020). As a result, some characteristics are the same in all cases, regardless of the sector classification:

- customer / consumer-centric approach,
- cost minimalization and revenue maximization,
- complex, value-added service 'bundle' delivery,
- innovative solutions to replace traditional business models,
- enhances big-data analyses based on huge databases,
- serves the needs of high levels of availability, flexibility, and customization.

However, not all technological developments are related to a specific segment of an industry. There are comprehensive solutions, which have the same goals among all "EverythingTech areas", regardless of the impacted circle of society or businesses: to achieve a green and sustainable way of living and operating – and that relates to the importance of adopting GreenTech solutions in all terms.

Table 1

Examples of EverythingTech solutions by selected sectors

Term	Sector / Segment	Short description and examples
PropTech (Property + Technology)	Real estate segment	PropTech at its heart comprehensively encompasses real estate software solutions for residential and commercial purposes. The digital transformation has impacted all parts of its value chain and phases of the asset lifecycle, such as portfolio management, real estate market analytics, real estate brokerage platforms, or real estate design, construction, and management software (e.g. BIM, CAD), including virtual and augmented reality-based visual world displays, as well as the use of smart home applications and other IoT tools (Maududy & Gamal, 2019; Siniak et al., 2020).
InsurTech (Insurance + Technology)	Insurance sector	InsurTech is often considered a branch of FinTech. In the insurance market, innovations through new technologies can affect both insurance practices and the regulatory environment. As per the former, technological achievements in risk analysis and assessment, as well as more efficient and comprehensive data analysis contribute to the combination of services that could make potential consumers more accessible, while customizable insurance packages can provide a wider range of coverage for their assets. Furthermore, the role of "big-data" analysis, virtual data warehouses and agents, and chat-bots are prominent in this segment (OECD, 2017; VanderLinden et al., 2018).
MedTech (Medical + Technology)	Healthcare sector	Thanks to continuous innovations in healthcare (robot technology, modern diagnostic tools, digital data systems, etc.), more and more effective solutions are available at all stages of patient care and health preservation, starting from disease prevention (health assessment tools, modern vaccines) to diagnosis and monitoring (high- tech technical devices, such as CT and MR machines) to more effective treatments and more precise surgical interventions provided by devices equipped with artificial intelligence (EY, 2019; MedTech Europe, 2020).
LegalTech (Legal + Technology)	Legal segment	At first, the digital transformation affecting the legal sector meant only the digitization and automation of legal administrative processes, but over time, new solutions also helped the evaluation and review of certain legal cases and contracts (e.g. smart contracts, predictive artificial intelligence), which could speed up, increase efficient and simpler the legal services, while significant cost reductions can also be realized (Salmerón-Manzano, 2021).
EdTech (Education + Technology)	Educational segment	Digital transformation has also transformed the education system, from educational methodology to the learning and examination processes, which affects all actors in the field (parents, teachers, and students) (Moro et al., 2023). The accessibility of technology (e.g. laptops for all students, free mobile internet network, modern wall boards), digital libraries and databases, computer-driven learning (educational platforms, skills development programs), distance teaching, and online examinations have all been the result of technological innovation and social adaptation (Weller, 2018).
RetailTech (Retail + Technology)	Retail segment	From a consumer point of view, the commercial sector has been one of the most visibly affected by digital transformation. Whereas previously only physical stores existed, traditional retailers have gradually strengthened their online presence as technology has evolved, to the point that there are now companies whose product range is only available through a virtual store (webshop). This kind of digital transformation has two main aspects (which are valid for other EverythingTech segments as well): cost reduction and revenue enhancement solutions, focusing on the potential customer and its experience (Beaumont, 2020; Valdez Cervantes & Franco, 2020). At the same time, (Linzbach et al., 2019) argue that the great challenge for the retail sector will be to find the right balance between the traditional type of retail system and the adaptation of new technologies, while the focus will always be on meeting the needs of customers.
FoodTech (Food + Technology)	Food industry	The massive population growth of the past century, as well as the changing shopping and consumption habits, mean continuous challenges to the food industry. Concerning food production to be able to keep up with the population explosion and to ensure the security of supply, as well as various preservatives, sugars, plastics, and chemicals in production, preservation, and during packaging to take a back seat, not to mention the need for more efficient waste management, continuous technological innovations are required (Valoppi et al., 2021). Modern food technology and digital solutions seek to solve some of these problems. The scope of FoodTech, therefore, includes practically all technologies and processes that improve food production, distribution and supply (supply-side), while influencing people's consumption habits (demand-side) (Renda, 2019).

Source: own compilation

GreenTech – Aspect of technological developments in a green context

Sustainability is a term currently much in vogue, however it is conceptually very complex and multidimensional in that there are multiple ways to live sustainably and "green". Using sustainable methods to protect the environment, natural resources, biodiversity, and habitats is known as "becoming green" as a way of life.

According to Purvis et al. (2019), it is widely accepted that society, environment, and economy are the three main pillars of sustainability, which interact with each other on different levels. As our planet's population is continually expanding – already exceeded 8 billion people in 2023 according to the World Population Clock –, the economy must keep up with the increasing demand from society, while the economic system also influences our social structure, thus the two dimensions have a mutual

connection. However, that's not the direct case with the environment pillar. The environment can't meet demands from the other two pillars in isolation, thereby inferring an overall responsibility for society to adopt greener lifestyles (Montt et al., 2018).

How can this be achieved or at least how can our way of living and doing the business move in that direction? The solution is bilateral as both demand-side and supply-side adjustments are needed. Demand-side influence relates to how we use the energy system and appliances every day, questioning whether are we properly energy efficient and savers (regardless of focusing on how we live at home or use our vehicle) as well as having self-awareness regarding our energy consumption is provided from cleaner and renewable production – which is not that easy question when on the other hand, our usual well-being could be at risk at a short-term (Creutzig et al., 2022). It is also important to acknowledge those businesses which declare a responsibility for achieving a neutral carbon impact via their operating models. This latter aspect leads to the fact that as the public's interests in the social, ethical, and environmental impact of business activities increase, companies are taking on more responsibility (Khan et al., 2021; Nave & Ferreira, 2019).

As a result – and turning the coin to the supply side of the subject, focusing on the micro-environment –, nowadays many businesses make their sustainable development efforts and fulfillment of related legal obligations mandatorily publicly available, or even voluntarily to raise society's awareness of it (Zhang et al., 2022). It can also be a matter of prestige for companies to move in a greener direction so that their products, processes, and investment decisions serve environmental, sustainability, and social goals at the same time (utilizing green marketing and impact investing) (Durmaz & Yaşar, 2016). These goals are summarized in their environmental, social, and governance (ESG) guidelines and corporate social responsibility (CSR) (Grim & Berkowitz, 2020).

At a macro level, decisions of authorities and legal institutes – both in regional and national aspects, for example, EU directives and packages or Hungarian's National Energy Strategy 2030 – oblige companies to comply with the requirements of lowering the greenhouse gas emissions of their operations, increasing the usage of renewable energy sources at sites and reducing the level of waste production (Ministry of National Development, 2012). Altogether, these aims can mostly be achieved if companies are adopting greener technologies through their full value chain, which leads to the importance of the transition to GreenTech solutions.

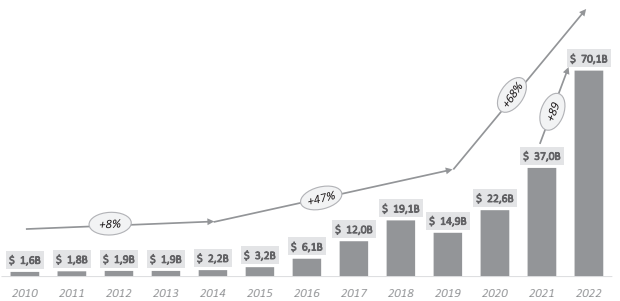
GreenTech (also known as "CleanTech") refers to any manufacturing production technology that can be regarded as environmentally friendly or sustainable, either in its production process or in its finished product (Hoff, 2012; Qamar et al., 2020). According to Christensen et al. (2011), green technologies are those that use fewer resources to create value than conventional alternatives, while Marra et al. (2017) suggest that the concept also relates to lower air pollution emissions as well as the production of energy decisively from sustainable, renewable sources. The term GreenTech is also known as EnvironmentalTech, CleanTech, or ClimateTech – however, this latter one relates to green technology solutions focusing on solving the climate crisis via adopting innovations used in reducing greenhouse gas emissions in any industry (PwC, 2022).

With the goals of assuring sustainability, protecting the environment, healing environmental harm, and conserving the Earth's natural resources, green technology solutions span a wide spectrum of scientific studies, such as energy, atmospheric science, agriculture, and hydrology (Hoff, 2012). Examples of real-world applications are low-carbon technologies, fuel cells, LED lighting, passive houses, electric vehicles, smart meters, and smart grids as well as most of the available digital solutions.

Emergence of the sector is visible from the volume and amount of investment and acquisitions, project finance and public grants, especially since 2020 (Figure 4.). These funding were mostly related to scalable GreenTech startups and clean energy technologies addressing global climate change. According to the ClimateTech report of HolinIQ, 2022 was an outstanding year of investment growth in absolute terms (+$33,1 billion), but also proportionally (+89%) compared to 2021. Most of this was related to storage capacity ($18,4 billion), electromobility ($11,4 billion), and GreenTech solutions in the AgroTech segment ($9,5 billion). As per the regional view, most of the investments occurred in the USA in the last years, but China and Europe follow closely (HolonIQ, 2023).

Figure 4

Global ClimateTech Venture Capital Funding, 2010–2022 (in USD billion)

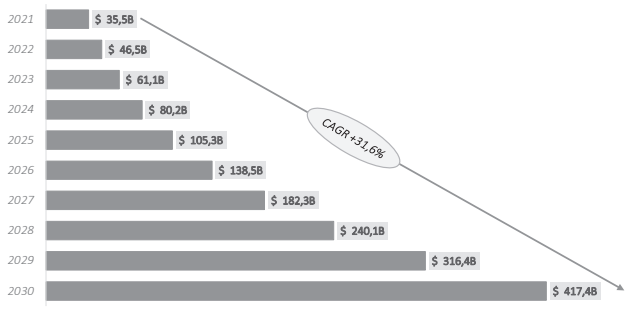


Source: own compilation based on HolonIQ (2023)

According to another worldwide market research and consulting organization, Precedence Research, several factors such as growing awareness regarding the environment, global warming concerns, policymaking with a green focus, lower cost of production, etc. are boosting expansion of the global green technology and sustainability market (Precedence Research, 2022). Although based on their database they calculated a lower market size in value for 2022 compared to the previously mentioned research institute, and used a different methodological approach, the organization expects the GreenTech market to exceed $ 400 billion market size by 2030 (Figure 5). This would result in a compound annual growth rate (CAGR) of 31,6% between 2021 and 2030.

Figure 5

GreenTech and sustainability market size, 2021–2030 (in USD billion)



Source: own compilation based on Precedence Research (2022)

Precedent Research also notes that the largest market currently in North America, however, Europe shall have the fastest growing rate of all territories, out of which the UK shall dominate the market. They also highlight the importance of the AgroTech market as well as the green buildings segment, which contributed the most in the recent year to the general market growth.

Both research institutes emphasize that the market for green technology and sustainability is expected to develop as a result of favorable government policies and regulations. Noh (2018) and Xia et al. (2021) also stated that besides the promotion of internal objectives that create higher corporate value and thus investment potential due to growing social and investor awareness, green technology transition in the corporate sphere can be facilitated by an appropriate external regulatory environment.

The EU's Renewable Energy Directive (RED), adopted in April 2009, provides a legal framework for the development of renewable energy in all EU sectors, setting out common principles and rules to remove barriers to entry, encourage investment and reduce the cost of producing renewable energy technologies. The Directive has been revised several times in terms of the targets to be achieved, with the European Commission increasing the target for the share of renewable energy in gross final energy consumption from 32% in current plans to 38-40% in 2030 (European Parliament, 2022).

The Paris Agreement, adopted in December 2015 and formally ratified in November 2016, was a milestone in climate policy – a treaty involving 194 countries that have put international cooperation on climate change on a new footing. The parties set concrete, quantitative targets, with universal commitments for developed and developing countries alike: the ultimate goal is to limit the global average annual temperature increase to no more than 2°C above pre-industrial levels and to limit global mean warming to 1.5°C in the optimum case. In addition, each country is required to submit so-called nationally determined contributions as action plans every five years, outlining its emission reduction status, which shall be kept under review (United Nations Climate Change, n.d.). Furthermore, the European Green Deal (EGD), proposed in December 2019, aims to make Europe the first climate-neutral continent by 2050 by developing a roadmap to a sustainable economic model. It is therefore in effect a commitment by the EU to meet the goals of the Paris Agreement, notably by making the 27-nation European Union carbon neutral in less than 30 years (European Commission, n.d.). This is an essential moment for all the actors to change their business models and practices in accordance with the obligations and aims, which also resulted in the increase of various available funding and investment potential from 2016 and 2019 again – as presented in Figure 4, serving as partly an explanation to the higher growth rates.

Ultimately, without GreenTech assets and services, these impressive goals could not be achieved, and digital solutions are part of the GreenTech elements. Green digitalization provides great opportunities in improving sustainability in various ways, however, sometimes it comes with a price, for which a general solution has yet to be found. The next chapter is focusing on the green and digital twin transition.

Green digitalization – digital solutions for a greener world

Green digitalization is assuming an increasing focus of research due to its growing importance in combatting negative aspects of climate change. Besides known management consulting firms dealing with the subject (Deloitte, 2019; EY, 2020; PwC, 2022), a decent number of researchers are assessing the digital sustainability phenomenon in different aspects. Wang et al. (2023) found a positive relationship between enterprise digitalization and green innovation, while Li et al. (2023) concluded that digital financial inclusion positively correlates to green innovations. Berger et al. (2021). George et al. (2021), Gregori & Holzmann (2020), and Di Vaio et al. (2020) centered the entrepreneurship, business models, and ecosystems in this matter, while Saberi et al. (2019) and Adams et al. (2018) examined the role of blockchain solutions in value creation, Camaréna (2020) and Frank (2021) measured the importance of AI in this manner, and Shaharudin et al. (2019) focused on the low carbon supply chain management in this aspect. Brenner & Hartl (2021) addressed the interrelationship between digitalization and three dimensions of sustainability – ecological, economic, and social.

Digital technologies may present a solution as well as the risk of adopting greener production methods. Dematerialization of physical operations and the use of digital assets such as cloud, IoT, blockchain, AI, and big data, environmental objectives could be rendered achievable by saving costs and time. Digital solutions are essential for understanding our environment and monitoring the impact we have on it since with technology, we can analyze and simulate real-world events, such as optimizing resource use, waste management, and emissions, utilizing smart meters and appliances, or operating a virtual power plant within an energy community (Muench et al., 2022).

Green digitalization has been explored and examined in various areas: sustainability in small and medium-sized

enterprises (Isensee et al., 2020), IoT-based smart systems (Alam et al., 2017), circular economy (Pagoropoulos et al., 2017) or quality management aspects (Carnerud et al., 2020). The extent of green FinTech solutions (e.g. smart contracts, digital payments, crowdfunding platforms) and green financing (e.g. green bonds and funds, energy efficiency loans, and grants) also stimulate and contribute to the matter. However, on the other hand, digital tools use electricity ("rebound effect" of digital hunger), and many digital technologies are resource-intensive (especially blockchain networks via mining) and produce electronic waste as well (EY, 2020).

Green and digital transformation should be supported with proactive and integrated management to be successful. Due to its enormous economic potential, the private sector will primarily lead the shift to digital technology. State and civil society involvement will be required to maximize its positive effects on environmental sustainability and minimize its negative effects.

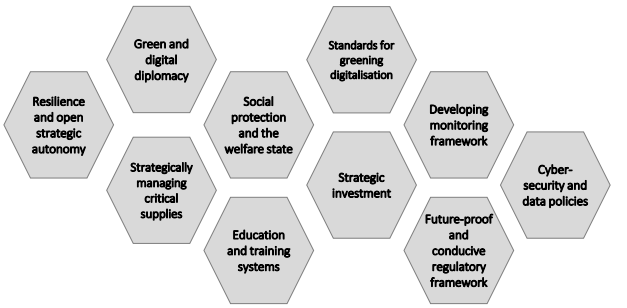
The importance of green digitalization was recognized and reflected in European Commission's (EC) recently adopted 2022 Strategic Foresight Report which draws attention to the green and digital transition in a new geopolitical environment. The aim is to accelerate dual transition to green and digital dimensions, particularly in areas where negative contributions to the climate crisis are the highest, namely in energy, transport, industry, buildings, and agriculture. The report discusses various digital technologies which could support the case, outlined as follows (European Commission, 2022):

- Within the energy sector, upgrading smart grid systems with new sensors, satellite data and blockchain to facilitate the management of weather-dependent power plants. Also, the energy-as-a-service concept could transform the usual supplier and consumer business model into a more favorable and efficient, two-sided cooperation.
- In the transportation sector, a major shift towards sustainability is related to the new generation of batteries and the electrification of various modes of transport, from public transportation to commercial aircraft. Furthermore, artificial intelligence and IoT solutions could lead to data-driven smart mobility, even to fully self-driving vehicles.
- Another very important aspect is improving the energy efficiency of residential and commercial buildings. According to the statistics, 40% of total energy consumption in the EU relates to buildings and infrastructure. The solution is twofold: to build new and efficient smart homes and real estate in parallel with proper retrofitting of existing, older ones. By applying smart meters and digital logbooks to monitor and optimize consumption and system usage as well as integrating solar panels, HVAC heat-pumps, and vehicle-to-grid solutions, an average consumer can effectively contribute to our climate goals meanwhile can have an interest in the smart grid system and energy market if acting as a small household/commercial power plant.
- Finally, the report discusses the importance of smarter and greener agriculture. As mentioned in the EverythingTech section, various smart sensors and data-driven selection of alternative resources to eliminate the amount of water, fertilizers, and other artificial materials could be a benefit to both human and animal environments. Besides smart farming, limiting food waste and securing biodiversity are also long-term goals of the segment.

To achieve improvements in these and other segments as well, EC urges the adoption of appropriate policies with reconsidered solutions and key steps. Figure 6 sets out the 10 key areas for action to effectively exploit the synergies and ensure coherence between the climate and digital objectives. Thereupon, the EU will strengthen its resilience and aims to be better prepared for unexpected global and regional challenges.

Figure 6

Key areas for action to support green digitalization



Source: adopted from European Commission (2022)

The European Commission has as such aptly highlighted the importance and necessity of using GreenTech and sustainable digital solutions in various areas to achieve a successful green transition to a carbon-neutral economy. Recent events and the current geopolitical instability confirm the need not only to accelerate the green and digital transition but also to increase national strategic interest by reducing dependencies in supply chains and securing access to critical raw materials.

Conclusion

Immense economic pressure has emerged in terms of seizing the opportunities offered by digitalization to remain competitive. Sustainability in turn has instigated public pressure for businesses to take stronger actions in this regard, hence the intersection of sustainability and digitalization has particularly key importance.

However, digital transformation presents a conundrum consisting of opportunities and deleterious effects. On one hand, it increases our energy consumption through the high digital hunger it creates, but it can also be the solution if it is properly managed in a green way, transforming not just physical to virtual, but business models and processes as well as societies' way of being, which contributes to the

ultimate goal, to progress sustainable development. It has a wide range of tools that can foster green innovations, optimize resources, maximize energy efficiency, and track sustainability progress.

Digitalization is as such key to leading to energy transition in different industries, while in a broader sense, the tech industry has the advantage to drive society's transition to a green and digital future. GreenTech is a crucial component of the future because by implementing such innovations businesses and individuals can contribute to alleviating adverse climatic change and providing humanity with the chance to build a sustainable planet for future generations.

Our study emphasizes a strong understanding that GreenTech can optimize the basis of any industry, but the support of regional and national legal institutes is essential to provide an adequate framework for continuous transformation. Crucially, the regulatory environment is treating the green and digital transition in a prominently favorable manner. As a result, acceleration of the expansion of digital transformation and the role of GreenTech solutions within it should assume much greater prominence in the near future.

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