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STUDY

GreenTech Made in Germany

Is Germany on the Right Path to Becoming a GreenTech Export Nation?

JULY 2022

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Preface

Setting the course for the future

The public perception of sustainability has shifted several times over the past few decades. In general, sustainability is understood to encompass **environmental**, **economic**, and **social aspects**.

During the years of the post-war economic boom and into the 21st century, economics was the dominant focus. Prosperity for all was the motto at the time. As far back as 1978[1], Professor Hoimar von Ditfurth was telling of the consequences facing the environment and climate on popular television. However, it was not until 1992 at the Earth Summit in Rio de Janeiro, the forerunner of the UN Climate Change Conferences and the UN Framework Convention on Climate Change, which came into force in 1994, that the potential consequences and counter measures were discussed at a political level. At the turn of the 21st century, the environmental perspective came to the forefront in the eyes of the public, which led to political agreements – or rather, in hindsight, to statements of intent – to counter the threat of climate change. The war of aggression against Ukraine on February 24, 2022 brought the social perspective quickly and dramatically into the spotlight. Peace in Europe, perceived as a matter of course, was swept away; the desire for freedom, security of supply, prosperity, and social justice pushed the other dimensions into the background.

It is important to acknowledge these shifts, as we can only create a successful future that is suitable for future generations if all three principles of the **magic triangle of sustainability** are balanced: economic, environmental, and social.

Achieving this balance does not mean that we have to make sacrifices, and historically this is neither desirable nor sufficiently enforceable. Offering rather than banning is traditionally a more successful approach for the human mindset. In addition to offers of long-term **systemic and behavioral changes** for people and companies, the appropriate use of technology also offers significant promise for a balanced triangle. It is a question of using tech to help with the transition away from fossil fuels and to manage the environment and resources.

These technologies are known as **GreenTech** and are used in energy production, its management and distribution, and the consumption and conservation of resources. They also open up opportunities for wealthier, industrialized nations to move their **Earth Overshoot Day** from the first half of the year to the end of the year[2].

Although Germany directly contributes "only" 2 per cent of global CO_2e emissions[3], it continues to serve as an example for many nations striving for prosperity. And if Germany or Europe manages to achieve **prosperity without compromising sustainability**, then there is nothing to stop these countries following its lead. This, in turn, offers new economic opportunities for us. This study will investigate whether Germany is on the right path to taking a pioneering role in the field of sustainability and to becoming a lead exporter of GreenTech.

I hope you gain extensive knowledge and wish you every success on this journey
– for increased sustainability, for a better future.

Dr. Oliver Kelkar
Associated Partner, Head of Market Intelligence and Innovation, MHP

[1] Hoimar von Ditfurth, Querschnitt – Der Ast auf dem wir sitzen (Cross Section – The Branch on Which We Sit), two-part broadcast on ZDF, 1978.
[2] On July 28, 2022, humanity will have used up all of the natural resources that the Earth can regenerate within a year and thus make available to us on a sustainable basis. Germany's individual Earth Overshoot Day is May 4, 2022.
[3] Note: Indirect emissions that arise along supply chains are many times higher.

Executive Summary

DO IT

The label "**GreenTech**" encompasses technologies that help us to contribute toward our sustainability goals, placing this concept at the interface between technology and sustainability. From a global perspective, technologies such as hydrogen, solar technology, wind power, or artificial intelligence are often developed in conjunction with the **United Nations Sustainable Development Goals (SDGs)**. GreenTech technologies such as these are recognized as having great growth potential and thus a significant impact on the prosperity of a country and the labor market.

Due to the claimed impacts of GreenTech, the topic is also highly relevant for the new **German Federal Government**. The strategy of the new Federal Government is closely integrated with European and global initiatives, such as the **Paris Agreement**, the **European Green Deal** and the recent **Climate Change Conference in Glasgow** (COP26). GreenTech plays an essential role in the fight **against climate change**. The new coalition is therefore relying on the impact of technology on sustainability and the associated significant economic growth that comes with a strong GreenTech strategy. These concepts are just as important for the **German domestic market** as they are for **exports**.

The **action of the Federal Government** is influenced by the **coalition agreement**. This study therefore draws upon the coalition agreement and analyzes the goals and strategies that have already been defined with regard to GreenTech for Germany. Specifically, the question arises as to whether the new Federal Government's strategy is sufficient to successfully position Germany as an internationally competitive GreenTech export nation.

In this sense, the definition of the term GreenTech and the **role of digital technologies** in the implementation of GreenTech are relevant to this study. As well as looking at GreenTech as a concept, the environmental, economic, and social impacts of GreenTech are summarized in the form of a reference model. This model describes the levers from a political and business point of view to successfully position GreenTech – Made in Germany as a key competitor on an international scale.

From a methodological standpoint, this study is based on a multi-stage approach. On the basis of existing literature from other studies, scientific publications such as working papers, and web pages on the topic of GreenTech, a detailed **meta-analysis of existing studies, scientific publications, reports, and web pages has been compiled**.

Like many of the latest buzzwords, the term GreenTech does not have an exact definition. In general, the label "GreenTech" encompasses a whole range of technologies that help us to contribute toward our sustainability goals, placing this concept at the **interface between technology and sustainability**. GreenTech is discussed in different ways from different perspectives. Depending on the approach, digital technologies are understood to be either cross-sectional technology, enablers, or independent divisions for GreenTech. There are also uncertainties with regard to the environmental, economic, and social effects of GreenTech.

The blurred concept and vague definition of the technologies and effects of GreenTech make it difficult to offer an effective evaluation of the political agenda for Germany as a business location. This **meta-analysis** therefore serves as a **reference framework** for assessing Germany's position as a business location.

The reference model can be divided into three sections: **concept**, **impact**, and **growth**. The concept section deals with the definition of GreenTech, essential technologies, and the relationship between climate transformation and digital transformation. The impact section summarizes the current state of research with regard to the environmental, economic, and social effects of GreenTech. Finally, the growth section addresses the political and industrial targets and measures for promoting the effects of GreenTech.

Deriving from this, a subsequent **evaluation of the coalition agreement** leads to the following conclusion: In general, the coalition agreement contains many targets and measures that can be classified in the reference model. However, the concept of GreenTech itself is not addressed within the coalition agreement. The link between **climate change and technology** is not awarded enough significance, given that it is of central importance for the transformation toward a socio-ecological market economy. **Environmental effects**, **economic growth**, and **social equity** should be established almost simultaneously. The interaction of these dimensions needs to be made clearer and substantiated in the form of a master plan.

A comparable finding applies to the topic of digitalization. The coalition agreement does address the key areas of digitalization. However, given the importance of digital technologies in transforming the economy and society, **a greater emphasis on the importance of digital technologies** for growth and for achieving environmental goals is desirable. The approaches outlined above with regard to **bundling the competencies of the Federal Government** and the promotion of key information technologies should be highlighted positively. Unfortunately, the connection between digital transformation, climate change, and GreenTech is not addressed thoroughly enough.

From an environmental point of view, the new Federal Government highlights the targets and **measures in place for tackling climate change**. These are urgently needed against the backdrop of the Paris Agreement targets and the European Green Deal. The individual building blocks of the coalition agreement have been set appropriately. Overall, the economic and social effects of GreenTech are not sufficiently addressed and the statements on these effects generally remain superficial. In particular, the interaction between the three sustainability dimensions is not adequately addressed.

In the discussion on growth strategies, the new Federal Government focuses on the **sectors of mobility and energy**, as well as promoting start-ups. The targets and measures outlined in these areas are very well formulated and clearly defined, meaning that the coalition agreement provides a good basis for further implementation. The Federal Government's strong focus on promoting start-ups and the plans to simplify access to risk capital should be highlighted in a particularly positive way. However, the statements in the coalition agreement regarding the promotion and transformation of small and medium-sized enterprises are much weaker.

What's more, the coalition agreement remarkably offers **relatively little content** in relation to other sectors such as **industry**, **agriculture**, and the **building sector**. The focus clearly lies on the energy transition, the expansion of renewable energies, the design of energy networks, and the sectoral adaptation of the automotive industry. Measures in the areas of energy and resource conservation or the circular economy, as well as corresponding implementation in the other sectors of the economy, are weak.

A **survey of 40 experts from politics and business** will be presented as the final phase of this study. The methodology follows an exploratory research design. Data was collected from individual interviews conducted either online as video conferences or by telephone. The results of the expert survey support the reference model. The experts consistently described digital technologies as a **key success factor** for GreenTech. Digital technologies are fundamental to GreenTech. They enable data analysis, create transparency, control systems, and create networks. Some experts even view digital technology as the heart of GreenTech.

Overall, it can be said that the respondents generally attribute a **high environmental potential** to GreenTech technologies and identify a large number of climate-friendly effects. However, most experts consider it to be very difficult to **quantify this environmental potential** at this point in time.

50%

of the experts surveyed expect this growth to be as a result of green technologies

The economic effects cited by the experts are primarily **positive growth effects**. Almost 50 per cent of the experts surveyed expect this growth to be as a result of green technologies, which falls in line with the **general growth momentum** of the GreenTech industry. The experts expect to see dynamic growth rates in the coming years and predict that GreenTech's share of German gross domestic product will increase in the short, medium, and long term. The economic growth of the GreenTech sector has a **positive effect on the labor market**.

In addition to their general evaluation of the economic effects, the experts were asked to rank a number of sectors according to the scale of their economic growth effects through GreenTech and their practical implementation potential by 2030. These sectors were: **industry**, **transport**, **buildings**, **energy**, **agriculture**, and **waste management**. The experts surveyed expect to see the greatest transformation from GreenTech in the energy and transport sectors, followed by industry and, to some extent, by buildings and agriculture.

With regard to evaluating the political agenda of the new Federal Government, the respondents approved of the targets and measures put in place to **promote GreenTech**. In total, almost **60 per cent of the respondents** rated the Federal Government's targets and measures as fundamentally suitable for promoting GreenTech. However, at the same time it is noted that the implementation of specific measures is still outstanding or has potential for expansion. The majority of respondents consider the targets and measures for **promoting the substitution of fossil fuels as primary energy sources** to still be **far from sufficient**. The targets set out in the coalition agreement are viewed positively, but concrete measures are only just beginning to be identified. Currently, the government's efforts to promote the **transition to a circular economy** seem to be the least noticed. However, the experts surveyed did believe that targets and measures to **position Germany as an export nation** are clearly recognizable. Almost half (43 per cent) of the respondents could identify the targets and measures, although the targets were more present than the measures.

Finally, the experts were asked about the **key success factors** needed to promote GreenTech by 2030. Most experts identified key success factors, particularly in the **areas of finance and funding**, **policy frameworks**, and **research and development**. The majority of the respondents see the finance and funding of GreenTech as a central design element. The experts hope that policies will include reliable and ambitious goals and framework conditions. The focus is on predictability through a long-term, stable, and calculated political strategy. The **reduction of red tape** is also mentioned as a success factor. As in the field of funding and financing, the experts call for faster decisions. In addition, the experts attached great importance to the major goals that are necessary to drive innovation. The European Green Deal was cited as a good example that helps to achieve a common goal. This is also important to achieve long-term goals. Private and industrial investment decisions in particular need a **clearly defined environment** and thus a clearly defined strategy. This is not only due to political factors and the Federal Government, but also to individual companies that want to position themselves in the field of GreenTech.

However, without the right partners on board, it is difficult to achieve ambitious goals. The experts rely on **players networking with one another** as it is no longer enough to simply be inventive. A common understanding and international partners are needed to enable Germany to compete in the international market. Internationally functioning value chains and models have long been indispensable for success.

In order to combat pollution and the wasteful use of resources, the experts see a need to **control and put a price on resource consumption**. CO_2 pricing with reliable growth

10 Recommendations for Action

RFA 1 Technology as a key factor in tackling the climate crisis

RFA 2 Digital transparency as a prerequisite for a circular economy

RFA 3 Vision and master plan for sustainable implementation

RFA 4 Interaction of the three sustainability dimensions

RFA 5 Increased momentum in the implementation phase

RFA 6 Focus on digital business models

RFA 7 Technology alone is not enough

RFA 8 Simple financing models for start-ups and SMEs

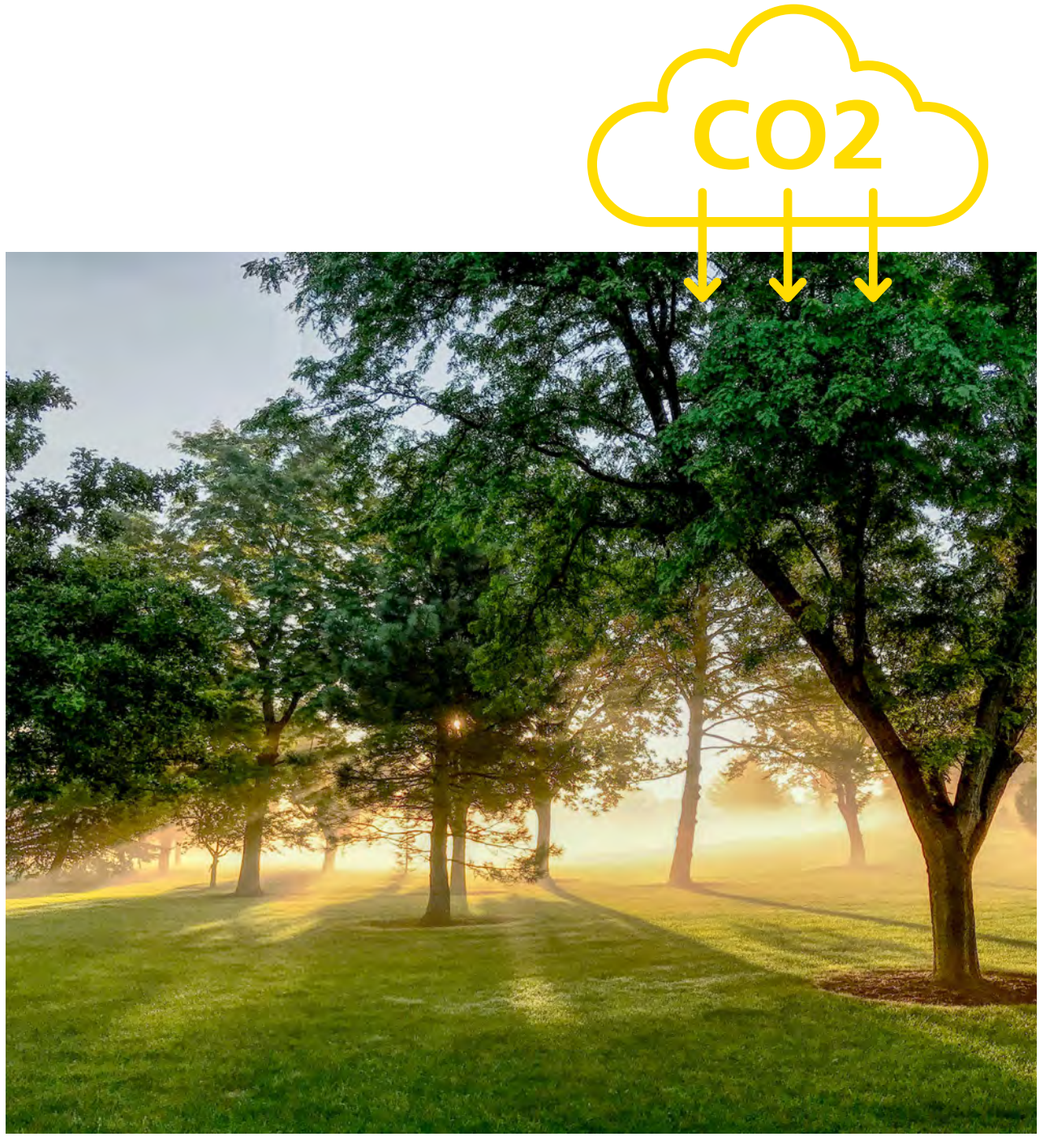
RFA 9 Review and adjustment of regulatory framework conditions

RFA 10 Specific measurement of sustainability effects

rates is seen as a suitable instrument for this. The carbon footprint of products and companies should also be included in company reporting alongside all of the financial factors, as the environmental impact is just as important as the generated turnover.

Finally, **ten recommendations** for action can be derived from the reference model, the analysis of the coalition agreement, and the expert survey. These recommendations are fundamentally relevant to the successful further development of GreenTech:

Although the **ten recommendations for action** presented above have been derived from the analysis of the reference model, coalition agreement, and expert survey, the set priorities should not be considered final. From reading the individual results, a large number of further recommendations can be defined that are relevant for politics and business. This demonstrates how the further development of GreenTech is characterized by a high degree of complexity. The density of the relevant design parameters is high. Reference models are an essential tool for presenting complex systems in a simplified way. In this way, further opportunities for sustainable development can be derived from the GreenTech reference model and the results of the meta-analysis and expert survey.



About the GreenTech Study

1.1

The problem

The label "**GreenTech**" generally encompasses technologies that help us to contribute toward our sustainability goals, placing this concept at the interface between technology and sustainability. From a global perspective, technologies such as hydrogen, solar technology, wind power, or artificial intelligence are often developed in conjunction with the **United Nations Sustainable Development Goals** (SDGs). GreenTech technologies such as these are recognized as having great growth potential and thus a significant impact on the prosperity of a country and the labor market.

Due to the claimed impacts of GreenTech concepts, the topic is highly relevant for the **new German Federal Government**. GreenTech plays an essential role in the fight against **climate change**. The new coalition is therefore relying on the impact of technology on sustainability and the associated significant economic growth that comes with a strong GreenTech strategy. These concepts are just as important for the **German domestic market** as they are for **exports**. The question therefore arises as to whether the new Federal Government's strategy is sufficient to properly position Germany as an internationally competitive **GreenTech export nation**.

The **Federal Government's strategy** is influenced by the coalition agreement. This study draws upon the coalition agreement and analyzes the targets and strategies that have already been defined with regard to GreenTech for Germany. The plans documented in the coalition agreement are being specified in more concrete terms on an ongoing basis by the Federal Government or the appropriate working groups. The analysis in this study therefore includes all measures defined up to the time the study was prepared in May 2022.

In addition, the study will evaluate which technologies are relevant from a GreenTech perspective as a whole and therefore which effects can be realized to help with the **substitution of fossil fuels as primary energy sources**, **the protection or efficiency of resources**, **or the transition to a circular economy**. There is a particular focus on the **discussion of the role of digitalization** in achieving sustainable economic management more quickly – the effect of digitalization on the impact of GreenTech is given special consideration.

In addition to the general discussion of GreenTech and the presentation of its links to the topic of sustainability as a whole, the study evaluates the existing strategies for **positioning Germany as a GreenTech export nation** and the associated effects of this on the economic structure.

This involves analyzing the connections between **economic**, **environmental**, **and social effects in the context of GreenTech**; or in other words, a design that balances technology, responsibility and trust. In this context, it is particularly relevant whether the Federal Government's goals and strategy regarding ESG (Environmental Social Governance) investment criteria end up having a positive impact on capital markets and on the economic success of Germany as a location for business in the medium- and long-term, or whether political concepts actually hinder success.

1.2

Questions in the study

For the economic structure of Germany, it is relevant to ask which sectors play an important role in the development and use of GreenTech. In accordance with the definition by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection, this study will look at the **sectors of energy, industry, transport, buildings, agriculture and waste management** [1]. For example, the success of Germany as an export nation in the field of engineering is still strongly influenced by small and medium-sized enterprises based in Germany. An investigation is made as to whether the success of GreenTech Made in Germany will be achieved in the same way both by and with German medium-sized enterprises, or whether an additional change in the economic structure will occur in parallel to this. Finally, the study will also discuss the timeline of the climate goals from the coalition agreement and highlight ideas and recommendations for further development. In this sense, the following questions will guide the course of the planned studies:

- How is the term GreenTech defined and which technologies are grouped under GreenTech? (Chapters 2.2.1 and 2.2.2)
- What role does digitalization play in the impact of GreenTech? (Chapter 2.2.3)
- What effects does GreenTech have on the environment (focus: substitution of fossil fuels as primary energy sources, protection and efficiency of resources, circular economy)? (Chapter 2.3.1)
- What are the macroeconomic implications of GreenTech and how can arguments for a balance between economic and environmental goals be made in the context of GreenTech? (Chapter 2.3.2)
- What social and societal impacts can be observed as a result of GreenTech? (Chapter 2.3.3)
- How can GreenTech's development and growth models be presented on a national and international scale? What changes in Germany's economic structure can be attributed to GreenTech? (Chapter 2.4)
- What targets and strategies has the Federal Government put in place to promote GreenTech and how should these be evaluated (particularly with regard to the balance between economic and environmental factors and the achievement of political objectives in a reasonable time frame)? (Chapter 3)
- How can Germany establish itself as an internationally competitive export nation for GreenTech on the basis of the targets and strategies set by the Federal Government? (See Chapter 5)

All of the questions discussed also form the basis for the expert survey (Chapter 4).

1.3

Study design and methodology

From a methodological standpoint, the study is based on a multi-stage approach:

1.3.1

Meta-analysis and derivation of a GreenTech reference model

On the basis of existing literature from other studies, scientific publications such as working papers, and web pages on the topic of GreenTech, a detailed **meta-analysis of existing studies, scientific publications, reports, and web pages** has been compiled. The aim of the analysis was to derive a reference model for GreenTech (see Chapter 2). In line with the questions mentioned above, the reference model outlines the following elements:

- Definition of the term "GreenTech" and definition of the relevant technologies
- Analysis of the role of digitalization in the use of Green-Tech
- Analysis of the impact of GreenTech on the substitution of fossil fuels as primary energy sources, protection and efficiency of resources, or the transition to a circular economy
- Analysis of the compatibility of environmental and economic factors in the context of GreenTech
- Analysis of social and societal aspects of GreenTech
- Analysis of growth models for technological leadership and the changes in Germany's economic structure as a result of GreenTech

1.3.2

Expert survey

To conduct the expert survey, **40 experts** were questioned in a **semi-structured interview**. The sample group was made up of experts who deal with the topic of GreenTech in their daily work in different functions and forms. In order to cover the bigger picture, interviewees from different organizational forms and sectors were interviewed. The following organizations were covered:

- Industrial companies
- Companies in the GreenTech industry
- NGOs (non-governmental organizations)
- Public sector
- Research
- Risk capital providers
- Consulting companies

The composition of the sample group is discussed in detail in Chapter 4.

The interviews were conducted by telephone or video conference, recorded as an audio file, and then transcribed. With the help of **qualitative text analysis in MAXQDA**, the statements were then coded and evaluated. This was used to derive the results report presented in Chapter 4.

1.3.3

Iterative comparison with the political agenda of the new Federal Government

The political agenda of the Federal Government in office since autumn 2021 is primarily set out in the **coalition agreement**. The reference model created as part of this study is used to analyze the targets and strategies defined in the coalition agreement that are relevant to GreenTech for Germany as a business location. Concrete details of the defined targets and strategies, for example in the form of sets of measures, are included in the analysis. In addition, a comparison is made between the evaluations of the expert survey results and the targets and measures set out in the current political agenda. Finally, the recommendations set out in Chapter 5 are derived from this.

GreenTech reference model

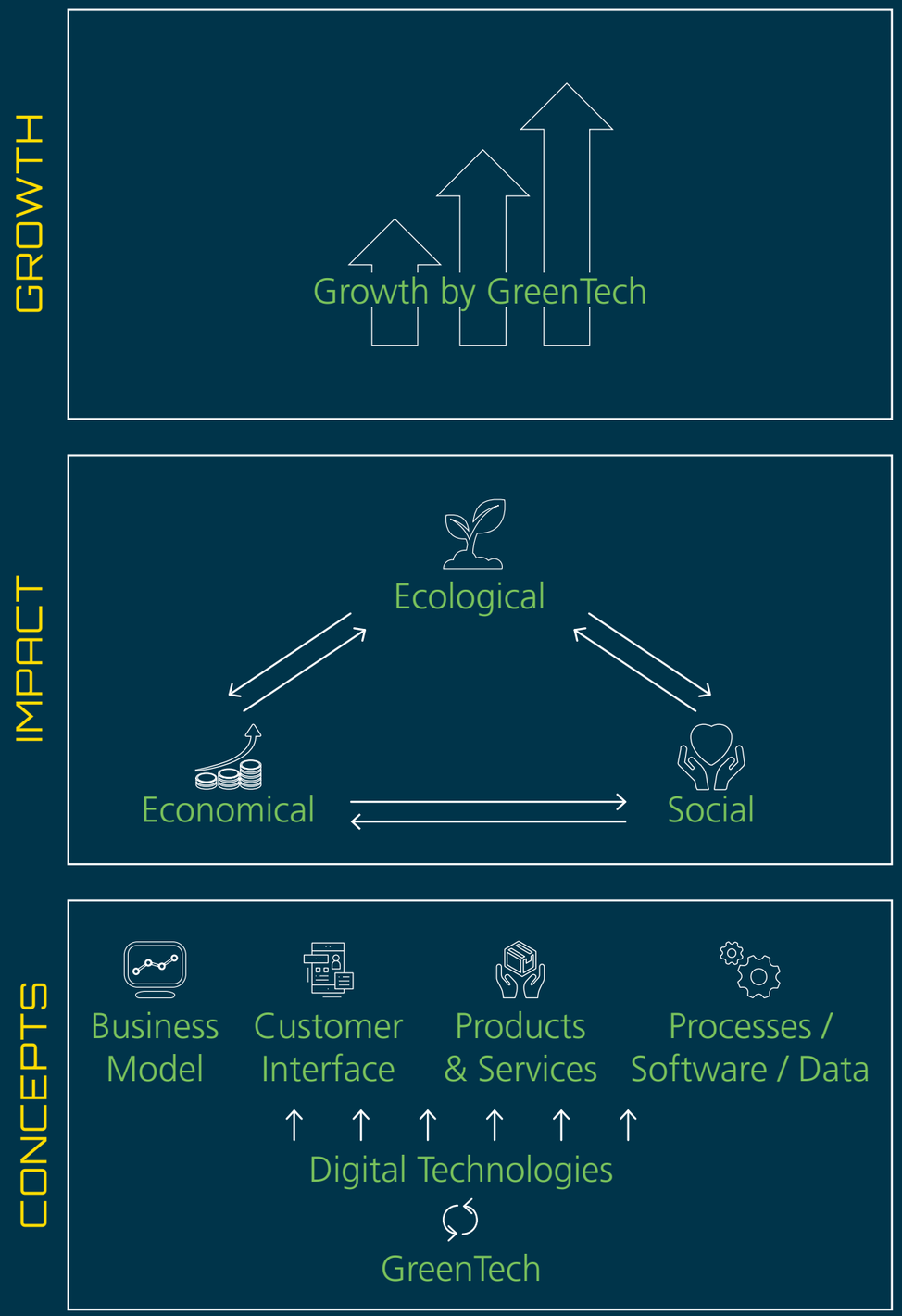


Figure 1: The GreenTech reference model

2.1

The GreenTech reference model

The GreenTech reference model is divided into three main areas: concept, impact, and growth. The **concept** section deals with the definition of GreenTech, essential technologies, and the relationship between climate transformation and digital transformation. The **impact** section summarizes the current state of research with regard to the environmental, economic, and social effects of GreenTech. Finally, the **growth** section addresses the political and industrial targets and measures for promoting the effects of GreenTech.

Like many of the latest buzzwords, the term GreenTech does not have an exact definition. In general, the label "**GreenTech**" encompasses a whole range of "**green**" technologies that help us to contribute toward our sustainability goals, placing this concept at the **interface between technology and sustainability**. GreenTech is discussed in different ways from different perspectives. The exact role of digital technologies in the context of GreenTech is a vague topic. Depending on the approach, digital technologies are presented as either **cross-sectional technology**, **enablers**, or **independent divisions** for GreenTech. There are also uncertainties with regard to the environmental, economic, and social effects of GreenTech.

The blurred concept and vague definition of the technologies and effects of GreenTech make it difficult to offer an effective evaluation of the political targets and measures for Germany as a business location. This **meta-analysis of existing studies, working papers, and web pages on the topic of GreenTech** therefore serves as a reference framework for assessing Germany's position as a business location. The GreenTech reference model is derived as the key result of the meta-analysis.

Reference models are now commonly established in various spheres of activity and often form a basis for the discussion and evaluation of concepts. However, the GreenTech sector is lacking such a reference model. For this reason, the model in Chapter 2 represents a substantial contribution to the discussion on suitable targets and measures to promote the effects of GreenTech.

2.2

The GreenTech concept

The GreenTech concept is currently subject to various developments. Consequently, the following chapter deals with the **fundamental terms**. The term GreenTech will first be defined. A list of the technologies associated with the GreenTech label in the context of this meta-analysis will then be presented. Finally, the **role of digital technologies** in the context of GreenTech will be discussed.

2.2.1

GreenTech: definition

There is no clear definition of GreenTech in existing literature [2]. Instead, the term "GreenTech" has to be defined according to its fields of application and impact [3]. The GreenTech label encompasses all technologies that contribute to national and international sustainability goals [4]. These sustainability goals can be tackled using various measures at different levels, which is why the GreenTech concept is divided into a 6-stage framework for action with the following priorities:

(1) Energy sources and energy carriers
(2) Energy production, distribution, and storage
(3) Energy efficiency
(4) Sustainable materials and products
(5) Sustainable product design, manufacturing, and value-added processes
(6) Circular economy and product life cycles

Unlike conventional, non-green technologies, **GreenTech saves resources and energy** while simultaneously reducing environmental impact [5]. In this sense, it is irrelevant whether GreenTech is used in products, services, or processes – it will still achieve the essential effects [6]. GreenTech is **cross-sectoral** and present in almost all areas of life [3], [7]. As such, GreenTech's success is dependent on the **interaction between science, economy, and technology**.

Energy sources and energy carriers

Energy sources are used to generate useful energy such as electricity or heat, which are made usable by different energy carriers. The German Federal Ministry for Economic Affairs and Climate Action lists **nine primary energy carriers** that are used as primary energy sources in Germany. Since the beginning of the 1990s, the share of renewable energy sources, such as hydro and wind power, in primary energy consumption has seen significant growth, reaching 16 per cent in 2021 (see Figure 2) [1]. In 2020, more electricity was generated from renewable energies than from fossil fuels such as coal, oil, and natural gas for the first time [8]. It is also expected that the growth in renewable energy sources and the production of green hydrogen will further accelerate as a result of the current conflict in Ukraine and the associated sharp rise in energy prices. Coal and nuclear power are currently being discussed as short-term bridging solutions.

GreenTech can already be used in energy production by making processes or products more efficient, whether for fossil, renewable, or nuclear energy sources. In addition to **optimizing our use of existing energy sources**, GreenTech can also facilitate the **development and introduction of new, clean energy sources**. One example of this is the use of hydrogen as an energy carrier, which can contribute to global decarbonization [9].

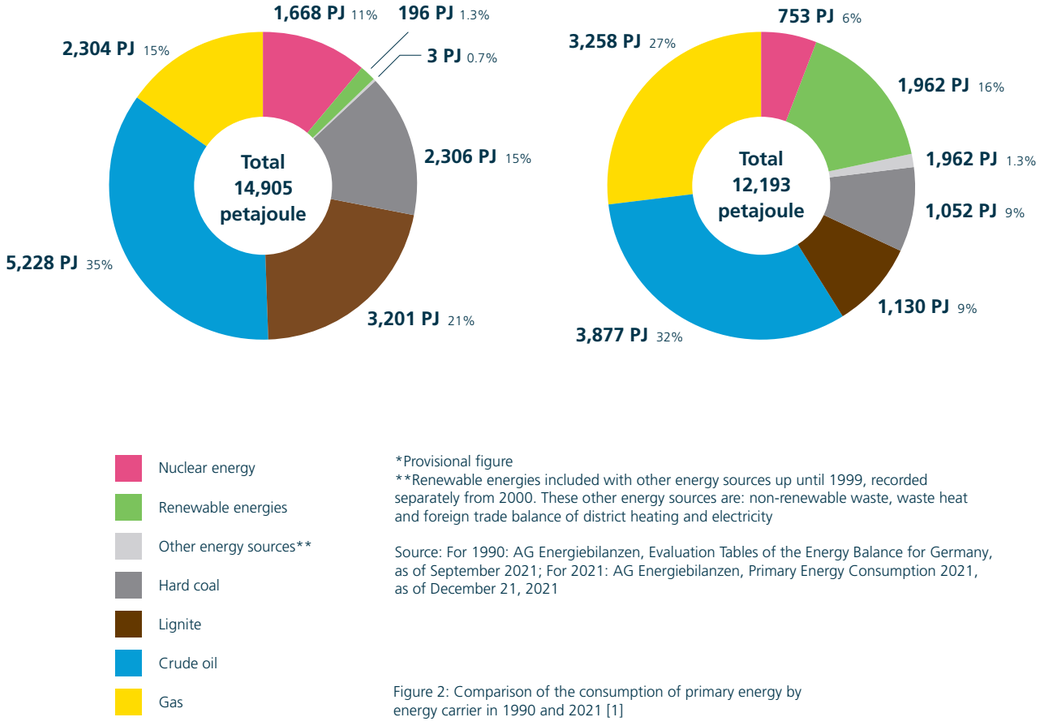
Energy production, distribution, and storage

Energy production describes the process by which the aforementioned energy sources are converted into useful energy. GreenTech can increase **efficiency in complex processes,** for example by reducing the quantity of raw energy sources used and by enabling sustainable energy production. A prominent example of GreenTech in power distribution is the use of **smart grids**, which use information and communication technology to create a network of power plants, storage facilities, and consumers in order to deal with power fluctuations. The energy produced, distributed, and stored is adapted to the current network situation [9]–[11].

Energy efficiency

In general, energy efficiency refers to the ratio between a particular benefit gained and the energy used (e.g. provision of light or heat). The less energy that is required, the more energy-efficient a product or service is. However, in the context of the energy transition, it is not only **energy efficiency** that is a deciding factor, but also the **reduction in the overall energy demand** [4], [12].

This means that the resulting **rebound effect** must be taken into account. The rebound effect refers to the phenomena when resources that were originally saved are used up elsewhere, for example through additional consumption or energy usage, meaning that savings that were originally achieved may be counteracted. It is considered to be an important factor with a long-term impact on CO_2 emissions and must therefore be taken into account when calculating savings potential. When rebound effects occur, the focus of environmental technologies should shift from energy efficiency to **reducing ecosystem damage**, such as the capture, storage, and disposal of polluted air or waste [13], [14].



*Provisional figure
**Renewable energies included with other energy sources up until 1999, recorded separately from 2000. These other energy sources are: non-renewable waste, waste heat and foreign trade balance of district heating and electricity

Source: For 1990: AG Energiebilanzen, Evaluation Tables of the Energy Balance for Germany, as of September 2021; For 2021: AG Energiebilanzen, Primary Energy Consumption 2021, as of December 21, 2021

Figure 2: Comparison of the consumption of primary energy by energy carrier in 1990 and 2021 [1]

Sustainable materials and products

In order to achieve climate goals, a holistic approach must be taken when it comes to sustainable materials. GreenTech plays a central role in the **manufacture and use of sustainable materials** in a wide range of fields, such as the construction, automotive, and textile industries that use linen, hemp, or recycled polyester [9], [15].

Sustainable product design, manufacturing and value-added processes

GreenTech encompasses products, processes, and services that incorporate renewable energy generation, green drive technologies and infrastructure, material, raw material and energy efficiency, and environmental and water management, and that make a significant impact in this area. The main aim here is to develop technologies that are **sustainable and protect the environment**, but also those that are **sustainable in their production**, including technologies with environmentally friendly supply chains. This also affects the design of GreenTech products. In this instance, the focus is on cradle-to-cradle design and the termination of the **cradle-to-grave cycle** of manufactured products [2], [16].

Circular economy

The concept of a circular economy is founded on the idea of a **completely regenerative value chain**, which does not require the consumption of finite resources and reduces the generation of waste [17]. Key components and principles of the circular economy are, for example, circular business models, circular product design, longevity, retrofitting, leasing and sharing models, repairing, and re- or upcycling. The path to a successful circular economy can be achieved with the 9R framework [18]. Green technologies can make a significant contribution toward the circular economy, particularly in establishing a sustainable product design, making efficiency improvements in the production process, or recycling end-of-life products [19], [20].

2.2.2 GreenTech: Relevant technologies

GreenTech technologies can be found in all fields and sectors. Their environmental effects differ depending on their application. The following overview gives an insight into the relevant GreenTech technologies in different fields of application and sectors, as found in the studies in this meta-analysis.

Renewable energies

Renewable energies are energy generation technologies that do not require fossil fuels and are either emission-free or have significantly reduced emissions. Renewable energies only reach their full environmental potential when combined with optimized energy efficiency, improved networks, and distribution and storage technologies [9], [11], [21]. In particular, these technologies include:

- Photovoltaics
- Solar-thermal power plants
- Solar-thermal energy
- Wind power (onshore, offshore)
- Hydropower
- Geothermal energy
- Biogas
- Biomass power plants
- Green hydrogen
- Liquefied natural gas (LNG)

Energy efficiency

Technologies that **reduce energy consumption or energy loss** contribute to energy efficiency. These include energy-efficient production processes, energy-efficient building technologies, and energy-efficient electronic devices [11], [13], [21], [22].

- Efficient heating, ventilation, and air-conditioning technology
- Passive houses/net-plus energy houses
- Smart buildings
- TopoActive vehicles
- Heating and cooling networks
- Heat pumps
- Combined heat and power plants
- Use of waste heat
- Energy-efficient lighting (e.g. LED)
- High-efficiency materials

Energy networks, distribution, and storage

In order to transfer as much energy production to renewable energies as possible, **energy networks and storage** must be adapted. Unlike coal-fired power plants, for example, the production of renewable energies is dependent on the environmental conditions. For this reason, the energy generated must be optimally distributed and stored so that the energy can be used where and when it is needed [7], [10]. GreenTech in the energy domain therefore represents a **synergy** of energy production, energy efficiency, and energy distribution and storage [6], [23]. Technologies that contribute to this optimization are:

- Long-term energy storage
- Advanced control systems
- Software and communication technologies
- Vehicle-to-grid integration
- Building-to-grid integration
- Green hydrogen
  - Hydrogen as fuel for road transport, aviation fuel, marine fuel
  - Hydrogen for ammonia production
  - Hydrogen for steel production
  - Hydrogen transport
- Smart grids
- (Smart) counting and metering devices

Water and water treatment

Within water usage and water treatment, GreenTech technologies are mostly used to **optimize existing processes** [2], [6]. However, GreenTech can also be used to make **water distribution** more environmentally friendly [3], [24]. Relevant fields of application for GreenTech in this area are:

- Water collection and treatment
- Water networks, leak detection
- Early detection of quality issues
- Digital twins: self-learning, flexible, and adaptive water systems
- Reducing the use of fossil fuels in the construction and operation of water-based facilities
- Smart optimization and securing of the water supply
- Collection and transport of waste water
- Waste water treatment, sludge processing, energy management
- Waste water treatment plants, recovery of substances during wastewater treatment
- Increased efficiency in water use
- Innovative sanitary systems

Sustainable mobility

In the field of sustainable mobility, GreenTech is focused on **emission-free drive systems** and the **reduction of emissions from conventional drive technologies** [7], [10]. A reduction in the number of kilometers driven thanks to **optimized private transport** and **efficient public transport** also falls under the umbrella of green technologies in the field of mobility [11], [16]. The technologies in this field include:

- Public transport, electric buses
- Electric trucks, electric bikes
- Hybrid drive
- Fuel-cell drive
- Rail vehicles and infrastructure
- Battery technologies, battery control systems
- Smart city solutions
  - Charging infrastructure
  - Smart and shared mobility
  - Traffic control and optimization, traffic light control (also for rail)
  - Networked individual transport
- Intelligent logistics
- Increased efficiency of combustion engines, lightweight construction technology, energy-saving tires

Sustainable agriculture and forestry

In agriculture and forestry, the use of green technologies is aimed at **increasing the efficiency of food production** [16], [25]. This is achieved primarily through the use of digital technologies [6], [11], [26]. However, in this context, the **production of substitute products** also falls under green technologies.

- Precision equipment
  - Robots
  - Drones for automated seed sowing, precise fertilization, and protection from insects
  - Sensor technology
  - Smart irrigation
- Vertical farming
- Blockchain technologies to create transparency and ensure compliance with environmental and social standards
- Artificial intelligence, e.g. for reducing waste by forecasting demand
- Meat substitutes
- Methane inhibitors
- Anaerobic manure processing
- Bioengineering
- Energy-efficient frozen goods
- Geotechnologies and land management
- Soil protection
- Noise protection
- Groundwater and surface-water protection
- Nature and landscape conservation

Sustainable industry

In industry, green technologies are used in different fields and sectors [9], [27], [28]. Particularly in **production**, the possibilities are wide-ranging [6], [16]. Here too, **digitalization** plays an important role:

- Digital twins
- Automation in production and logistics
- Mobile working
- Measurement, control and monitoring technology, process control
- Pump systems
- Fans
- Electric drive systems
- Heat exchangers
- Compressors
- Multi-packs/returnable (deposit) packaging
- Compressed air and vacuum technology
- Material and supply chain transparency

Sustainable building management

Green technologies in the building industry are primarily aimed at **optimizing energy efficiency** and r**educing emissions** from building materials [6], [9]. Particularly noteworthy in this field are energy technologies, digital control, and material technologies [16]:

- Smart home
- Building automation
- Networked buildings
- Internet of Things and energy management
- Thermal insulation
- Building Information Modeling (BIM)
- Augmented reality for reducing rework, material consumption, etc.
- Light transport (natural lighting)
- Planted paneling and exterior walls
- Integrated photovoltaics

Digital technologies

Digital technologies play a crucial role in many GreenTech technologies. They are therefore considered to be an example of cross-sectoral technology and are discussed in detail in Chapter 2.2.3 because of their high significance for GreenTech.

Raw materials and other materials

Sustainable materials management uses technological approaches to **efficiently extract, produce, and use** raw materials and other materials [6]. GreenTech approaches in this field not only help to use raw materials and other materials more efficiently, but are also the basic prerequisite for creating a circular economy [11], [21].

- Green materials, decarbonization of primary industries
- Material-efficient production processes
- Renewable raw materials
- Protection of environmental goods
- Green mining
- Ocean tech (sustainable use of marine resources)
- Manufacture of material and plastic products
- Processes in the chemical industry
- Paper and pulp production
- Biotechnology, nanotechnology, organic electronics
- Natural insulation materials
- Bioplastics
- Composites
- Packaging 4.0, reduction of waste in the production of packaging and prevention of product loss due to ineffective packaging
- Sustainable smartphones

Carbon capture

The term carbon capture describes technologies that aim to collect, bind, and partially recycle CO_2 from the air [13], [20]. This also includes technologies that absorb CO_2 at the source of the emissions as soon as they are generated [10], [29]. Some examples include:

- Afterburning technologies
- Direct air capture
- Bioenergy with CO_2 capture and storage
- Biocoal
- Carbon-enriched cement

Circular economy

The aim of the circular economy is to return, wherever possible, all used resources to the **recycling loop** [17]. The ultimate goal is a net-neutral consumption of resources [20]. Technologies in this area include classic recycling or product design [30]:

- Recycling
- Waste collection, transport, and separation
- Material and energy recovery
- Raw material recovery
- Waste-to-energy
- Plastic roads
- Circular by design

2.2.3 The role of digital technologies

Reciprocal relationship

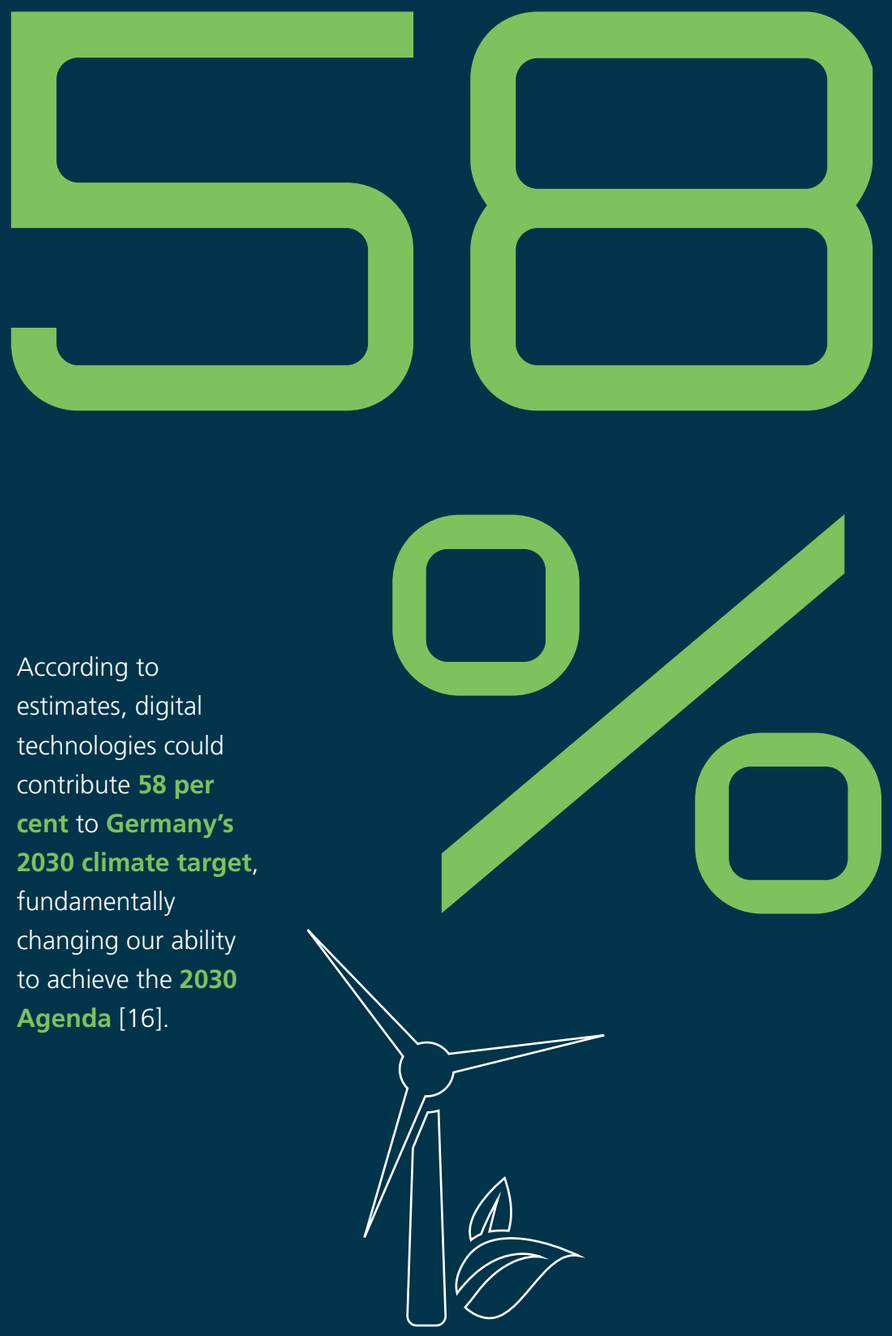
Digital technologies are considered to be extremely important for the implementation of GreenTech, as the use of digitalization technologies is present in almost all of GreenTech's fields of application [6]. **GreenTech and digitalization** are often viewed as having a reciprocal relationship. The Digital Policy Agenda for the Environment, published by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection in March 2020, makes it clear that the two major trends of the 21st century, **digitalization and the protection of the environment and climate**, must be brought together [11], [31]. Sustainability must be facilitated through technology – and vice versa: Until now, the use of data, technologies, and digital solutions in sustainability initiatives has focused mainly on efficiency gains, for example reducing energy and resource use, improving decision-making through AI, or transparently tracking materials and goods along the supply chain [15].

Cross-sectoral technology

In many fields, digital innovations are the only gateway to enabling the use or application of sustainable, green technologies. Digitalization is therefore often viewed as an **enabler of GreenTech** [5], [11], [30], [32], [33]. In certain areas of application, this dependence is so pronounced that digital technologies have become synonymous with GreenTech [34]. Since the use of digitalization technologies runs through almost all areas of GreenTech, digitalization is generally seen to be central to the implementation of GreenTech and is referred to as **cross-sectoral technology**.

Accelerating factor

By enabling new business models and platform solutions, **digitalization is proving to be an accelerating factor across all sectors** [11], [17]. Digital technologies are also driving innovation in the areas of emissions avoidance and efficiency improvements by creating transparency in production processes and supply chains. It is often only through this knowledge that opportunities for optimization become identifiable [15]. **In this way, GreenTech is developing faster and faster with the help of digital technologies**. The use of digital solutions for work, shopping, and leisure and their underlying infrastructures has increased significantly in a short period of time and thus further strengthened the already established long-term growth trend. It is



According to estimates, digital technologies could contribute **58 per cent** to **Germany's 2030 climate target**, fundamentally changing our ability to achieve the **2030 Agenda** [16].

particularly important to stress the significance of data infrastructure and the availability of high-performance broadband for the entire population, economy, and society.

A driver and central component

Digital solutions drive innovation in many GreenTech initiatives [17]. However, digital technologies are also a central component of many solutions. Automation and smart solutions such as smart farming incorporate **digital technologies** as a central function to achieve savings potential or efficiency gains [21], [35]. For example, many concepts that currently use artificial intelligence would be impossible without the use of AI with current technical requirements.

There is a great level of hope surrounding innovative technologies in the fight against climate change. According to estimates, **digital technologies** could contribute **58 per cent to Germany's 2030** climate target, fundamentally changing our ability to achieve the 2030 Agenda [16]. A well-designed, environmentally friendly digitalization strategy is therefore seen as a tool for socio-ecological reconstruction, in which a sustainable economy and sustainable way of living, working, and living together are developed.

Applications

Digital technologies enable companies to d**esign their processes efficiently and flexibly** and thus open up additional capacity. The main organizational advantage of digital capabilities is **the creation and analysis of resource consumption and production data** [15]. In this way, digitalization can contribute to resource efficiency. The automated processing of information opens the door to many efficiency gains [33]. In addition, digital technologies establish central reference points for company-wide indicator systems, which help to make the sustainability goals set by the company and its digital strategies measurable and transparent. Digital technologies can make a significant contribution by enabling the real-time monitoring of a product throughout its entire life cycle. In the manufacturing process, this involves transferring current consumption data or forecasting future consumption data using big data and AI solutions. The transfer and analysis of data in the subsequent use phase is of great relevance to companies wishing to obtain information on user behavior. To make products sustainable, information is required **throughout the entire product life cycle**. Digital solutions for the collection, processing, and analysis of data enable sustainable products to be created.

Products, services, customers

Digital technologies transform businesses into intelligent systems that **produce intelligent products and services**. Digitalization is also used as an information and communication tool and paves the way for new forms of information and communication.

CO_2e savings potential as a result of digital technologies per sector in 2030, in per cent

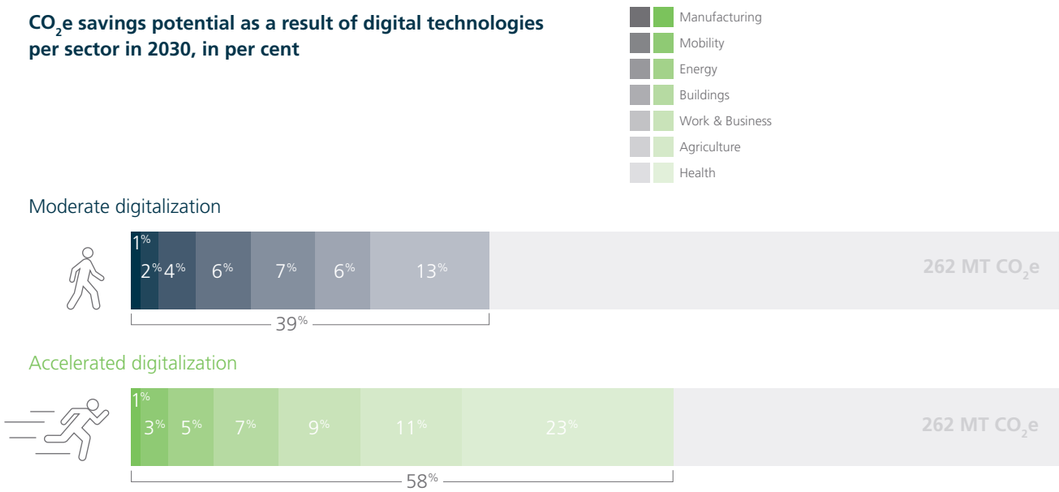


Figure 3: Potential CO_2e savings from digital technologies by 2030 [16]

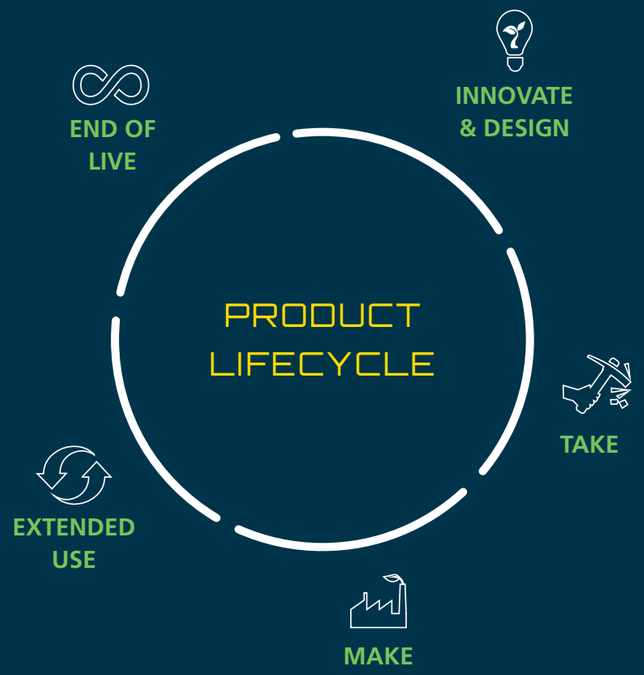
Business models

Digital technologies not only create new products and services, but also new business models. They enable a **shared economy and thus reduce individual consumption**. By nature, these shared economy examples are associated with a reduction in resource consumption and an increase in resource efficiency [15]. The most well-known example of a shared economy is car sharing, where users can access a vehicle whenever they need it without having to own one themselves. Further demand-oriented models, known as made-to-order or subscription models, aim to avoid waste and only produce products to order.

Circularity, production patterns, and consumption patterns

Digital technologies can change existing **production and consumption patterns** in all sectors of the economy to make way for significant efficiency gains [17]. With digitally supported production processes, industrial companies can continuously adapt their materials, raw materials, and energy usage to the consumption pattern. In this way, digital technologies are transforming **companies into intelligent systems** that create smart solutions in the form of products and services [15]. The data collected as a result enables the use of resources and production to be analyzed in real time. Digital systems support companies in their transition to a product life cycle that is compatible with the circular economy through these production and consumption mechanisms [17].

Data satisfies information needs



We need information at every point in the lifecycle to make products sustainable.

Figure 4: Data from the product life cycle as a basis for creating sustainable products (original illustration)

2.3

The impact of GreenTech

The impact of GreenTech is relative to the contribution made by the relevant technologies to **sustainability goals**. In addition to the environmental effects, the economic and social implications of GreenTech must also be taken into account. The meta-analysis for presenting the effects of GreenTech is structured according to these dimensions. The focal points listed within the three sustainability dimensions are derived from the analysis of the existing contents of the analyzed studies.

2.3.1

Environmental effects

The use of GreenTech can have a **variety of environmental effects** and thus make a significant contribution to achieving environmental goals. The focus lies on three key aspects: the **substitution of fossil fuels as primary energy sources**, the **protection and efficiency of resources,** and the transformation to a **circular economy** [5], [9].

Overall potential

Current studies estimate the potential of using GreenTech to be high [13], [36]. However, it is difficult to quantify GreenTech's specific contributions to environmental protection [33]. There is often a l**ack of specific measurement models and traceable procedures** for quantifying the effect of GreenTech.

In the substitution of **fossil fuels as primary energy sources,** GreenTech can help to conserve natural resources and limit environmental damage. The switch to renewable energy sources will enable a reduction in emissions of 55 per cent by 2050 [37], which will make a central contribution to the achievement of the United Nations' sustainability goals [9]. Studies also consider green innovations to play an important role in resource protection and efficiency, for example by reducing environmental pollution, in manufacturing industrial goods, or by improving the efficiency of production processes [38]. In many places, GreenTech is also the only way to transition to a circular economy and see the associated environmental effects. It is assumed that circular economy activities will make an important contribution to reducing the remaining 45 per cent of emissions [37]. Innovations in GreenTech can therefore be described as a catalyst in the creation of a green economy and make a central contribution to the green transformation.

Technology and climate

The use of GreenTech can be a powerful l**ever in the fight against climate change**. It allows greenhouse gas emissions to be reduced across various sectors, making way for the associated effects on the climate. Technological progress is seen as a major factor in reducing greenhouse gases [15], [27].Natural CO_2 storage systems play a key role in resolving climate issues by absorbing carbon and binding it in biological and chemical processes [39]. GreenTech technologies can relieve these CO_2 storage systems by reducing emissions. In this way, green innovations in technologies, processes, and products can enable the strict carbon emission targets to be met. Compared to the levels during the industrial revolution, the consistent use of GreenTech has the potential to **reduce greenhouse gas emissions by 60 per cent** [36].

Impacts of the substitution of fossil fuels as primary energy sources

One impact of GreenTech technologies relates to the **substitution of fossil fuels as primary energy sources** (such as coal, oil, or gas). GreenTech aims to reduce or even eradicate the use of fossil fuels. By reducing or stopping the use of fossil energy sources, the resulting greenhouse gas emissions can be avoided [9], [11].

Impacts on protection and efficiency of resources

GreenTech technologies can help us to protect resources and to use resources more efficiently. In particular, the extensive use of renewable raw materials can make an important contribution to environmental protection. GreenTech technologies can also contribute to increasing resource efficiency in existing production plants, for example through the productive use of waste heat [38], [40].

Impacts on the circular economy

GreenTech technologies are set to give rise to environmental improvements within the framework of circular economy models. Resources are recovered and re-introduced into the production process, which helps to avoid emissions that would otherwise be generated if these resources were procured from new. By using GreenTech, materials can also be optimized so that they can be fed back into the production process more easily. Alternative green materials can also replace the materials previously used, again causing knock-on positive environmental impacts [17].

Sector-specific impacts

As mentioned above, GreenTech applications are found across all sectors and in various departments within companies, as well as in public life and private applications. The following are examples of sector-specific applications and their environmental impact in the following sectors:

- **Industry/production**
- **Mobility**
- **Buildings**
- **Energy**
- **Agriculture**
- **Waste management**

The switch to renewable energy sources will enable a reduction in emissions of

55%

by 2050

[37]

Industry/production

GreenTech technologies allow the industrial production process to become more efficient and increase the associated environmental benefits. Efficiency improvements in particular can be achieved through the use of green production technologies [40]. Particular focus should be placed on the substitution of fossil fuels as primary energy sources – a crucial step toward meeting climate targets by 2030.

Above all, the use of digital innovations to implement GreenTech has enormous environmental potential. In this way, a digital twin can result in improved production quality, reduced throughput times and reduced resource utilization for physical products and processes. When calculating savings potential in medicine production, for example, the use of a digital twin could reduce approximately 80 per cent of energy consumption and around 80 per cent of CO_2e[4] emissions [16]. The digital twin enables the collection and analysis of valuable data, both in the manufacturing process and throughout the subsequent use phase, thus contributing to sustainable decisions throughout the entire product life cycle.

However, the use of **green chemicals** in production can also have knock-on environmental effects. A lot of potential lies in the u**se of waste heat** from production plants, which in turn brings macroeconomic and environmental effects [41].

Mobility

GreenTech technologies have also found their place in the further development of mobility. In order to achieve greenhouse gas reductions, it seems sensible to take a multifaceted approach. For example, the use of GreenTech and digitalization can lead to increased efficiency in **urban traffic management** [16]. A prerequisite for this is an appropriate urban infrastructure. New, innovative **forms of mobility and mobility services**, such as bicycle rental systems and car sharing, also aim to make individual mobility sustainable and are closely linked to urban design. GreenTech is also used in the context of conventional individual mobility. Innovations in internal combustion engines, for example, point toward a future with greater efficiency. Alternative drive systems also play a major role. For example, the further development of electric or hydrogen drive systems can lead to a significant reduction in greenhouse gas emissions from vehicle use. This cannot be done without the appropriate electrical and hydrogen infrastructure. Powerfuel also appears promising for the energy transition. This uses the latest technologies to convert CO_2 into climate-friendly fuel. In other words, it produces electricity-based fuel from carbon dioxide [41].

Buildings

Smart GreenTech **energy management** technologies (such as smart meters) can reduce emissions from buildings. The combined use of GreenTech and digitalization in the context of smart home technologies can help to reduce energy consumption in buildings and avoid the resulting emissions [16].

GreenTech also offers environmental potential in the insulation of buildings and in reducing the use of environmentally damaging chemicals when constructing and operating buildings. In the context of a circular economy, the re-usability of building materials is also becoming increasingly important in the construction of buildings. This is made possible, for example, by using manufacturing methods such as plugging and screwing rather than bonding. The switch to green energy sources is also an essential aspect of GreenTech in the building sector [41].

Energy

In the energy industry, there is a wide range of environmental impacts that result from the use of GreenTech. By creating **smart grids**, emissions from the energy grid can be reduced [16]. The use of advanced energy storage technologies can make a significant contribution to reducing the high demands on electricity generation. In addition, GreenTech solutions promise to increase the flexibility of the power grid [41].

Agriculture

GreenTech can be used to protect **agricultural ecosystems** and contribute to conscious conservation efforts for these systems. The combination of GreenTech and digital technologies can also prove beneficial in the transition of agricultural practices [16]. For example, emissions can be reduced by increasing the efficiency of livestock farming and soil management. A reduction of or change in chemicals offers further environmental benefits [42].

Waste management

GreenTech also offers economic benefits in the field of waste management, for example through the recycling of reusable materials, which also makes it possible to reduce emissions. In addition, the waste heat generated from waste incineration can be used for district heating to help reduce emissions in cities [16].

Rebound effect

Against the backdrop of the **rebound effect, the way in which GreenTech manages the environmental savings potential must be carefully considered** (see Chapter 2.2.1). With regard to the synergy between GreenTech and digital technologies, the efficiency gains achieved through the application of GreenTech technologies can lead to increased demand and thus to a macro-level consumption increase [33]. This, in turn, means that the savings potential from efficiency increases is not (fully) exploited or even completely counteracted from an economic point of view. For this reason, it is also important to address people's consumption behavior in order to avoid completely undermining any small efficiency gains through additional consumption, which would also jeopardize the achievement of climate goals [16]. The technologies used can also lead to increased energy consumption themselves.

[4] CO_2e is a unit of measurement that allows the effect of all greenhouse gases on the climate to be compared with one another.

2.3.2

Economic impacts

Macroeconomic impacts

Against the backdrop of increasing environmental awareness in Germany and the setting of national and international climate protection goals, **the demand for intelligent GreenTech technologies** is increasing. This is set to lead to dynamic growth across the entire GreenTech market. GreenTech companies in Germany expect to see an average annual sales growth of 9.9 per cent by 2025 [11]. By 2030, the current domestic market volume will more than double from 2020 values to EUR 856 billion. In 2020, the global market volume exceeded the EUR 4 trillion mark. The global market volume for the GreenTech sector is forecast to reach EUR 9.38 trillion in 2030 [11].

For this reason, it can be expected that the path to achieving the United Nations' sustainability goals will lead to a **strengthening of the German GreenTech industry**, which can in turn may bring positive economic effects in terms of contributing to gross domestic product and securing jobs, as well as the resulting prosperity [9]. However, it may result in a shift of jobs to the GreenTech industry [9].

Start-ups in the GreenTech industry are also of great importance. With their business models, these start-ups enable the creation of highly innovative GreenTech products and are able to react quickly to changing market conditions and customer requirements due to their flexibility. Through these technological developments, they play an important role in the economy and make a significant contribution to its innovation dynamics [9].

Furthermore, the use of GreenTech technologies makes it possible to **increase efficiency** in established industries. These efficiency gains free up financial resources, which can then be used elsewhere to increase competitiveness. In addition, GreenTech can help stabilize industries. Particularly in the current context of unwanted dependence on fossil fuels, these stabilizing effects can be of great economic importance.

At a macroeconomic level, GreenTech technologies can also generate market opportunities for the GreenTech industry. The performance of the industry can lead to a **competitive advantage** on the international market. This, in turn, promises new **export opportunities** with subsequent economic returns that would benefit Germany as an industrial location. In order to take advantage of these opportunities, it is important that both politicians and companies in Germany find quick ways to implement and apply the latest technologies to keep up with the international competition [11], [43].

Microeconomic impacts

Positive economic effects can also be observed at an individual company level through the use of GreenTech. From a company perspective, it can be seen that economic considerations are the major deciding factor when it comes to moving to GreenTech. As a rule, companies take more sustainable action if this leads to **economic benefits** [44].

Companies can increase their **competitiveness** through the use of GreenTech technologies. Green innovations in particular offer competitive advantages. With the help of GreenTech, companies can take up superior market positions against competitors, which is then reflected in economic returns. Occasionally, GreenTech can also enable the development of innovative products that meet the **changing needs of customers** [27].

In this way, GreenTech can help companies to achieve a range of financial targets through an **increased return on investment**, higher turnover, or even an increase in the value of the company [9].

If these effects are to be realized, a rapid adoption of GreenTech technologies is seen as important. Using the **first-mover advantage** allows companies to be the first to leverage the potential of GreenTech and thus the first to reach and consolidate their new competitive position. This position typically brings rewards both from customers and investors [9]. Moreover, companies can account for changing customer requirements by implementing GreenTech activities. With awareness of environmental issues increasing all the time, more and more customers are demanding that companies focus their purchasing

decisions on this issue. Particularly in the end-customer business, it is extremely important for companies to implement GreenTech activities and to make this visible to customers. The same applies to the increasing relevance of environmental and socially responsible aspects when allocating capital [4], [19].

Sector-specific economic impacts

Once again, a distinction can be made between the following industries: (1) Industry/production, (2) Mobility, (3) Buildings, (4) Energy, (5) Agriculture, and (6) Waste management.

Industry/production

GreenTech technologies in conjunction with digital technologies enable **further added value to be created** in manufacturing companies. In the case of complex value chains, such technologies can first ensure emissions are transparent and then optimize or reduce them throughout the entire value chain. In this respect, companies can improve efficiency and reap the subsequent financial advantages [43], [45].

Mobility

By developing **future-oriented mobility technologies,** companies can secure market positions that will pay off in the future. There is a global need for the various mobility services on offer to be networked – a need that can be met by companies [9], [11].

Buildings

Changing consumer needs make the development of GreenTech technologies appealing from an economic point of view. GreenTech can deliver solutions that will win over consumers and thus increase company profitability, **both in the construction and operation of buildings** [46].

Energy

Integrated energy management solutions can bring benefits to the energy industry. Questions about the location of energy production and the transport of energy are often left unanswered, meaning that the development of energy storage technologies, for example, holds great economic potential for GreenTech companies [11].

Agriculture

Against the backdrop of efficiency pressures in the agricultural industry, GreenTech technologies are highly desirable in this sector. Farmers are generally open to using such technologies, making improvements in agricultural process efficiency a lucrative market [42].

Waste management

Unresolved waste management issues make this an appealing market segment for GreenTech companies. Environmentally friendly technologies can help to address such issues, which pays dividends in the market [11].

2.3.3 Social impacts

The multi-dimensional nature of GreenTech has to be considered when looking at its impact – in addition to the environmental and economic effects, the **social and societal dimension of GreenTech** is also impacted. For years now, there has been a growing demand for new, sustainable ways of living and doing business at a societal level, with green products being very popular among consumers due to their increasing environmental awareness.

Environmental awareness in society

Environmental awareness is of great importance in society. According to the environmental awareness study conducted by the German Environment Agency before the outbreak of war in Ukraine and the rise in inflation, 65 per cent of Germans consider the environment and climate protection to be very important [47]. This is reflected in the increasing popularity of environmentally friendly products.

Future viability

The green transformation will secure the **future viability of our society**. Concern about climate change and the high consumption of resources in our way of life and economy and has been high on the international political agenda for some time. Large parts of the economy are also strongly committed to improving environmental protection and are driving a variety of initiatives out of vital self-interest [13]. If Germany succeeds in creating the necessary conditions in good time and by consistently following the transition plans, we will be able to combat climate change not only in time, but also cost-effectively across society as a whole. In order to achieve climate neutrality, additional investment in tangible assets of EUR 40 billion per year will be required across all sectors if climate change reversal measures are to be implemented quickly and consistently by 2045 – this represents approximately 1% of GDP. These additional investments are offset by considerable savings, particularly in the building and transport sectors, meaning that the aggregated savings from the green transition can free up the capital that would otherwise have been spent in the estimated investment period up to 2045 [9].

Healthy living spaces

The increasing **urbanization of living spaces** brings with it many challenges. In particular, communities have to contend with direct environmental problems such as poor **air quality**, complex **waste management,** or **water supply** issues, with residents directly exposed to these adverse factors on a daily basis. Technologies that eliminate or reduce these negative environmental impacts from people's living spaces contribute to creating a healthy living space. Environmentally oriented projects and products must be integrated directly into the living spaces of those affected, regardless of whether these spaces are homes, schools, or businesses [4].

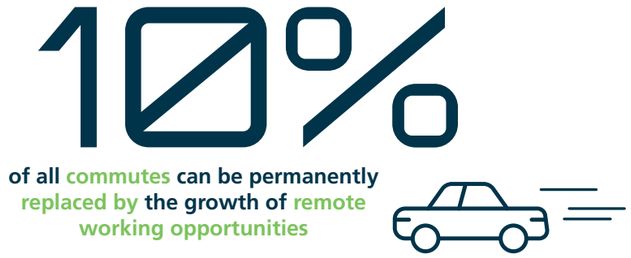
The future of work

The global sustainability goals and Paris Agreement targets affect all areas of our daily lives. During the COVID-19 pandemic, digital technologies enabled employees to move to remote working, which allowed regular operations to continue in many industries. In addition, digital technologies open the door to flexible scheduling opportunities, low operating costs, and reduced volumes of traffic when working remotely. Surveys conducted by the University of Mannheim show that high-income workers in particular tend to have jobs that are compatible with home-office working. This means that 10 per cent of all commutes can be permanently replaced by the growth of remote working opportunities and 30 per cent of all business trips can be replaced by virtual meetings [31].

However, working from home requires IT resources, which is why data and communication centers should be consistently geared toward energy and resource efficiency as well as a sustainable energy supply [9].

Social justice

According to a study by the Federal Ministry for the Environment, the **field of tension between social justice and environmental protection** is becoming increasingly relevant. Many respondents fear that environmental policy measures and the energy transition could put too much financial strain on low-income earners in particular. However, people are less aware of the positive social effects that environmental protection measures can bring. For example, poorer people are more likely to live in a worse-affected living space and suffer the social and health consequences of this, and in this sense benefit more than average from environmental protection measures. It should also be kept in mind that environmental protection can sometimes directly lead to cost reductions, for example through increased energy efficiency (e.g. by the use of digital technologies). Climate solutions can promote both social and economic justice if they are used sensibly and correctly. However, this raises some questions: who decides, who benefits from it, and how are any disadvantages mitigated? It is important to understand how much money a particular solution will cost or save compared to the status quo of the technology or practice it replaces. Politicians should therefore consider it an urgent task to prevent the consequences of non-sustainable actions from being socialized and the costs of sustainability being individualized. Suitable environmental tools for this are the setting of CO_2 taxes at an appropriate level and restrictions on emissions trading.



2.4

Growth through GreenTech

The area of "growth through GreenTech" in the reference model refers to the **status quo of the GreenTech industry in Germany** as well as to **appropriate measures taken by politicians and companies to increase growth momentum**. The term "growth" describes an extension of the environmental, economic, and social impacts associated with GreenTech. "Growth" is interpreted in its broadest sense.

2.4.1

The status quo of the GreenTech industry

The technologies associated with GreenTech are widely used in all sectors of the economy as a whole. In this way, GreenTech companies are a **cross-sectoral industry**. Companies in this industry continue to grow dynamically.

In Germany, the **GreenTech market volume in 2020** amounted to **EUR 392 billion**. Within the German GreenTech industry, the "energy efficiency" segment is the largest leading market with a share of 30 per cent and a market volume of EUR 117 billion in 2020. The second-largest leading market, "sustainable mobility," reached a market volume of EUR 91 billion. Among other things, the strong position of German manufacturers and suppliers in the field of efficiency enhancement technologies (e.g. in combustion engines) has made an impact. The market volume of the leading market for raw material and material efficiency was EUR 78 billion in 2020 [11].

On both a global and national scale, **growth is forecast at an average of 7.3 per cent for 2030**, with figures for some leading markets estimated to be significantly higher. Innovations in the fields of electrification and hydrogen, circular economy and smart city applications also create long-term growth and sales opportunities for the German GreenTech industry on the global market.

In Germany, GreenTech will expand its market volume by 2030 with an average annual growth rate of

8.1%

The global market volume of the GreenTech industry amounted to **EUR 4,628 billion** in 2020 and is expected to grow to **EUR 9,383 billion** by 2030 (see Figure 5). With a volume of EUR 1,224 billion (2020), "energy efficiency" is the largest green leading market worldwide. In Germany, GreenTech will expand its market volume by 2030 with an average annual growth rate of 8.1 per cent, meaning that the **rate of expansion in the GreenTech sector in Germany is slightly higher** than the global average.

High demand in the German domestic market opens up promising opportunities for Germany-based GreenTech companies: They are much closer to their customers and can work with users to develop new technologies tailored to their individual needs. Cooperation in the domestic market also promotes systemic approaches in the GreenTech industry. Providers from Germany in particular can achieve international success using their technological know-how and expertise in systemic solutions, and win large shares of the German market volume.

Looking at the **individual leading markets** from a global perspective, it is clear that the **rate of growth** varies across the overall market. The leading market "sustainable agriculture" is expected to experience the fastest rate of expansion. It is set to expand between 2020 and 2030 with an average annual growth rate of 11.3 per cent. The leading market "sustainable mobility" is ranked second with a growth rate of 8.7 per cent. Alternative drive technologies play a key role in the decarbonization of the transport sector, with the growth of this market segment providing a tailwind for the strong development of the entire leading market. The growth rates of the leading markets "environmentally friendly production, distribution, and storage of energy" and "raw material and material efficiency", at 8.5 and 8.4 per cent respectively, are also above average compared to the GreenTech industry as a whole. Renewable raw materials play an important role in the leading market of raw material and material efficiency, for example through the use of renewable raw materials as combustion or insulation materials or in the chemical industry.

The leading market "energy efficiency" shows moderate growth at a high level, which is partly due to the fact that many measures have already been implemented, particularly in energy-intensive sectors. The "circular economy" is the leading market with the smallest volume. It has slightly underperformed in comparison to the overall industry (5.9 per cent). Reasons for this include the lengthy innovation cycles, especially in the case of new recycling processes (e.g. plastics recycling, battery recycling) and the complexity of changing basic production and consumption patterns. The speed at which these hurdles are overcome in practice depends to a large extent on the market and the political environment. As explained in Chapter 2.3.1, an established circular economy can make a considerable contribution to reducing the 45 per cent of CO_2 emissions not dealt with by switching to renewable energy sources. This market, which is currently relatively inconspicuous in comparison to other sectors, should therefore be given very serious consideration despite its low growth rate [48].

At 26.4 per cent of the total volume of the GreenTech industry, energy efficiency products, processes, and services currently make up the largest share of the total global market. This is followed by the leading market of environmentally friendly production, storage and distribution of energy at 18.2 per cent, then by the markets of sustainable water management and raw material and material efficiency at 17 per cent. Due to the differing growth rates of the individual leading markets, their shares in the global GreenTech market will change in the period up to 2030.

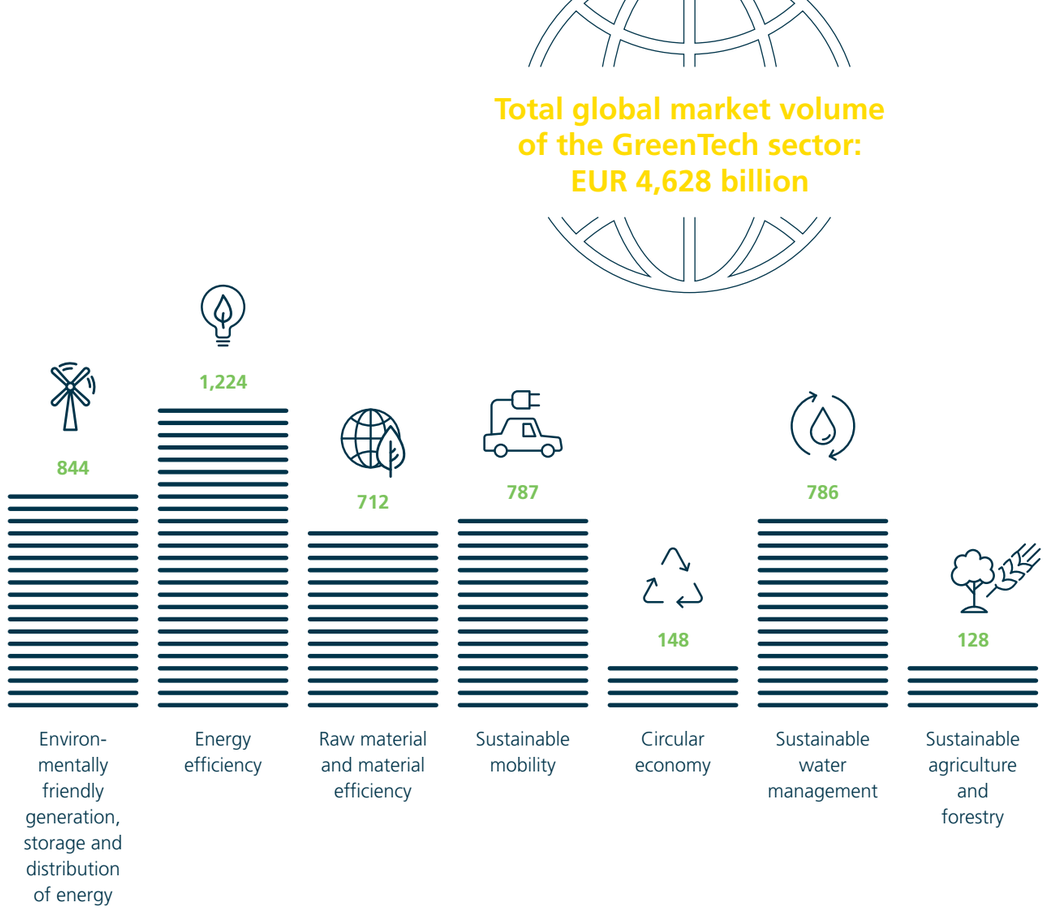


Figure 5: Global market volume of the seven leading markets for GreenTech [11]

In addition to estimates of sales growth, the **development of employment** figures is also an important growth indicator. Companies in the GreenTech sector expect to see an average annual increase of 6.8 per cent in their number of employees by 2025. The companies with a focus on the leading market of energy efficiency have particularly ambitious goals: They expect their employee numbers to grow by an average of 8.7 per cent each year. The expectations are lowest for companies with a leading market focus on the circular economy: The respondents expect an average annual growth of 4.5 per cent in the number of employees by 2025 [11].

2.4.2

Environmental-economic growth models

Growth models for the GreenTech industry are developed on the basis of environmental-economic theories that focus on political framework conditions for the protection of natural resources, institutional regulations, and economic innovation theories. From a political point of view, it is a question of creating appropriate framework conditions for the protection of resources through regulations and technological innovations.

The concept of innovation in GreenTech technologies plays a central role in this regard. **Resource protection** a**nd economic growth** can be integrated with one another on the basis of innovation theory. This means that increased start-up activities, entrepreneurial growth, expansion, and innovative technologies form core components of their relevant growth models.

Another essential concept is the pricing of negative environmental effects. By taxing the unsustainable effects of economic activity (e.g. CO_2 emissions), companies can only achieve an economically positive result if they invest in green technologies, despite the higher investment costs for GreenTech. In addition, the associated costs of green technologies are offset by a significant reduction in emissions costs. In this way, an effective combination of regulation, pricing, and promotion of innovation is essential to stimulate the growth effects associated with GreenTech [49].

2.4.3
The starting point for GreenTech companies

"GreenTech – Made in Germany" is in demand. German providers have gained a strong global market position in recent years. Products, processes and services "Made in Germany" have a great reputation worldwide and lay the foundations for the strong export performance of the German GreenTech industry. While the German share of global economic output as a whole is around 3 per cent, GreenTech companies contribute around 14 per cent to this global market [11]. **Europe remains the most significant market for German GreenTech providers**. Meanwhile, international competition is significantly increasing. Particularly in the USA and China, innovative GreenTech clusters have developed [21], [45].

The GreenTech sector in Germany is **heavily characterized by medium-sized enterprises**: Some 91 per cent of GreenTech's players are small and medium-sized enterprises (SMEs), with 44 per cent of companies employing a maximum of ten employees. Global transformation processes, for example in the energy sector and the automotive industry, are accelerating demand. In the future, this will require a **greater focus on innovation** and efficiency along the entire value chain: from customer acquisition and financing to operation and maintenance [11].

GreenTech companies with a focus on the leading markets of "sustainable mobility" and "energy efficiency" expect the highest growth dynamics: an average annual sales growth of 12.9 per cent by 2025. The expectations for companies with a market focus on the "circular economy" are much less ambitious [11]. This is reflective of the differing starting situations across GreenTech's leading markets: For example, the providers in the leading market of sustainable mobility expect to see a growth spurt, which is largely due to the increasing demand for alternative drive technologies. New providers offering innovative mobility solutions to compete with established players in the automotive industry, such as Google in the field of autonomous driving or Tesla in battery construction, are giving further impetus to these developments. Products and services such as these act as additional drivers of innovation and ensure that the leading market continues to expand.

In contrast to other industries, some of which have suffered heavily from the consequences of the COVID-19 pandemic, GreenTech is largely **crisis-resistant**. Almost half of the providers (48 per cent) rate the current business climate as "satisfactory" and 37 per cent consider it to be "good". Looking ahead, companies also estimate the impact of COVID-19 on the GreenTech industry to be significantly lower than on the economy as a whole [11].

2.4.4
Importance of digital technologies

In order for Germany to achieve its climate targets by 2030, there must be a reduction of 262 metric tons of CO_2e in the next 10 years. Accelerated digitalization could s**ave up to 58 per cent CO_2e** [16]. This not only helps to protect the environment and climate; digitalization also improves the competitiveness of the German economy.

The systemic integration of digital solutions, technologies, products, and services forms the **basis for GreenTech ecosystems**, e.g. in the mobility sector. Other specific applications exist in the energy sector, for example in the digital energy management of buildings, or through the building information network, a networking system for construction processes that aims to maximize the resource productivity of building materials throughout the entire life cycle [12], [50].

In addition to new business models and platforms, digital technologies form an essential basis for cost efficiency. One challenge for the German GreenTech suppliers will be to maintain their good position in the global market. In order to secure future market success at home and abroad, German companies need not only innovative products but also a competitive cost structure [11]. Talent and expertise, as well as the ability to pair successful start-ups with innovative business models [45], are also key factors in competing globally alongside the "digital giants" of China and the USA.

In product development, the development costs, product design, and manufacturing and material costs must be continuously optimized. At the same time, process costs in purchasing, logistics, sales, and energy supply must be reduced. Therefore, digitalization, process efficiency, and strict value orientation are among the most pressing challenges in the industry, for companies that want to remain competitive in the long term [11], [21].

2.4.5
Political measures

National and European political initiatives, as well as investors' increasing interest in sustainability, are benefiting the GreenTech industry. For example, the **Green Deal of the EU Commission** has a positive or even very positive effect on the further development of the companies [11], [51].

The impact of **standardization and certification** is similarly encouraging. **Sustainable finance**, i.e. the consideration of environmental aspects in financial decision-making, is seen as beneficial in the industry. By contrast, studies show that the European Emissions Trading System (ETS) – reformed by the European Green Deal – and CO_2 pricing have been of rather limited importance so far [11], [12]. The lack of impact these measures have had is due in particular to low CO_2 pricing, the emissions trading system not functioning, and all-inclusive participation not being compulsory [52].

Driving factors can create the conditions required to generate solutions faster and on a larger scale. Some factors, such as the change in the policy framework and the shift in capital, are more relevant and have a direct impact [49]. Other factors, such as the development of cultural consumption patterns and the development of political power, are less relevant and have an indirect effect. Some factors are highly dependent on social and political contexts and operate at different levels, from individuals to larger groups to entire nations [41].

Political power is a prerequisite for creating change. In the past, too much power has been wielded against climate protection and too little has been focused on advancing solutions. **Political targets** determine the direction. What do we want to achieve, and why? In terms of climate, but also more generally, targets can be specific and numeric (e.g. "carbon neutral by 2050"), or they can be higher-level, systemic aspirations (e.g. "a climate-conscious future") [41]. Sometimes a new target can dramatically change the direction we are heading – and the solutions and approaches we implement [49].

Rules set limits and indicate what is desirable and encouraged, or what is undesirable and sanctioned. Laws, regulations, standards, taxes, subsidies, and incentives are ways to change the state of affairs in terms of climate, but this depends on who is writing the rules. Political change can advance solutions while stopping the root causes of the problem [41], [51].

In our economic system, money is the necessary fuel for change. **Public and private investment** and philanthropic donations can stimulate and support climate solutions and efforts to drive them forward. Disinvestment is also very effective, as it takes away capital from the perpetrators of the problem, restricting their actions [41].

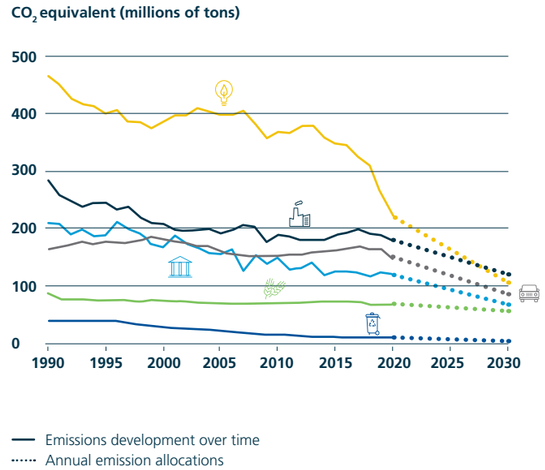
To stop the sources of emissions, the **technology** must evolve. "Now is better than new" when it comes to climate solutions, but through innovation and research and development, the technology can be further improved and contribute to the existing solutions. This is particularly important for the most difficult sectors, such as heavy industry and air transport.

To meet the SDGs and achieve green, sustainable development, many countries have introduced special programs and subsidy schemes. For example, the Chinese government has provided a large number of R&D incentives to promote green energy and to provide intensive support for green innovation, new eco-technologies, environmental protection, and the optimization of the industrial structure [45]. Most companies need **external support and incentives** to subsidize social and environmental activities.

Policy makers provide incentives for companies **to switch from high-emission and high-energy processes to green activities** and sustainable practices. Governments and public institutions in emerging markets prefer to invest in the industrial sector to shape green innovation and green activities. Regulatory pressure and government intervention have a significant impact on green activities and green innovations in companies. Governments provide funding and supporting materials to promote and improve green practices and innovation in the corporate sector [41], [45].

2.4.6
Measures in sectors

In addition to general measures to promote the growth of GreenTech, it is also worth looking at individual sectors. As in the reference model, the sectors of industry, mobility, buildings, energy, and agriculture are considered separately.



Eine Übersicht mit detaillierten Werten je Sektor und Jahr befindet sich im Datenanhang. Quelle UBA (2021a), Bundesregierung (2021)

Figure 6: Development of greenhouse gas emissions and agreed annual emission levels according to sector by 2030 [8]

Annual reduction targets are set for the different sectors from the year 2020 in the German Climate Protection Act (Klimaschutzgesetz) by setting annual emission levels. Emissions from the energy, industrial, transport, agriculture, and waste management and recycling sectors were within the permitted annual emission levels for 2020. In particular, the energy industry remained significantly below the annual emissions permitted for the sector – by just under 60 million tons of CO_2 equivalent. By contrast, the target value in the building sector was exceeded by 2 million tons of CO_2 equivalent [8]. The requirements of the new German Climate Protection Act demand a significant reduction in CO_2 emissions in the coming years. By 2045, greenhouse gas neutrality will be set as a strategic goal across all sectors (see Figure 7).

Industry

One approach to promoting GreenTech is based on **Carbon Contracts for Difference** – (CCfD). Carbon contracts compensate for the additional costs of greenhouse gas-neutral technologies compared to fossil-fuel reference technologies. Studies focus on CCfDs for products in the development and growth phase as well as for renewable energy sources [39]. In the case of product CCfDs, the cost difference in the end product, including specific invest-

ment costs, is considered and compensated (relevant in the steel, basic chemicals, and cement and lime industries, for instance, when introducing process technologies). In the case of energy carrier CCfDs, the cost difference resulting from the use of renewable energy sources is compensated.

Depending on the industry sector, existing fossil-fuel heating systems will have to be replaced by **power-to-heat**, **biomass**, and **hydrogen technologies** by 2045. The investment incentives required for this can be stimulated by funding programs or special depreciations. In addition, there are investments for **pilot plants for new production** processes (smart factory, digital twins, etc.). Studies address funding programs for corresponding investments amounting to 40 per cent of the investment value [39].

Other measures in industry relate to the **definition and promotion of efficiency standards**. These are standards that aim to efficiently combine cross-section technologies. The definition of standards should be based on the existing European Ecodesign Directive. In addition, funding programs for efficiency improvements must be adapted in such a way that highly efficient technologies can be implemented with accelerated depreciation. The **promotion of "green lead markets"** is also important. To create secure markets for sustainably produced end products and green raw materials (mainly in cement and steel), end producers in selected industrial sectors could be obliged to purchase raw materials from green production. This can be combined with sales regulation within the EU. This means that only end products produced from green raw materials will be able to be sold in the EU [39], [53].

Other approaches for promoting GreenTech in industry include the definition of green raw materials, general support for innovation and research, the reform of building standards, higher recycling and recycled material rates for plastics, and an increase in recyclable materials. Options for compensating significantly affected industries should be included in the introduction of appropriate measures. **Suitable compensation instruments** include, for example, the continuation of the existing electricity price exception stocks and the electricity price compensation, state transmission grid subsidies, hardship funds (limitation of the additional burdens to a still-to-be-defined share of gross value added), the elimination of the EEG (German Renewable Energy Sources Act) levy as a function of CO_2 prices, and the extension of the "New ETS" to BEHG industries in order to avoid intra-European distortions of competition [39], [49]. Further approaches to promoting GreenTech in industry include the **definition of green raw materials, general support for innovation and research, the reform of building standards, higher recycling and recycled material rates for plastics, and an increase in recyclable materials**. Options for compensating significantly affected industries should be included in the introduction of appropriate measures. Suitable compensation instruments include, for example, the continuation of the existing electricity price exception stocks and the electricity price compensation, state transmission grid subsidies, hardship funds (limitation of the additional burdens to a still-to-be-defined share of gross value added), the elimination of the EEG (German Renewable Energy Sources Act) levy as a function of CO_2 prices, and the extension of the "New ETS" to BEHG industries in order to avoid intra-European distortions of competition [39], [52].

The relevant core instruments relate to the promotion of the charging and H2 infrastructure in order to create the **earliest and most extensive expansion of charging and H2 infrastructure**. Appropriate investment support should be provided to bridge non-economic operating phases. This amounts to approximately four billion euro in funding requirements in 2025, and approximately two billion euro in 2030 [39].

In addition, **sales incentives for battery and H2 cars** are crucial. Purchase incentives to partially overcome the purchase cost disadvantage of cars with alternative drive systems should be extended beyond 2025, but gradually reduced. The purchase premium amounts to around 12 billion euro in 2025 and between 2 and 3 billion euro in 2030. The reductions in car tax and company car tax should be maintained [39].

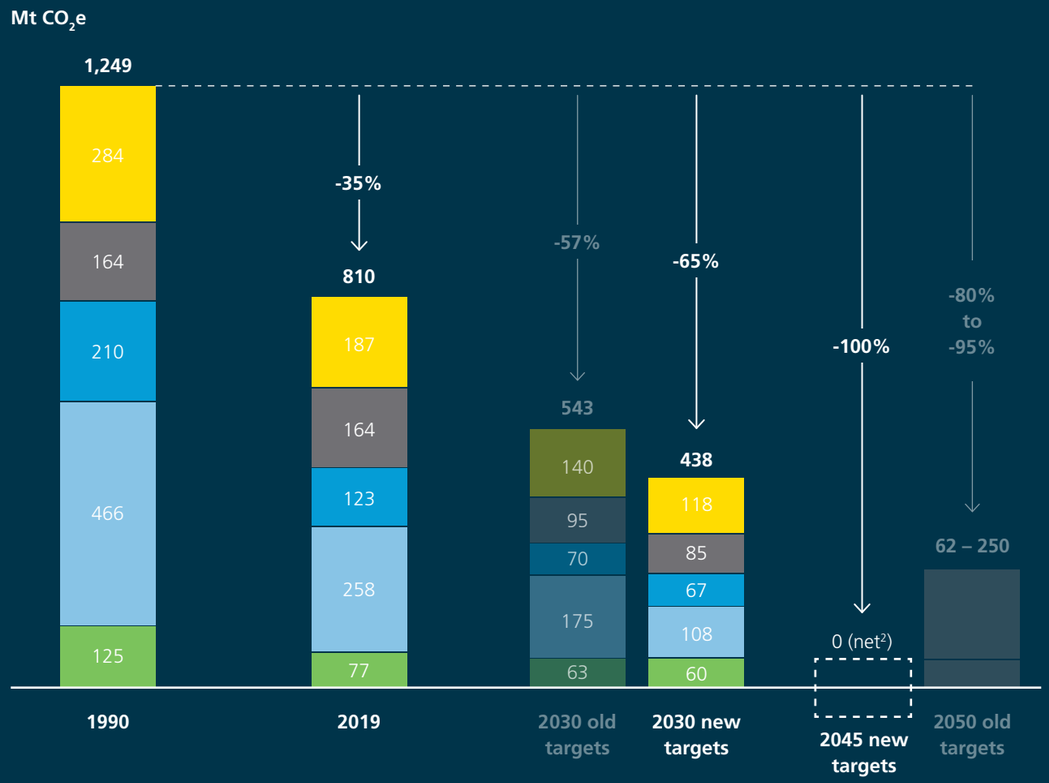
Studies also call for an **extension of the agreed toll exemption for electric and fuel-cell HGVs**. In principle, the toll should be based on the CO_2 emissions of the drive system in anticipation of the revision of the Eurovignette Directive. In the longer term, the toll advantages should be gradually reduced in line with market ramp-up and full-cost development of alternative HGVs [39].

Mobility

The mobility sector is characterized by different developments. They include the t**ransition from propulsion technologies to electric mobility**, **car sharing, autonomous driving, and new mobility services**. This transformation has similar effects on climate change and involves substantial investment. Major investment includes **constructing charging and H2 infrastructure**, converting cars and HGVs to alternative drives, and **constructing PtX (Power to X) plants** abroad [39].

In addition, comprehensive instruments for reducing CO_2 can be used, for example, through p**ricing fossil fuels via ETS and BEHG**, or by shoring up the "New ETS" price via the energy tax. In addition, studies indicate that **energy taxation needs to be harmonized**. Green hydrogen and green synthetic fuel such as electricity should be taxed. The taxation of biofuels is based on the degree of sustainability. The difference in tax treatment between gasoline and diesel should be abolished [52].

The German Climate Protection Act requires greenhouse gas neutrality by 2045



	1990-2019 (1990=100%)	2019-2030 (2019=100%)
Industry	-34%	-37%
Transport	-0%	-48%
Building industry	-41%	-46%
Energy industry	-45%	-58%
Other[1]	-38%	-22%

Figure 7: The German Climate Protection Act requires greenhouse gas neutrality by 2045 [39]

Studies also call for a **progressive PtX quota for fuel suppliers** with a target value of 10 per cent in 2030 (national). The PtX ramp-up should be supported by a double-auction mechanism, which concludes purchase contracts with PtX producers and resale contracts with customers through a public intermediary. A public cost risk could be avoided, for example, by a levy on fuel customers [39].

Further approaches to promote GreenTech relate to **information campaigns** on the promotion and advantages of alternative drives, **structural standards** for electromobility, a digital register for charging stations, the design of the vehicle tax for commercial vehicles as an incentive to switch to alternative drives, the definition of PtX sustainability standards, **partnerships** with PtL export countries, the acceleration of **rail infrastructure** measures, the expansion of overhead line infrastructure within the framework of the overall concept of "**eco-friendly commercial vehicles**," as well as **research funding for aviation** [39].

Building industry

Within the scope of GreenTech, the building industry can be transformed above all by means of **standards on energy demand and infrastructure planning**. On the basis of the meta-analysis of existing studies, the identification of building-specific primary energy requirements planning must be documented [39]. Targets for space heating and hot water requirements must be identified, together with a phased commitment to prepare renovation timetables between 2023 and 2028 (starting with the buildings most in need of renovation). At the same time, studies within the framework of an innovation clause call for a regular **review of the CO_2e sector targets** and, if the targets are not met, as a last resort, an announced, staggered obligation to meet the primary energy demand targets within ten years. This can be coupled with additional promotional offers [39].

To optimize infrastructure planning in municipalities, systematic and economically efficient **planning of heat and network infrastructures** is required. This should be based on a demand survey in urban municipalities and rural districts where the determination of energy sources is specific to the buildings. The infrastructure planning, which must be made mandatory by the municipalities, can be carried out gradually. Urban areas must be prioritized. As part of an innovation clause, the CO_2e sector targets should be regularly reviewed and, in the event of a failure to meet the targets, possible application-related (for example, when replacing a gas boiler) specifications should be made for heat planning-compliant heating [39].

In addition, studies suggest that the **funding programs should be combined with faster, more comprehensive renovation and a change of energy source**. This also includes a combined bonus for several renovation measures as well as a sprinter bonus for the replacement of energy carriers up to 2030. The promotion of energy solutions (for example hydrogen boilers) should be linked to the availability shown in the municipal infrastructure plans or to a proven local operation, which is completely greenhouse-gas-neutral, from start of operation [39].

Further measures relate to the **renewable energy requirement** in new builds. From 2025 at the latest, only local, completely greenhouse-gas-neutral heating solutions should be approved for installation in new builds (heat pumps and district heating; in the case of oil and gas boilers, only fuels that are neutral for greenhouse gases from start of operation) [39].

In addition, approaches to the promotion of GreenTech relate to **promoting skilled workers** including technicians, planners, and tradesmen, p**romoting innovation in serial renovation**, information campaigns on energy renovation, as well as the BEHG transfer capacity for the tenant depending on the energy-related building condition, the **definition of standards to ensure the reuse and resource efficiency** of building materials, formulating standards and **quality criteria** for building automation (e.g. interoperability, technical flexibility), r**eforming the German Ordinance on the Supply of Heat** (Wärmelieferverordnung), and **considering rising CO_2 prices** for fossil fuels [39].

Energy

The energy industry is particularly in the spotlight because of the significance of the energy transition. One key approach concerns the **development of renewable electricity generation capacity**. The current renewable generation capacity must more than double by 2030 to meet the increasing demand for renewable electricity during the energy transition. The target path includes 140 GW of photovoltaics, 98 GW of wind power on land, and 28 GW of wind power at sea to meet a rise in net electricity demand to 722 TWh while meeting the emissions budget (2019: 507 TWh) [39].

In addition, a **network expansion is required** at all voltage levels. An enormous network expansion is needed to integrate renewable energies (especially wind at sea), connect large new consumers (for example electrolysis, power-to-heat in industry, electric mobility), and create a flow of electricity that is as free from bottlenecks as possible. The **ambitious current network development plan** must be exceeded by 2035 and accelerated as early as 2030. At the same time, the distribution networks need to be considerably expanded and digitalized, and **consumers need to be made more flexible** within the framework of technical and economic limits, so that electrical consumers such as battery vehicles or heat pumps receive price signals for flexible operation in the electricity system [39].

Finally, the **expansion of thermal power** is essential to ensure security of supply. To hit the climate protection target for anticipated electricity consumption, coal generation will be phased out by 2030. In order to remove these capacities from the grid, more than 40 GW of gas-fired power stations would have to be built up by 2030 to ensure security of supply (especially in times of low wind and sun), otherwise coal-fired power will continue to be required. This corresponds to the **most ambitious increase in thermal power** ever to take place in Germany over such a period [39].

Parallel measures relate to the development of **hydrogen and CO_2 transport infrastructures**. To use hydrogen as a new climate-friendly energy carrier in all sectors, it is necessary to set up an individual hydrogen infrastructure connecting central production on the coast and later imports, especially from the South, with large customers (in particular steel, basic chemicals, and later energy). The necessary use of carbon capture and storage (unavoidable process emissions, negative emissions) also requires the installation and conversion of CO_2 pipelines in Germany [39].

The **pricing of fossil fuels via ETS and BEHG** and the support of the "New ETS" price via the energy tax are relevant as overarching CO_2 instruments. To stimulate the faster expansion of renewable electricity generation capacity, **auction volumes and remuneration for renewable energy** should be adjusted. Compulsory area quotas and bilateral differential agreements for wind and photovoltaics as well as significantly accelerated planning, approval, and objection procedures should ensure the achievement of the expansion goals [27], [39].

Digital technologies continue to be relevant when it comes to making **electricity consumption more flexible**. Electricity distribution networks, consumers, and suppliers need to invest heavily in digitization and flexibility, for which appropriate incentive regulation should be put in place. The introduction of incentives for customers such as matching algorithms can also lead to more system-friendly consumption.

Other possible approaches in the energy sector relate to the social support of the earlier phase-out of coal generation, increasing the attractiveness of roof-mounted photovoltaics, H2-ready standards for new gas-fired power stations, increasing the attractiveness of trade in renewable electricity, the coordinated development of electrolyzers, introducing a "target network" in the network development plan, measures to increase the acceptance of the energy transition, integrating decarbonization incentives in the Combined Heat and Power Act (KWKG), the expansion/federal funding of efficient heat networks, and optimizing municipal heat planning [39].

2.4.7 International cooperation

Promoting the growth effects associated with GreenTech is relevant for Germany as a business location, but special national programs must be integrated into the general orientation of the EU. The European Green Deal provides a good basis for this. Results of existing studies indicate that the **growth of green technologies benefits immensely from international cooperation** [54], [55]. Empirical studies show a clear link between the expansion of international cooperation in the development of green technologies and the decline in CO_2e. This finding indicates that measures taken by politicians and industry leaders results in an expansion of international cooperation in research and development, leading to a decline in CO_2e. For example, the US significantly expanded its activities between 1990 and 2018, focusing mainly on the international development of green technologies [54].

2.4.8 Social and cultural change

The development of green technologies is integrated into a **social and cultural framework**. This is expressed, for instance, in **established patterns of production and consumption** as well as in the **fundamental importance of questions of sustainability**. Therefore, **culture is a crucial factor** for climate solutions and measures. Cultural patterns limit what is right or wrong and thus indicate what is possible or impossible. The players involved in the climate transformation must keep cultural change in mind if society as a whole is to orient itself toward sustainability [41].

Visions, stories, art, and dialog are some of the means that can be used to (re-)shape culture and collective beliefs about how the world works or can function. Cultural change also always expresses itself in changes in behavior. From individuals to businesses and beyond, behavior is what is done and how it is done. All climate solutions have a behavioral dimension and some depend almost entirely on human habits. Knowledge, norms, criteria, and motivations can change behavior and create new ways of working. When behavioral changes add up, the results can change significantly [41].

Evaluation of the political agenda

The **coalition agreement of the new Federal Government** as well as corresponding legislative procedures and further political implementation can be used to evaluate the political agenda with regard to GreenTech. In addition, European and global initiatives, such as the Paris Agreement, the European Green Deal, and the recent Climate Change Conference in Glasgow (COP26) are crucial.

3.1

Global and European initiatives

The **Paris Agreement** is an international treaty signed by 197 countries at the **United Nations Climate Change Conference in Paris (COP 21)** on December 12, 2015, on the occasion of the United Nations Framework Convention on Climate Change. The Paris Agreement aims to protect the climate, following on from the Kyoto Protocol. As of today, 180 countries have ratified the agreement, including the world's largest CO_2 emitters, China, the USA, and India, along with the European Union and Germany. The common objective of the Convention is to limit the increase in the global average temperature to well below 2 degrees Celsius above pre-industrial levels and to limit the increase in temperature to 1.5 degrees Celsius above pre-industrial levels. The pre-industrial level is defined as the average value for the years 1850 to 1900. The aim is to significantly reduce the risks and effects of climate change. It also aims to increase the capacity to adapt to the adverse effects of climate change.

The **26th World Climate Change Conference (COP 26) in Glasgow** took far-reaching decisions on international climate protection. For the first time, the international community stated that the production of energy through the burning of coal is to be phased out. Inefficient subsidies for oil, gas, and coal will also be a thing of the past. The contracting states stressed that national efforts must be increased this decade to limit global warming to 1.5 degrees Celsius. The final declaration from Glasgow therefore calls on states to improve their climate targets for 2030 as early as 2022. In future, the gap between the 1.5 degree target and the global level will be checked every year, rather than every five years. The European Union has already laid down stricter climate protection targets by law. Germany wants to become climate-neutral by 2045 and reduce greenhouse gas emissions by at least 65 per cent by 2030.

The **European Green Deal** is a concept presented by the European Commission on December 11, 2019 with the aim of reducing net greenhouse gas emissions to zero within the European Union by 2050 and thus becoming the first "continent" to become climate-neutral. The Green Deal will become a central component of the European Union's climate policy and comprises a number of measures in the areas of financial regulation (sustainable finance), energy supply, transport, trade, industry, agriculture, and forestry. The current target of reducing the European Union's CO_2 emissions by 40% per cent compared to 1990 by 2030 will be stepped up to a reduction of 50 to 55 per cent. To this end, the EU member states will adapt their climate plans accordingly by 2023. The EU Commission presented a corresponding law (**European Climate Act**) on March 4, 2020. In addition, the countries particularly affected will be supported with a total of 100 billion euro in the transition to an emissions-free economy. The second action plan for the circular economy was also presented in March 2020.

3.2

The political agenda of the new Federal Government

The coalition agreement of the new Federal Government was presented in November 2021 and relates in many areas to the European and global initiatives mentioned above. The coalition agreement includes a wide range of targets and measures that are compatible with the GreenTech reference model. Many targets and measures are only roughly outlined. Further details can be expected as the political implementation continues.

In addition, the coalition agreement sets priorities. Certain directions and technologies are clearly focused, while some approaches are not dealt with at all. The connection between technology and climate transformation is hardly examined at all and can only be found in a few subclauses. In general, the following findings can be recorded on the basis of the GreenTech reference model.

Concept level

The term GreenTech is not used within the coalition agreement. In general, the **link between climate change and technology** is only addressed in two passages. For example, digital twins and other technologies are characterized as a key factor in a competitive and climate-neutral industry. But the emphasis on the importance of technology and the reference to integrating climate transformation and digital transformation is surprisingly weak.

Importance of digital technologies

Regardless of the climate debate, the importance of digital technologies is underlined at various points in the coalition agreement. This is already the case in the preamble ("We want to make better use of the potential of digitalization"). In total, twelve passages contain **specific references to targets and measures in the context of digital transformation**. This initially includes general passages on the importance of digitalization and the transformation of the economy and society. In three passages, the Federal Government calls for the bundling of its competencies in the field of digitalization, an agile administration, and the promotion of digital innovations. Digital technologies are highlighted in three other passages as a means of simplifying planning and approval processes. The focus will be on **implementing the German Online Access Act** (Online-Zugangsgesetz), simplifying IT-based procedures, identity management, an **open source cloud in public administration**, as well as strengthening **digital civil rights** and **IT security**.

Questions on **digital infrastructure** are addressed in two further passages. The first concerns the expansion of the supply of fiber-optic and mobile phone standards. In addition, a data infrastructure will be set up that enables data to be integrated, sets high standards in data security, and makes data available in the form of open data.

Germany is to be maintained and expanded as a technology location. Corresponding targets and measures can be found in two further passages. This addresses, for example, the **promotion of key IT technologies** such as artificial intelligence, quantum computing, cybersecurity, distributed ledger technologies, robotics, and the **technological sovereignty** of Germany as a whole. Finally, the coalition agreement establishes specific references to individual sectors in two other passages, namely the promotion of **Building Information Modeling** (BIM) in the construction and real estate industries as well as the **digitalization of schools through the digital pact**.

As an interim conclusion, it can be stated that the Federal Government provides space for the topic of digitalization within the framework of the coalition agreement. Important issues are addressed. However, given the importance of digital technologies for the transformation of the economy and society, individual measures should perhaps have been emphasized and identified. The approaches outlined above are desirable for bundling the competencies of the Federal Government and promoting key IT technologies. Unfortunately, the connection between digital transformation, climate change, and GreenTech is not addressed at all.

Environmental effects

One key motivation of the Federal Government is to **strengthen measures to tackle climate change**. Therefore, the discussion of environmental effects within the framework of the coalition agreement takes up a large amount of space. In total, environmental effects as well as the corresponding targets and measures are outlined in 37 passages.

Reference is made primarily to a **general emphasis on the climate crisis** and the orientation of the German government's work in relation to the Paris climate protection goals in six passages. The political targets and measures should be aligned with ecology and economy in equal measure. In addition, the Federal Government is committed to the **17 Sustainable Development Goals of the UN**.

The **energy transition** occupies the largest space within the sub-area of environmental effects. The Federal Government stresses the need for **developing renewable energies.** The main aims are the orientation around the 1.5 degree path and the achievement of technology-independent climate neutrality in the Federal Republic of Germany by 2045. This should go hand in hand with removing bureaucratic barriers to the development of renewable energy sources. In the future, 80 per cent of the national energy requirements will be met by renewable energies. Some of the measures include expanding PV plants to 200 GW by 2030, using wind energy on 2 per cent of the land area, **promoting bioenergy and geothermal energy**, and implementing modern gas-fired power plants.

Within the coalition agreement, individual measures in different areas are then described and linked to the outlined climate goals. Reference is made, for instance, to the issue of **energy efficiency and promoting efficiency measures**. The energy networks will be expanded. This is an essential factor for producing and transporting electricity from renewable energy sources. Particular emphasis is placed on **expanding electrified and digital networks**. In some passages, reference is made to **green hydrogen**. Research and implementation of the use of green hydrogen will be accelerated. This is also linked to the development of a hydrogen infrastructure for the production and transport of green hydrogen. In this context, the Federal Government wants to push ahead with the implementation of the IPCEI (Important Projects of Common European Interest) for green hydrogen. Another focus is on the promotion of **battery technologies**. The Federal Government wants to set up a center for research, production, and recycling of battery technologies. Further specific measures relate to the promotion of biodiversity, the creation of synergies between nature conservation and climate protection, the implementation of carbon capture strategies, the promotion of a circular economy, and the reduction of primary raw material consumption.

Finally, the coalition agreement sets special priorities for individual sectors. They apply in particular to the industrial, agricultural, and mobility sectors. **Reducing the consumption of resources in industry** is addressed in three passages. The aim is to promote the **implementation of digital twins** for better planning and control of production processes as well as for resource conservation. In view of the increasing demand for cloud infrastructures, the development of green data centers is supported. In general, the coalition agreement calls for the use of technologies for a competitive and climate-neutral industry. The Federal Government intends to make an intensive effort to formulate an **industrial strategy for the Green Deal at EU level**.

The implementation of **sustainable agriculture** is also addressed in three passages. From the Federal Government's point of view, this requires regional value chains. In addition, **technologies for reducing drift** and for the p**recise application of crop protection** and fertilization will be promoted. The **availability of public data** for agriculture is an essential precondition for this. This will strengthen the general development of a data infrastructure and the joint production and use of data in agriculture.

The mobility sector is the most important sector in the coalition agreement. This is fundamentally linked to the **transformation of the automotive industry**. Corresponding

Germany aims to become climate-neutral by

2045

passages can be found at seven points of the coalition agreement. They call for **concepts for sustainable mobility of the future** and for the decarbonization of the mobility sector. Germany will be expanded as a **leading market for electromobility**. This is linked with the considerable modernization of the general infrastructure and especially the rapid and massive expansion of the charging infrastructure. Looking ahead to further disruptive developments within the automotive industry through sharing concepts and autonomous driving, Germany will be positioned as an **innovation location for mobility concepts** of the future. Further priorities are set in the digitalization of the rail network, the **promotion of digital mobility services**, car sharing, and the creation of a pioneering position for CO_2-neutral flying.

The following should be noted as an interim conclusion: The new Federal Government is focusing on the issue of climate and dedicates a total of 37 passages in the coalition agreement to the various targets and measures. The focus is on the energy transition, the promotion of renewable energies, and the transformation of the automotive industry. The individual building blocks of the coalition agreement have been set appropriately. From the perspective of GreenTech, it would be desirable for the role of various technologies in the realization of the set goals to be emphasized. The influence of digital technologies is also addressed in individual measures, but is still insufficient in its overall scope.

Economic and social effects

In addition to the outlined environmental effects, the coalition agreement also addresses the other dimensions for sustainability. However, the description of economic and social effects is much shorter. Altogether, relevant content can be found in only six passages.

In this context, the objective formulated by the Federal Government to convert the economic system into a **socio-ecological market** economy is important. This is linked to a **set of rules for innovation** to bring Germany on the 1.5 degree path through various measures. The coalition agreement also emphasizes the aim of creating safe markets for energy-friendly products. This will be implemented, for example, by means of minimum quotas in public procurement.

From an economic point of view, the Federal Government also addresses compensatory measures. This concerns, for example, **ensuring competitive electricity prices for businesses**. At the same time, all potential for the switch to renewable energies will be exploited. **Energy partnerships** will be established between different actors in relation to green hydrogen.

Overall, the coalition agreement formulates the aim of **modernizing Germany as a location** f**or industry through new business models and climate-neutral prosperity**. Sustainable jobs will be created through technological innovations. This approach is also anchored in the GreenTech reference model.

As an interim conclusion, the combination of environmental, economic, and social targets and measures in the coalition agreement does not go far enough. The interaction of the three dimensions for sustainability is recognized by the new Federal Government and addressed in a few passages. Overall, however, the statements on the economic and social effects remain superficial. In particular, the interaction between the three sustainability dimensions is not adequately addressed.

Growth models

The coalition agreement addresses different targets and measures in the creation of the framework conditions for growth by GreenTech. These are not directly related to GreenTech. However, the policy-making measures can be linked to the content of the reference model. There are a total of 65 passages that can be interpreted as political support in the context of climate change.

Most of the passages on policies for growth relate to the **mobility sector**. A total of 16 passages address the changes in the automotive industry in particular. The German government wants to focus on promoting the mobility transition. Related measures are discussed in the **strategy platform "Transformation of the automotive industry"** (Transformation Automobilwirtschaft). The change will be implemented by pushing the transformation toward electromobility. In this context, the coalition agreement provides for targeted cluster funding and the further development of European battery projects. The establishment of cell production sites is to take place with measures from the development to the recycling of battery technologies. Only **CO_2-neutral vehicles will be eligible for registration** by 2035. Compliance with fleet limits for CO_2 emissions is adjusted and defined as a standard for all manufacturers. The promotion of electric vehicles is only envisaged if there are positive climate effects. This is linked to phasing out the funding of plug-in hybrids. An **electrical minimum range of 80 km** is set for new vehicles. In addition, support will be provided to implement the ambitious Euro 7 pollution standard. A target of one million public charging points by 2030 has been set for the expansion of the electromobility charging infrastructure. This requires removing red tape when developing the charging infrastructure. The new charging infrastructure should also enable bi-directional charging and provide more transparency on prices and availability status. In addition, a comprehensive system of **fast-charging hubs** is required. Further measures relate to the implementation of a mobility data act on the free availability of mobility data. This makes it possible to use data on mobility activities in a way that is neutral for competition. Finally, the new Federal Government plans to **implement a law on autonomous driving**.

Further targets and measures in the field of mobility relate to the **expansion of transport infrastructure with a focus on rail travel**, a CO_2 differentiation in the HGV toll, and the **introduction of CO_2 prices for freight transport from 3.5 tons**. The funding program for climate-neutral buses will

be maintained. In addition, the development of a 2030+ aviation concept for the future of airports is planned. This also includes reducing short-haul flights as well as improving rail connections.

The second major focus of GreenTech's targets and measures for growth is **promoting start-ups.** The coalition agreement contains ten passages on the subject. These relate, among other things, to the general improvement of conditions for start-ups in Germany as an industrial location and the **strengthening of venture capital provision**. One special focus in the coalition agreement is access to venture capital. In addition, this will be supported by the start-up grant, easy access for start-ups to public tenders, **establishing KfW as co-venture capital provider for key technologies**, opening up the venture capital market to institutional investors, and facilitating public offerings and capital increases through dual-class shares. In addition, the acquisition of private sources of capital for transformation projects will be supported as part of an "Alliance for Transformation." The conditions for start-ups will continue to be improved through the **promotion of start-ups from universities and companies**, start-ups from business succession, as well as comprehensive contact points for start-up advice, and **simplifying start-ups**. In addition, the Federal Government wants to create incentives for leading markets and climate-neutral products. The start-up measures will be accompanied by **support for small and medium-sized enterprises** (SMEs). This is particularly true for strengthening SMEs in the use of digital technologies and simplifying support programs.

The third focus of the Federal Government is on the energy sector, with nine passages. This is particularly linked to the **development of renewable energies**. In this area, the coalition agreement provides for an extension of instruments for **non-subsidized enlargement**, **strengthening of the decentralized expansion of renewable energies**, and **accelerating planning and approval procedures**. In future, all suitable roof areas will be used for solar energy. The expansion of PV plants and wind farms as well as securing sea areas for offshore plants in the external economic zone is being pushed forward. Further targets and measures are aimed at **developing a biomass strategy**, **improving the data situation** for geothermal energy, **promoting tenant electricity and accommodation concepts**, as well as comprehensive **municipal heat planning**.

From the perspective of primary energy sources, the Federal Government is aiming for an **accelerated phase-out of coal-fired electricity generation**. Natural gas is regarded as a transition technology. In response to the war in Ukraine, the Federal Government has adapted this strategy and is pushing forward the **import of liquefied natural gas** (LNG) and the expansion of LNG terminals. In the medium term, the plan is to switch to **climate-neutral gases** (H2-ready) in combination with renewable energies. This is linked to the establishment of an **efficient hydrogen economy**, fair competition conditions for **importing hydrogen**, and the **certification of hydrogen** and its derivatives. In this context, an ambitious formulation of the Renewable Energy Directive that is technology-independent will be implemented.

The coalition agreement sets further priorities for improving electricity networks. A total of five relevant passages can be defined. The focus of the coalition is on **developing a climate neutrality network**. This relates to the development of "**electricity highways**" and f**acilitating the planning and implementation of electricity and hydrogen networks**. Aspects of digitalization are also included in the coalition agreement, for example with regard to digitalizing distribution networks and accelerating the **roll-out of intelligent measuring systems and smart grids**. Storage will be legally classified as an independent pillar of the energy system. The coalition agreement also calls for greater **citizen participation in the expansion of the network**.

In addition to the electricity grids, the coalition agreement also addresses **electricity markets** as a whole. Corresponding targets and measures can be found in six passages. In the view of the Federal Government, a new **electricity market design** will be developed. A platform on the topic of the "climate-neutral power system" will be established for this purpose. According to the Federal Government, corresponding efforts must be integrated into the European internal market. Guidelines for further development include **consideration of market prices** in support of combined heat and power, **creating incentives** for the cross-sectoral use of renewable energies, **promoting decentralized** production models, and **reviewing state-induced price components**. In addition, a **sector coupling in pricing** will be implemented, taking into account CO_2 prices. Financing of the EEG (Renewable Energy Sources Act) levy via electricity prices will be ended. Tax incentives for the economic use of electricity will cease in the future.

The targets and measures relating to the design of the electricity market illustrate the German government's European ambitions. In total, the coalition agreement contains six passages relating to **European coordination on energy issues**. They relate, for example, to the **harmonization of European standards** and the **establishment of an international climate club**. The aim is to find a **uniform minimum price for CO_2** and a common approach for **balancing CO_2 limits**. This is also reflected in participation in the EU's "Fit for 55" program. In the revision of the European emissions trading system, the Federal Government wants to promote an **ETS minimum price** and a **second emissions trading scheme** in the field of mobility and heat (ETS2). This is linked to the implementation of **social compensation mechanisms**. A harmonized emissions trading system in the EU should be in place by the 2030s.

From a sectoral point of view, the coalition agreement advocates, among other things, **promoting the transformation of industry**. A total of three relevant passages can be identified. The targets and measures relate to **regional innovation clusters** and to supporting industry in the climate transformation. Suitable instruments include **carbon contracts for difference** and other climate agreements. The new Federal Government wants to promote a Europe-wide mechanism for balancing CO_2 limits. This also takes into account technical negative emissions and **operating permits for fossil fuel energy infrastructure until 2045**.

Similar targets and measures to promote the **transformation of the building industry** can be found in two passages. This includes a funding program for new housing, taking into account greenhouse gas emissions. **Binding quotas for renewable energies** in new builds will be prescribed by 2025. This will be implemented in the same way for major extensions and conversions. In addition, **a switch to rent that includes part of the heating costs** and a **fair distribution of the CO_2 price** on heating costs between tenant and landlord is being sought.

The promotion of digitalization in agriculture is mentioned in one passage of the coalition agreement. This addresses the availability of public and state data in a harmonized format and the **creation of a data space based on the Gaia-X standard**.

For the financial industry, the new Federal Government plans to promote Germany as a leading brand for **sustainable finance and fintech**. This objective is driven by support for framework conditions for **sustainable financial products**. This should take into account European minimum rules for ESG ratings, sustainability risks in ratings, and transparency standards for sustainability information.

Irrespective of individual sectors, the coalition agreement dedicates a lot of space to the **design of better framework conditions for science and research**. A total of three relevant passages can be identified. They relate to the **promotion of knowledge transfer**, the **establishment of an agency for transfer and innovation**, and the e**stablishment of lighthouses and innovation regions** for research and transfer.

Other general positions of the new Federal Government include the **further development of the German Climate Protection Act**, the imposition of a program of short-term measures, the definition of climate protection as a cross-sectional task, and the examination of legislative proposals for their climate effects. In addition, the **climate effects for each sector of the economy** will be examined and reported in an annual monitoring process. The Federal Government wants to avoid the purchase of **EU emission trading certificates**. In addition, the **German sustainability strategy** will be further developed. This includes a program of measures on sustainability as well as an **increase in the binding nature of sustainability measures** through corporate governance.

Finally, another passage in the coalition agreement deals with promoting the **transformation to a circular economy**. The aim is to implement the **adaptation of legal framework conditions** and to drive the **development of a national circular economy strategy**. This includes, but is not limited to, standards for raw materials, product design, and raw material recycling, strengthening producer responsibility, digital product passports, waste prevention through return and deposit systems, the promotion of ideas for shared use, incentive systems for the recovery of raw materials from electrical appliances, the reduction of returns destruction, and incentives for recycling-friendly packaging. Quality-assured waste products will be given product status. Binding recycling quotas for companies are planned. Finally, chemical recycling will be promoted, municipal waste will no longer be sent to landfill, and a harmonized, level playing field for plastic recycled material will be created.

3.3

Evaluation in the context of the GreenTech reference model

An evaluation of the coalition agreement as well as the associated targets and measures of the new Federal Government in the context of the GreenTech reference model produces the following findings. In general, the coalition agreement contains many targets and measures that can be classified in the reference model. However, the concept of GreenTech itself is not addressed within the coalition agreement. In general, the importance of the **link between climate change and technology** is not awarded enough significance, given that it is of central importance for the transformation toward a socio-ecological market economy. Climate change can only be successfully managed on the basis of technological innovations combined with an orientation toward environmental, economic, and social aims. **At the same time, environmental effects, economic growth, and social equity should be established**. The interaction of these dimensions needs to be made clearer and substantiated in the form of a master plan. The coalition agreement contains many relevant individual measures in this area, especially with regard to the formulation of the desired environmental aspects. However, it is not adequately expressed as a complete idea.

A comparable finding applies to the topic of digitalization. The coalition agreement does address the key areas of digitalization. However, given the importance of digital technologies in transforming the economy and society, **a greater emphasis on the importance of digital technologies for growth and for achieving environmental goals** is desirable. The approaches outlined above with regard to bundling the competencies of the Federal Government and the promotion of key information technologies should be highlighted positively. Unfortunately, the connection between digital transformation, climate change, and GreenTech is not addressed thoroughly enough.

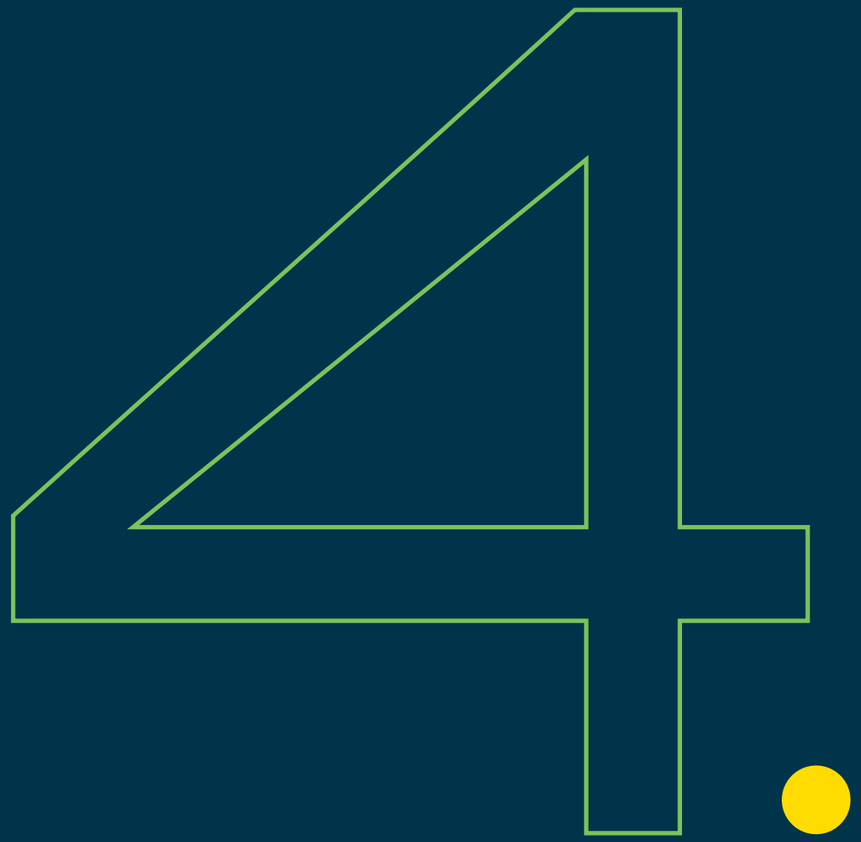
From an environmental point of view, the new Federal Government highlights the **targets and measures in place for tackling climate change**. These are urgently needed against the backdrop of the Paris Agreement targets and the European Green Deal. In the outlined targets and measures, the focus is on the energy transition, promoting renewable energies, and transforming the automotive industry. The individual building blocks of the coalition agreement have been set appropriately. From the perspective of GreenTech, it would be desirable for the **role of various technologies in the realization of the set goals to be emphasized**. The influence of digital technologies is also addressed in individual measures, but is still insufficient in its overall scope. Overall, the **economic and social effects of GreenTech** are **not sufficiently addressed** and the statements on these effects generally remain superficial. In particular, the interaction between the three sustainability dimensions is not adequately addressed.

In the discussion on growth strategies, the new Federal Government focuses **on the sectors of mobility and energy**, as well as promoting start-ups. The targets and measures outlined in these areas are very well formulated and clearly defined, meaning that the coalition agreement provides a good basis for further implementation.

The Federal Government's **strong focus on promoting start-ups** and the plans to simplify access to risk capital should be highlighted in a particularly positive way. However, the statements in the coalition agreement regarding the promotion and **transformation of small and medium-sized enterprises** are much weaker. Most companies in the GreenTech industry today are medium-sized enterprises. A large number of other medium-sized companies are starting points for the integration of GreenTech. In this respect, the coalition agreement makes no statement as to how small and medium-sized enterprises can play a more significant role in the growth dynamics of GreenTech.

What's more, the coalition agreement remarkably offers **relatively little content** in relation to other sectors such as **industry**, **agriculture**, and the **building sector**. The focus clearly lies on the energy transition, the expansion of renewable energies, the design of energy networks, and the sectoral adaptation of the automotive industry. Measures in the areas of energy and resource conservation or the circular economy, as well as corresponding implementation in the other sectors of the economy, are weak. The coalition agreement thus sets the right priorities, but remains imprecise in many key areas of formulation.

The Federal Government allows citizens to follow the work of the "traffic light coalition" through the **coalition tracker** [56]. There are 255 projects on the online platform, divided into areas such as digital, environment, climate and transport, and housing and construction. For each area, the number of planned projects and their status are indicated. Of the 255 projects, 18 are digital and 26 are environment, climate, and transport.



Expert survey

The methodology of the qualitative expert interviews follows an exploratory research design. A **qualitative survey with semi-structured interviews** was carried out for this purpose. Data was collected from individual interviews conducted either online as video conferences or by telephone. To ensure better traceability, all interviews were recorded digitally and then transcribed. The transcribed source text was initially analyzed on a case-by-case basis. This was the basis for developing a category system for the structured evaluation of the text material. The individual transcripts as well as the digital recording were destroyed after an aggregated evaluation to ensure the anonymity of the interviewees.

The methodical evaluation of the interviews is based on procedural models of **qualitative data analysis** according to Kuckartz et al. (2008). From a methodological perspective, qualitative data analysis consists of forming categories (=codes) and assigning individual passages to these categories (=coding). The data and analysis software MAXQDA was used to support the coding. The transcribed texts were first imported into MAXQDA. It was then possible to assign individual passages of the transcribed interviews to the defined categories.

On this basis, the data for each category was quantitatively evaluated and qualitatively interpreted. The quantitative evaluation refers to the quantity of codes per category. Appropriate evaluations can be visualized and thus provide an overview of the code frequencies or the significance of a specific topic from an empirical point of view. Subsequently, the individual categories can be interpreted with regard to the formulated objectives of the qualitative investigation.

The sample group for the qualitative survey was made up of **40 experts** who deal with the topic of GreenTech in their daily work in different functions and forms. The interviewees were assigned to different forms of companies or organizations (see figure 8). A distinction was made between experts from **industry**, **research**, **companies belonging to the GreenTech sector**, **NGOs** (=non-governmental organizations), **venture capital providers** (venture capital), **public sector organizations and companies**, and **consulting companies**.

As can be seen from figure 8, at 35 per cent (14 respondents), the majority of interviewees are in industry. Some 15 per cent (6 respondents) work for GreenTech companies and are the second largest group represented. The public sector and research institutions are represented among the interviewees at 13 per cent and 12 per cent respectively. 10 per cent each (4 respondents) are employed by NGOs or venture capital companies and two interviewees are employed by consulting companies. Figure 9 also shows the composition of the sample in terms of the **hierarchical position** of the interviewees in their organization.

Organizational form

Figure 8: Composition of the sample according to organizational forms (n=40)

Hierarchy levels

Figure 9: Composition of the sample by hierarchy levels (n=40)

For example, the management level of **CEOs/managing directors** and other members of the management board is represented by **43 per cent** of the experts. A further **48 per cent** of the interviewees work as **section or department heads**. Some 10 per cent of respondents are employees with no management responsibility.

4.1

GreenTech and relevant technologies

As outlined in Chapter 2.2, there is no single definition of the concept "GreenTech." For the definition of terms, multiple answers were possible in the interview. The six fields of action described in Chapter 2.2.1 are extensive: (1) energy sources and carriers, (2) energy production, distribution, and storage, (3) energy efficiency, (4) sustainable materials and products, (5) sustainable product design, manufacturing, and value-added processes, and (6) circular economy and product life cycles. Roughly speaking, **any technology that contributes to the pursuit of sustainable goals** can be defined as GreenTech. The experts surveyed broadly agree with this definition of the term.

"GreenTech describes any technology that makes our economy climate-neutral."

Sebastian Schaule,
Head of Division, Energy, Bitkom e. V.

Among the respondents who define GreenTech more precisely according to fields of action, most associate **GreenTech with decarbonization**. Forty per cent of respondents associate GreenTech with reducing or preventing CO_2. Examples include producing energy from renewable resources and creating **alternative forms of propulsion**. Thirty per cent of experts see technologies to **increase the efficiency** of resource consumption or energy use as part of the GreenTech concept.

A quarter of the respondents draw parallels with the established concept of **environmental technology**. They see environmental technology as a sub-area of GreenTech. In some cases, properties such as environmental protection or resource protection are classified as a pillar of GreenTech, and in some cases the experts surveyed even use the terms GreenTech and environmental technology interchangeably.

Around ten per cent of respondents see **environmentally friendly products as a dimension of GreenTech**, and choose a concept that goes beyond the purely technological component. Accordingly, they classify **products based on (green) technologies** as GreenTech. In the context of the product dimension, there is some discussion of a more sustainable replacement for existing products. The experts therefore also refer to technological products with sustainable properties that replace established and less sustainable products as GreenTech.

"GreenTech is everything that is better than average. This means that every product, every service, and every offer has to be reduced to its environmental compatibility or friendliness, and be evaluated by this, and is therefore naturally in competition with other services."
Sven Krüger, CEO & Co-Founder GREENTECH FESTIVAL

Ten per cent of the experts also consider the term GreenTech more narrowly in terms of technological optimization in production, as is the case with **saving raw materials and other materials in production**. This includes process optimization, process improvement, and value chain optimization.

The answers to the question of relevant technologies are as varied as the definitions of terms for GreenTech (see Figure 10). Multiple answers were possible in this case. At a total of 80 per cent, **alternative energies** are most commonly referred to as GreenTech technology. **Almost half of the respondents (45 per cent) see solar energy** as a highly relevant technology for substituting fossil fuels as primary energy sources. Thirty per cent of the respondents cite wind energy as another regenerative energy source. Hydropower is mentioned by only six per cent of the respondents. Some experts view hydropower more critically because of its impact on the habitats of the affected areas and its centrality.

In addition to solar energy, **digital technologies** are at the top of the list of GreenTech technologies at 45 per cent. They are referred to as **drivers and enablers** of GreenTech in various areas, in particular when it comes to optimizing value chains using **data analytics**, **digital twins**, and **intelligent algorithms** and **AI**. In addition, the interviewees mentioned digital technologies such as blockchain being used to monitor and optimize the product life cycle, and therefore avoid waste and analyze usage patterns. Due to the special importance of digital technologies for GreenTech, this is dealt with in a separate question in Chapter 14.2.

At **36 per cent, hydrogen and e-fuel, as well as energy storage systems**, are the third most important of the listed GreenTech technologies. The experts define energy storage systems as **battery technologies**, **other electrical storage systems**, and **heat energy storage systems**. In the context of hydrogen and e-fuel, the experts surveyed preferred their use in logistics, ship propulsion, aircraft propulsion, and industrial applications.

Fifteen per cent of the respondents respectively name **electric mobility** and **recycling** technologies as GreenTech technologies. Some respondents stress that the positive effects of electromobility can only be expected if the efficiency and resource protection of battery technologies are developed accordingly.

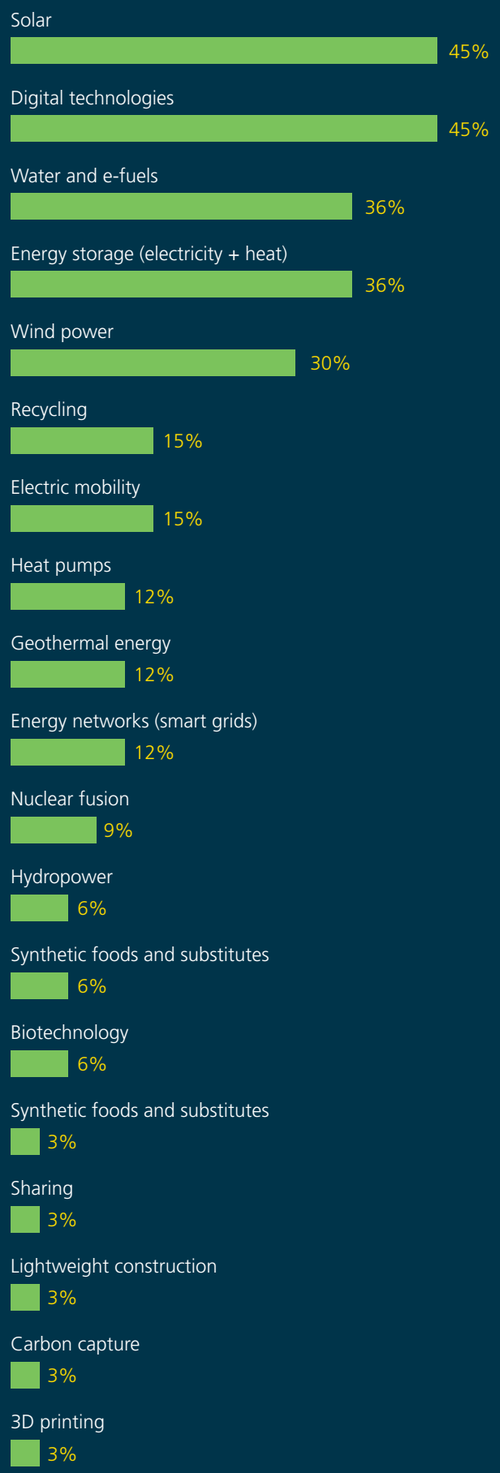


Figure 10: GreenTech technologies listed in expert interviews (n=40)

In addition to energy generation technologies, around **12 per cent of the respondents mention smart energy distribution and use**, such as through smart grids. However, some of the respondents cite not only the distribution of electrical energy, but also **heat networks** as a relevant technology for the distribution of energy.

Similarly, 12 per cent of the respondents identify the use of green electricity to operate **heat pumps** in the field of energy and energy networks. The interplay of the listed technologies for the production, distribution, and use of energy is occasionally mentioned, both in the household sector and also for the use of process heat.

Referring to the presentation of GreenTech described in Chapter 2.2, the impressions of the experts correlate with the reference model. In particular, the relevance of digital technologies is repeatedly highlighted by the participants. The technological landscape described in the model is supplemented by the experts listing particularly relevant technologies. As described in the reference model, the **technologies provide the basis** of the concept and play out their interactions. The product dimension of GreenTech, as explained in the reference model, is also confirmed by some experts.

“A circular economy will not be possible without data exchange along the supply chain. It is important to ensure confidentiality via a third party through verifiable certificates.”

Dr. Gunter Beitinger,
Senior Vice President Manufacturing, Head of Factory Digitalization & Head of Product Carbon Footprint, Siemens AG

“I need something like a digital twin for my product that will be with it throughout its life cycle. This is the only way I can achieve transparency and track, measure, evaluate, and optimize my product cleanly. It also makes me a little more independent of supply chains. We all know just how uncomfortable it is when they don’t work.” **Expert**, anonymous

4.2

The role of digital technologies

Almost all experts agree that **digital technologies are the foundation of GreenTech**. They enable data analysis, create transparency, control systems, and create networks. Some experts even view digital technology as the heart of GreenTech. This estimate is the same as in the previous chapter, with 45 per cent of experts equating GreenTech technologies with digital technologies. Only a few interviewees do not consider digital technologies to be particularly important for GreenTech. In the interview, multiple answers were possible to describe the role of digital technologies for GreenTech.

“GreenTech isn’t possible without digitalization. It would be like removing lungs from the body.”
Kevin Bär, Senior Manager Sales and Growth Global, E.ON

70%

of the experts surveyed see digital technologies as enablers of GreenTech

Approx. 70 per cent of the experts surveyed see digital technologies as **enablers of GreenTech** because they enable the implementation, application, and monitoring of sustainable initiatives through complex technologies. The study participants describe various GreenTech use cases that are not possible without digital technologies. Examples include **digital product passports**, **traceability of the product life cycle**, and other **approaches to the circular economy.** The experts see **digital technologies as the core prerequisite for enabling a circular economy**, especially in the case of industrial products. In addition, digital technologies bring flexibility to the market, thereby increasing the dynamics in the development of products and business models.

“We need digital product passports! All important information on our products must be included, such as carbon footprints, supply chain information, etc..”
Daniel Ostner, Head of Corporate Sustainability, DRAEXLMAIER Group

In addition, a third of the experts define digital technologies as **cross-sectional technology**. The omnipresence of digital solutions in all areas of life will also be continued through GreenTech. Digital technologies are used in all areas of GreenTech by algorithms controlling intelligent systems such as smart grids, making product development possible through digital models and analyses, and monitoring the production of sustainable products. In some cases, digital technologies are considered the core of GreenTech.

“Digitalization is an absolutely key component, a cross-sectional technology without which we cannot tackle the issue of charging infrastructure and therefore the entire area of the battery-electric drive.”

Conrad Hammer,
Head of the Federal-State-Municipal Coordination team, National Center for Charging Infrastructure at NOW GmbH

Six respondents view the contribution of digital technologies to sustainability more critically due to the **rebound effect**. They stress that the determination of the effect must be evaluated on a case-by-case basis. Technologies that involve a great deal of computing power, such as artificial intelligence or blockchain, are particularly mentioned in this context as possible triggers of a rebound effect.

Some experts focus on the **collection and analysis of data**. Digitalization plays an essential role in the collection of data. Automation and intelligent controls are not possible

“Both cleantech and green tech I would say are just pointing to technology that reduces environmental impacts. I would say that I hear cleantech more in the context of climate change and green tech perhaps a little more generic, which may apply to other things like agriculture or other industries, not so much just about energy and climate.”

Prof. Dr. Wayne Visser,
author of Thriving: The Breakthrough Movement to Regenerate Nature, Society and the Economy

without a reliable data basis. In addition, data creates the transparency needed to identify consumption and consumption patterns, analyze **product life cycles**, and monitor value chains. They are the basis of a successful sustainability strategy. By applying algorithms to collected data, decisions can be made automatically and complex systems can be controlled intelligently.

“Having data and digital technologies throughout the entire product life cycle is crucial to developing a sustainability strategy.”

Dr. Gunter Beitinger,
Senior Vice President Manufacturing,
Head of Factory Digitalization & Head of Product Carbon Footprint, Siemens AG

How important are digital technologies to unlocking GreenTech’s growth potential?

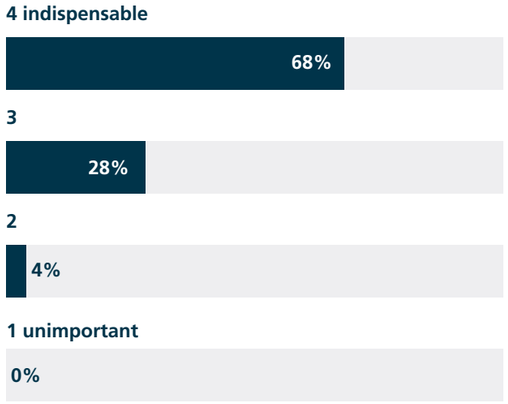


Figure 11: The importance of digital technologies to unlocking GreenTech’s growth potential (n=40)

This **complexity management** would not be possible otherwise. The experts see digital technologies as the key to increasing efficiency in all areas. Complex systems such as energy networks, logistics, and mobility systems can only fully exploit their **efficiency potential** through digital solutions. Finally, the experts rank the importance of digital technologies to GreenTech on a scale from 1 (= unimportant) to 4 (= indispensable). The following figure shows the result.

Almost 70 per cent of the respondents consider digital technologies to be **indispensable** to unlocking the growth potential of GreenTech. The reason given is that every innovative technology contains digital elements. Some experts point out that digital technologies are necessary not only to unlock growth potential, but also to remain competitive in the market, and are therefore essential to survival. A further 28 per cent of experts rate the importance of digital technologies on the 1–4 scale as 3 and therefore very important. The reason for this assessment was the indispensable importance of digital solutions for many GreenTech technologies and the fact that there are few technologies that can do without digital solutions, or where digitalization at least facilitates the implementation of GreenTech technologies, although it is not absolutely essential.

“Digital technologies are a very important tool for the solution building blocks of GreenTech.”

Tobias Großmann,
Head of City Planning Office, Backnang

Only two participants think digital technologies have little importance in unlocking the growth potential of GreenTech. Digital technologies were not considered unimportant by any interviewee. This corresponds to the assessment of the interviewees on the role of digital technologies as **enablers** and **cross-sectional technology** as outlined above.

In comparison to the reference model, it is clear that the experts surveyed confirm the importance of digital technologies shown in the model. They see digital technologies as enablers, cross-sectional technology, and drivers for GreenTech. Some experts even view digital technology as the heart of GreenTech. The role of digital technologies as enablers for process control and data analysis is confirmed by the experts. Some of the study participants go so far as to consider digital technologies as important in designing and delivering green products and services, right up to the creation of GreenTech business models.

4.3

Environmental effects of GreenTech

In order to analyze the environmental effects of GreenTech, the experts were asked to identify the effects of GreenTech in the following areas: **substitution of fossil fuels as primary energy sources**, protection and efficiency of resources, and **transformation to a circular economy**. Multiple answers were possible. The distribution of the expert opinions among the three areas of environmental effects mentioned above is almost equal. In addition, the experts largely agree that some key challenges are (still) hampering the environmental effects of GreenTech.

Overall, it can be said that the respondents generally attribute a **high environmental potential** to GreenTech technologies and identify a large number of climate-friendly effects. However, most experts consider it to be very difficult to quantify this environmental potential at this point in time.

“...how can we leave the world dirtier than we find it with no compelling need to do so...”
Sven Krüger, CEO & Co-Founder GREENTECH FESTIVAL

Substituting fossil fuels as primary energy sources

The majority of the study participants (just over 70 per cent) agree that the greatest environmental effects of GreenTech are seen in connection with **reducing fossil fuels as energy sources**. While initial steps in this direction have been taken, it is generally believed that major leaps are still required. The experts see a key lever for GreenTech in the agreed **energy transition**. In particular, the move to renewable green technologies can be seen as an accelerator for GreenTech. The shift away from fossil fuels as primary energy sources (such as oil, gas, and coal) to renewable energy sources (such as solar, wind, and hydro) promises great progress in climate protection. The main contribution of GreenTech technologies lies in **reducing emissions of CO_2, which is harmful to the climate**. Indeed, GreenTech technologies are already making a significant contribution to the substitution of fossil fuels as primary energy sources, accounting for as much as 16 per cent of energy production in 2021 [1]. The experts surveyed confirm that the use of **green electricity**, for example, is easy to implement in many sectors. Energy sources based on fossil fuels can already be substituted in these cases. This assessment corresponds to the development outlined in Chapter 2.2.1, whereby it was possible to generate more electricity from renewable energies than from fossil fuels for the first time in 2020. [13].

At present, Germany is one of the world’s largest consumers of energy sources based on fossil fuels. In particular, the three sectors of industry, building, and mobility are considered to play a central role in the generation of fossil-fuel energy consumption. One reason for this high energy consumption is probably the **volatility** of the green alternatives (e.g. wind and solar power). These are not always available, meaning they do not meet an essential requirement for manufacturing companies. Nevertheless, the corresponding **storage technologies** can guarantee end-to-end availability and achieve the corresponding environmental effects.

“For the substitution of fossil fuels as primary energy sources, the storage capacity, will play a crucial role.”

Tobias Großmann,
Head of City Planning Office, Backnang

The experts envisage a positive effect on environmental targets primarily through progress in **electrification**. Particularly dynamic development is seen in the production, distribution, and consumption of green electricity. The experts predict that there will be great **potential for implementation** in the coming years, provided efficient power grids and storage technologies are available. In the mobility sector, the establishment of a widespread **mobility charging infrastructure** is considered a central prerequisite to implement the intended environmental effects. The experts also point out that digital technologies will also be of great importance to electrification. These types of **digital technology** are needed, for example, to control green power systems in order to transfer electricity efficiently from the producer to the consumer. Digitalization in the form of smart meters can also boost the positive environmental effects of GreenTech in individual buildings.

Protection and efficiency of resources

In the protection and efficiency of resources through GreenTech, 63 per cent of respondents see great environmental potential. The goal is to prevent resource consumption or reduce it with corresponding positive environmental effects in comparison to the status quo. The fundamental idea is that no more resources can be extracted from the environment than **can be generated in the same period**. It is also important to use **renewable resources** that reduce CO_2 emissions. The experts first recommend limiting resource consumption by **eliminating** unnecessary consumption. Green resources can then be used. In industry in particular, attention is increasingly being paid to the conservation of natural resources in the production of materials. This means that savings can already be achieved today, particularly in the case of electricity-based processes. The production processes are tested step by step for **sustainability** and adapted accordingly in order to save resources during production. There is a general view that this results in desirable environmental effects on a significant scale.

63%

of respondents see great ecological potential through GreenTech in the areas of resource protection and efficiency

The experts see three main requirements for triggering sustainable, positive environmental effects from GreenTech. Firstly, regulatory frameworks are needed to halt actions that are harmful to the climate. This regulation can create the basis for GreenTech-induced environmental effects. Secondly, the experts are in favor of **harmonized CO_2 pricing**. This would ensure that damage is balanced out correctly and that the resulting costs are properly accounted for. However, this CO_2 pricing would have to be introduced globally in order to create a level playing field for all market participants. Thirdly, the experts envisage environmental effects primarily through the development of **GreenTech innovations**. Since these can make a decisive contribution to reducing CO_2 emissions, their development should be encouraged appropriately.

In this context too, the interviewees mention the great environmental potential of GreenTech in connection with digital technologies. The analysis of large amounts of data promises to increase efficiency while conserving resources – both in the private sector and in industrial production. Further developments in automation, the Internet of Things, and artificial intelligence facilitate the monitoring and control of resource consumption on an unprecedented scale. Digital technologies can make a major contribution to sustainable actions, particularly when it comes to virtualization and data-based control. In this context, the topic of prediction is of great importance. Data-based forecasting enables gains in efficiency and a more efficient use of resources.

The environmental potential of GreenTech is viewed critically due to the rebound effect mentioned above. The experts cite the construction of solar panels and the production of electric cars as examples. The rebound effect can also be seen in the context of digital technologies. With the help of digital data and automation, energy can be saved in numerous production processes. However, the operation of IT infrastructure also requires energy, which can neutralize the cost-saving effects. This shows that, in addition to green technology, there must also be a change in production and consumption patterns for the environmental effects to be realized in the long term.

"From an energy point of view, we say that flying is a terrible thing because you obviously need to use the energy to stay in the air. But if I could generate enough energy from renewable sources and had it at my disposal, I could save myself all the expense and infrastructure measures such as roads, parking lanes, etc. and could have beautiful forests everywhere and fly around using electricity, even if it did require more energy at first."
Sven Krüger, CEO & Co-Founder GREENTECH FESTIVAL

Circular economy

Of the three areas in which GreenTech can develop its environmental potential, the circular economy is particularly complex as it typically requires a complete transformation of the corporate value chain. Seventy per cent of experts indicate that there are positive environmental effects of circular systems. The circular economy is closely linked to the protection and efficiency of resources, especially in the case of manufacturing companies. If production processes are aligned with a cycle, this entails the reuse of materials from previous products in the production of new products. By recycling materials, natural resources can be conserved and corresponding environmental effects can be achieved. However, circular economy systems are difficult to implement, especially in the case of products consisting of a large number of components. Logistical challenges arise that require completely new component streams. If it is possible to implement circular material cycles, immense environmental effects can be realized. For example, it is assumed that standard cars consist of 95 per cent recyclable material. This illustrates the potential for climate protection and the urgent need for companies to address its realization.

"I don't know of any large corporation that isn't setting up its own unit or business unit for the circular economy. I'm optimistic that this will happen and will accelerate."
Timon Rupp, Founder & CEO, The Drivery GmbH

Circular approaches typically follow the overarching directive of **energy neutrality.** This is based on a systemic understanding of economic cycles. Rather than disappearing from the system, the resources used should ultimately be reintroduced into the cycle after appropriate treatment. However, the experts point out that linear economic processes are still currently the norm and that circular systems have so far barely established themselves in commercial enterprises. To promote these systems, it will be extremely important to develop appropriate business models. This is expected to happen in the long term and may therefore have an environmental impact in the longer-term future.

"The development will mean that we will be responsible for recycling our own products."

Daniel Ostner,
Head of Corporate Sustainability, DRAEXLMAIER Group

The establishment of circular systems requires **regulatory framework** conditions that enable existing products to be recycled. For example, regulations can be implemented stipulating that companies must take products back at the end of their life cycle. With appropriate quotas, the legislator can ensure that recycling activities are initiated. Increased **awareness on the part of the end consumer** is also of central importance. The experts agree that only a change in demand from customers in this regard will generate organizational remanufacturing and refurbishment efforts in the long term.

"I think it is a tech topic because a lot of the changes we need to get to circular economy are not just about people recycling. For example, it is about changing the design of how we do things."
Prof. Dr. Wayne Visser, author of Thriving: The Breakthrough Movement to Regenerate Nature, Society and the Economy

Challenges

The experts identify various challenges in the realization of environmental effects through GreenTech. These effects will only materialize if companies find the **right incentives** to develop and/or use GreenTech. If GreenTech is not worthwhile from a business point of view, then companies will tend to turn to other things. In addition, the development of new business models requires a **long-term approach** and appropriate **resources**. Political initiatives are also needed so that GreenTech is provided with the necessary regulatory framework. These initiatives should also introduce the topic of GreenTech to the population and raise awareness of it in the long term.

To further develop GreenTech, it should be noted that there is a high **demand for research and development**. The development of carbon capture technologies, for example, may generate environmental effects that bring the climate targets within achievable realms. This is closely linked to the funding of GreenTech companies. For GreenTech startups in particular, funding the high costs of research and development presents a real challenge. Ultimately, much of the environmental impact depends on the **behavior of people** themselves. A great danger lies in the cementing of a "We've always done it that way" mentality. The experts surveyed agree that a change in human behavior is needed to achieve the climate targets – both on the supply side and the demand side. In summary, we can see that the expert interviews **confirm the content of the reference model.** Further developments, such as circular economy systems, may contribute to the conservation of resources, but these require a **fundamental overhaul** of current economic practices. The environmental effects interact with the economic and social effects, which are explained below.

"In the end, we will not be able to save the world's climate, weather, biodiversity, and everything with what we currently produce. But we can be suppliers of technologies that can do this, that can exist in the market. We've managed this with other technologies."

Expert, anonymous

4.4

Economic effects of GreenTech

The experts identify different economic effects associated with GreenTech. However, in a similar way to the environmental effects, they say that these effects of GreenTech are **extremely difficult to quantify**. As with the previous question of the environmental effects, multiple answers were possible.

42%

of the experts surveyed see an important socio-economic effect of GreenTech in the creation of new and sustainable jobs.

“GreenTech is a growth market, definitely. But one with a question mark over it.”

Timon Rupp,
Founder & CEO, The Drivery GmbH

First and foremost among the economic effects mentioned by the experts are **positive growth effects**. These are expected by almost 50 per cent of the experts surveyed as a result of green technologies. This corresponds to the general growth dynamics of the GreenTech industry, which is generally acknowledged to have a high growth potential. The experts expect dynamic growth rates in the coming years and predict that GreenTech’s share of Germany’s gross domestic product will increase in the short, medium, and long term. In the expert interviews, the growth opportunities were compared with the **potential of digital technologies** over the past 25 years. Substantial returns can be generated in a market that has so far only been **partially tapped**. In fact, this is referred to as an empty ecosystem that has so far been underused and can be conquered. GreenTech technologies could replace established environmentally harmful technologies in many places. This is why there are enormous **market opportunities** for innovations from the GreenTech sector. According to the experts, the growth of the GreenTech sector will create additional prosperity in Germany. GreenTech can therefore be described as the **growth engine of the economy**.

The economic growth of the GreenTech industry is associated with a positive **effect on the labor market.** Therefore, 42 per cent of the experts surveyed see an important socio-economic effect of GreenTech in the creation of new and sustainable jobs. Jobs are created in various locations in connection with GreenTech, for example at GreenTech providers (large, medium, and small companies, as well as startups), NGOs, and on the demand side (such as at manufacturing companies). With regard to the question of jobs, the experts are sure that the number of jobs in the GreenTech sector will **increase massively**. Due to the economic potential, GreenTech specialists will be needed in the coming years and corresponding positions will be created. In addition, the development of the GreenTech sector may lead to jobs that were relocated abroad from Germany at the beginning of the 2000s being brought back to the country due to the change in the framework conditions. Meanwhile, the experts forecast a reduction in non-green sectors due to the declining demand for non-green technologies. Jobs will be moved from environmentally harmful sectors to green sectors. However, due to increased international competition within the GreenTech industry, there could be another reduction in jobs in the medium term. The overall impact of the job-related effects described here is currently difficult to predict. The experts are not sure whether these **opposing employment** effects will lead to an increase in the number of jobs.

“GreenTech has to be economical, otherwise it won’t work because our society is structured like this.”

Christian von den Brincken,
General Manager, Ströer Core GmbH & Co. KG

In addition to growth effects, 22 per cent of the study participants cited positive financial effects from GreenTech in the form of **cost savings** and **reduced life cycle costs**. For example, procurement costs can be reduced by reusing recycled materials, using materials more efficiently, or extending their service life. Increased efficiency in production also leads to lower costs in the production process. This is particularly relevant against the current background of rising resource prices. However, if GreenTech initiatives become too expensive and lead to excessive price increases, the **opposite effect** could occur. Instead of green technologies, companies will then increasingly rely on non-green technologies to reduce costs. Through strong **basic research** (for example, through research networks such as the Fraunhofer Society or the Max Planck Society), Germany can achieve a leading position in the global market for GreenTech. The experts tend to confirm that it is difficult to quantify economic growth effects.

Ten per cent of experts also believe that GreenTech activities can translate into an **increase in the company value**. The background to this is that the financial sector rewards activities in this area due to increased sensitivity to climate protection aspects. Within the end customer business, too, a greater emphasis is placed on environmentally friendly production, with purchase decisions made on this basis. As a result, GreenTech companies tend to **report higher sales and profit figures**, which is reflected in their company value. Many study participants stress that companies must primarily comply with the **requirement of profitability**. Accordingly, investments in GreenTech must also pay off for companies and contribute to a positive return on investment (ROI). In the absence of these financial advantages, companies will see little reason to favor sustainable economic management.

“In the beginning, nobody was really interested in green products, in sustainable products. There was no interest from the customer side, or in other words the market, or from the company’s perspective. But for about the last six months there has been a real run on it and now it’s about delivery! That’s the challenge of thinking long-term and investing some money and saying that we’re developing green products now.”
Expert, anonymous

The experts surveyed also point out the considerable **transformation in the economy and society** that is associated with GreenTech. Ten per cent of the experts are convinced that GreenTech will trigger major transformation processes in various industries. Green technologies are changing **business models** and entire **industries**. This can be clearly seen in the automotive industry. The switch from combustion engines to electric drives involves a **complete transformation of value creation** for automotive companies. Instead of producing complicated combustion units, the task now is to achieve efficient storage of electrical energy as well as a seamless charging infrastructure. Accordingly, business processes have to be adapted. It is often the case that this does not run smoothly. Some experts even expect a transformation of the entire German economy. GreenTech can therefore be understood as a **megatrend** that, especially in conjunction with digitalization, has the potential to drive economic value creation toward sustainability. In this context, the importance of the **necessary structural change** is highlighted. At the same time, this poses the risk that GreenTech will be researched and produced in Germany, but that production will then migrate to other countries in the medium term. This mechanism was clearly observed in the German solar industry, which, despite a strong start, fell behind the competition from other countries and ultimately had to admit defeat.

“Traditional business models must be questioned or turned upside down and structures broken down in this way. This allows genuinely new markets to emerge, which can then bring about a much faster change for the better once the corresponding push has taken place in the population. But this is precisely why we need appropriate players who firstly show in the market that it is possible, and secondly show in some way that it is attractive.
Sven Krüger, CEO & Co-Founder GREENTECH FESTIVAL

In principle, the experts agree that the use of GreenTech **technologies is rewarded by customers.** This can also translate into competitive advantages (10 per cent of the experts). However, the experts also point out that the implementation of GreenTech technologies can translate into higher costs and therefore, for example, higher product prices. In turn, this would lead to a deterioration in the competitive position. The challenge for companies is therefore to **balance environmental and economic aspects** in order to achieve stable and sustainable competitive positions. The experts believe that there is another economic advantage from the use of GreenTech in the fact that companies can **quickly gain market share** and **secure it in the long term** through speed in particular. This could enable the German GreenTech sector to **become a global leader**. Overall, Germany’s competitive position in the global market is considered to be solid but with potential for expansion.

Due to the environmental aspects of GreenTech outlined above, entire supply chains may change. For manufacturing companies, this could mean serving a larger share of the supply chain themselves in the future and cooperating with fewer suppliers. Resources can be reused, especially in circular economy systems, so that primary products would not have to be sourced externally but would be recycled from within the company, for example. This would enable companies to achieve greater **independence** from supply chains, leading to **improved stability** of corporate value creation, especially in times of uncertainty.

In addition to the general assessment of the economic effects, the experts were asked to rank the sectors of **industry**, **transport**, **buildings**, **energy**, **agriculture**, and **waste management** according to the dimensions of **economic growth effects through GreenTech** and practical implementation potential by 2030. Growth effects are those that

theoretically lead to positive or negative economic growth in a sector. The implementation potential, on the other hand, is intended to determine the extent to which the potential of GreenTech can be exploited on the basis of existing framework conditions in a sector such as legal requirements, mindsets, or active interest groups. The experts were asked to provide an assessment for the period up to 2030. These two dimensions were combined to produce a 9-field matrix in which the aforementioned sectors were ranked by the respondents.

Industrial sector

The **growth potential of GreenTech in the industrial sector** is considered to be **above average** by more than **50 per cent of the respondents**. Another **45 per cent** see **moderate industry growth** through GreenTech. The clear majority of the respondents are also optimistic about the realization of these potential growth effects and consider the **implementation potential to be high or moderate**. A third of the study participants choose a combination of above-average growth potential with high implementation potential. This puts the industrial sector's potential second highest behind the energy sector (see below). The reasons for the high growth potential are primarily the technological developments in the industrial sector and their potential. The experts surveyed also regard the development of new products and services through digital innovations and Germany's position in this sector as largely positive. In the industrial sector, **very high implementation pressure** is also seen due to the requirements for reducing CO_2 emissions. However, the relatively short observation period is regarded critically, since successful action within the eight years remaining until 2030 is considered difficult in German industry, which is typically very **investment-intensive**. It is also emphasized that the growth potential can only be exploited by companies that have the **necessary financial means and resources** to deal with issues such as GreenTech and sustainability. This is assessed critically for small and medium-sized companies in particular, and the need for a stronger incentive policy or state support is highlighted.

Only 2 per cent of respondents rated the **growth potential** in the industrial sector as negative. The main justification for this is that the industry is facing the major challenge of **reducing CO_2 emissions** and GreenTech is therefore leading to a **substitution** of existing technologies and processes, but this will not generate any additional industry growth, at least in the period up to 2030.

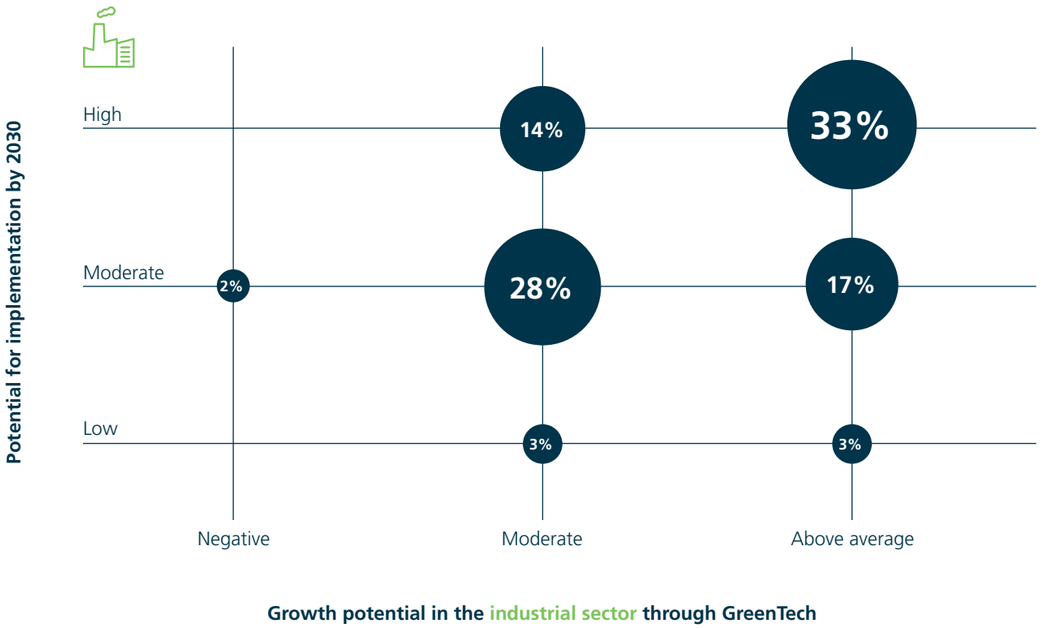


Figure 12: Assessment of growth and implementation potential in the industrial sector (n = 37)

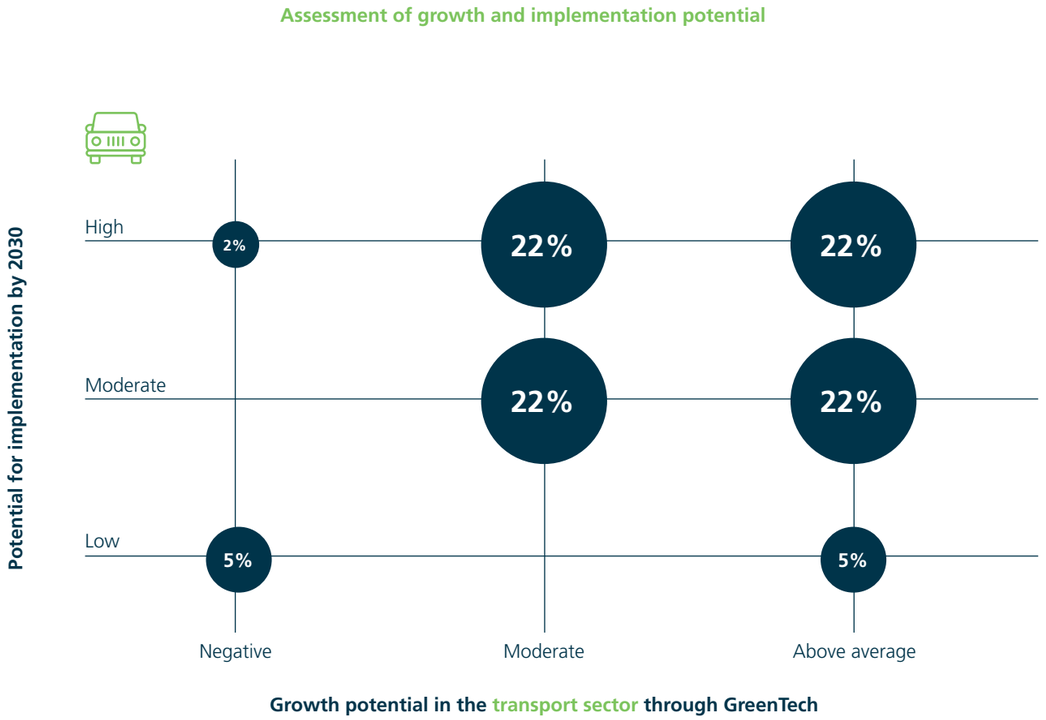


Figure 13: Assessment of growth and implementation potential in the transport sector (n=37)

Transport sector

What is striking here is the perfectly even **distribution of expert assessments of 22 per cent** each across the four combinations of moderate/above-average growth potential and moderate/high implementation potential. This suggests that the experts surveyed have different assessments of the impact of current developments and technological innovations in this sector up to 2030. For example, according to the experts, the moderate growth effects are explained by the fact that in the transport sector, GreenTech innovations such as **electromobility** are primarily replacing existing products. Innovative services will also increase **sharing offers**. In addition, the mindset of the younger generation contributes to the fact that fewer people are buying their own car. This contrasts with the opinion of other experts, who – precisely because of the development of low-noise, more environmentally friendly **electric cars** – predict an **increase in car purchases in urban areas** and among the younger generation, and therefore see the possibility for industry growth. Some experts also see the increase in mobility due to the possibilities of e-mobility such as e-bikes and e-scooters as an opportunity for a growth market. In a similar way to the industrial sector, the transport sector is believed to be under **high pressure to act,** even though some experts think that the established German automotive industry is sometimes still too hesitant to make the big technological leap. They feel that it should push ahead more intensively with **in-house developments** and is dependent on strategically important **cooperation**. The availability of **sufficient green electricity and the expansion of the infrastructure** for implementing electromobility are also viewed critically.

"Anyone can build electric cars now, but what's really important here is the issue of infrastructure and energy supply. And that can't be done without the state."
Timon Rupp, CEO & Founder, The Drivery GmbH

Only **7 per cent** of respondents are critical of the sector's development. They expect **negative growth effects** with low implementation potential.

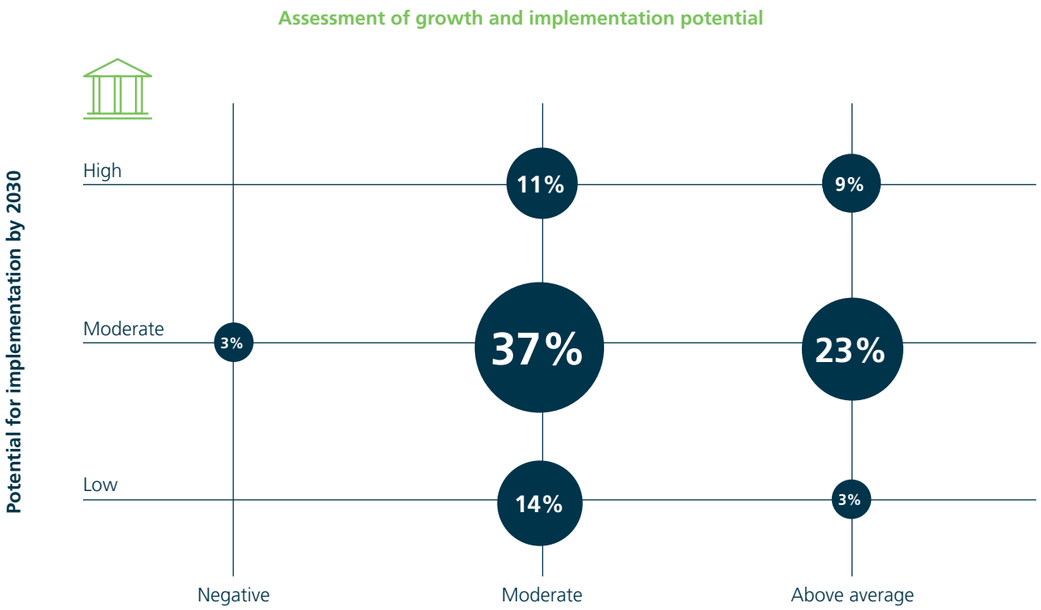


Figure 14: Assessment of growth and implementation potential in the building sector (n = 35)

Building sector

Well over half of the respondents (60 per cent) rated the **potential industry growth through GreenTech** in the building sector as **moderate (37 per cent)** or **above average (23 per cent)**, with moderate implementation potential. The experts surveyed see potential for industry growth through GreenTech primarily due to the fact that the construction sector is very **CO2-intensive** and the building sector, as the largest energy consumer, needs to become more energy efficient. Strong **investments**, existing **technological innovations**, especially for increasing energy efficiency, together with the current high **demand for PV systems**, the **shortage of housing** in large cities, and the **backlog of renovations** therefore suggest positive growth prospects.

It is striking that only 20 per cent of the respondents see high implementation potential in the building sector. According to the experts surveyed, the reasons for the rather cautious assessment of the implementation potential is the **shortage of skilled workers**, the **lack of willingness to invest** in existing properties, **low cost-effectiveness**, or **difficulty implementing** GreenTech measures such as building insulation in industrial areas or heat pumps in old buildings. This is combined with the general inertia in the sector, caused by a very long product life cycle, which affects not only the building itself, but also the energy used in the building. The experts are also critical of the **erratic policies** in this sector, combined with **too little funding** to cover the enormous costs involved in complying with the energy and construction regulations.

Only 9 per cent of the respondents see a combination of above-average growth and high implementation potential in the building sector.

Some of the respondents therefore cite drastic cuts and clear legal requirements as indispensable to bringing about the major transition in the building/construction sector. It is also necessary to rethink the size of housing in order to meet future needs for living space.

“Continuity, predictability, and adequate funding are the key political courses of action that must be taken in the real estate industry in order to seriously advance climate protection in the building sector.”

Stefan Hinz, Sustainability Team Leader, ECE Group Services GmbH & Co. KG

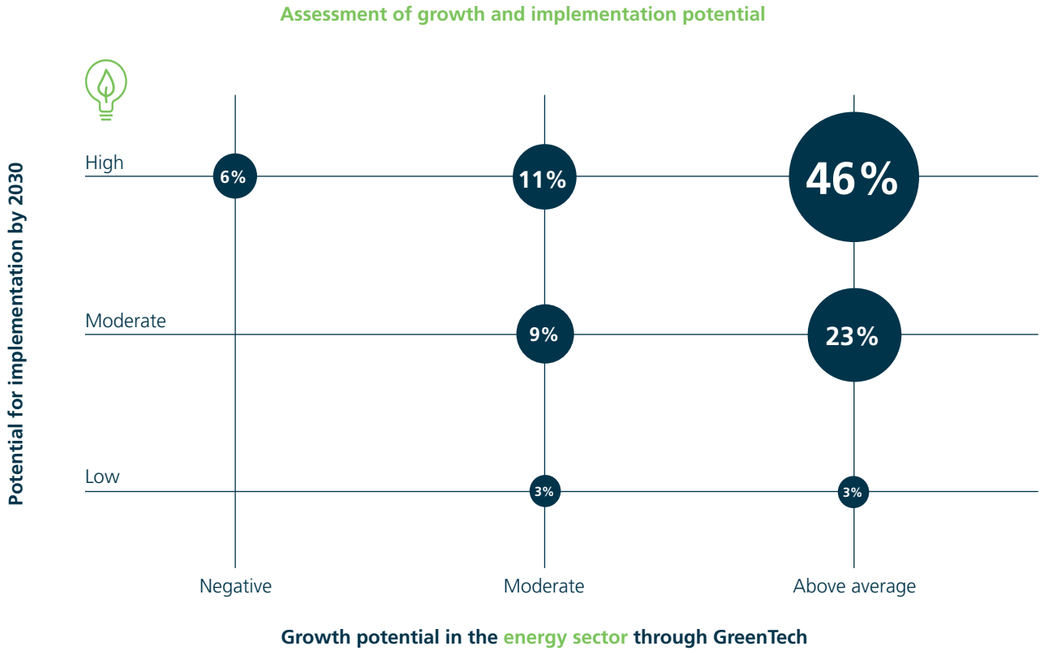


Figure 15: Assessment of growth and implementation potential in the energy sector (n=35)

Energy sector

Almost **half of the respondents (46 per cent)** believe there is potential for **above-average industry growth in combination with high implementation potential** in the energy sector. This puts the energy sector at the top of the sectors analyzed in this study. The reason for this positive assessment of future industry growth through GreenTech is primarily the clear **political orientation in the energy transition** to achieve climate neutrality. Examples given include the expansion of wind, hydro, and solar energy, as well as electrification in other sectors such as heat pumps in the building sector or electromobility in the transport sector. The growth of the energy sector is therefore largely dependent on the implementation of the energy transition in the other sectors.

The **realization of the growth potential** is also viewed positively by most of the respondents. For example, almost three-quarters of all respondents rate the implementation potential of above-average growth as moderate (23 per cent) or high (46 per cent). In the opinion of the respondents, the reasons for this lie in the clear political roadmap, a now broad social consensus on achieving climate neutrality, and the presence of green technologies.

In this context, Germany's position is viewed in two very different ways. Some experts think that Germany will adopt a leading international role in the field of renewable energies in the future and praise the existing technological innovations. Others complain that Germany is not fully exploiting its potential.

"I think the sustainable energy economy is a huge driver of growth and Germany should definitely be leading the way."
Kevin Bär, Senior Manager Sales and Growth Global, E.ON

Only **6 per cent** of the study participants are critical of the implementation of the growth potential and therefore **rate the implementation potential low**. The reasons given are a monopolistic market with little innovation and competition, as well as the challenge of **security of supply**, which is intensifying against the backdrop of the war in Ukraine. In addition, **long planning and approval periods**, a **long product life cycle** in the area of energy sources (e.g. gas turbines, wind turbines), and long system run times hinder rapid implementation. Some respondents also believe there is a need to catch up when it comes to smart grids.

"The potential for the energy sector is of course huge if we assume the ideal image of the fully digitalized energy system."
Sebastian Schule, Energy Officer, Bitkom e. V.

Agriculture

The agricultural sector is viewed very differently by the respondents. What is striking, however, is that the **growth potential through GreenTech is judged to be significantly worse** than in the other sectors. With moderate implementation potential, only 6 per cent of the experts see above-average growth, while 28 per cent see moderate growth and as many as **18 per cent actually see negative growth potential**. The implementation potential is also rated as low by more than 20 per cent of the respondents and is therefore viewed critically.

The experts' main justifications for the n**egative growth forecasts** are the effects of organic farming and sustainable livestock farming, as both lead to a **lower yield** per hectare or per animal and a lower land consumption.

Respondents see the **conservative attitude** of the agricultural industry, long **investment cycles**, and the reluctance of political players to exert pressure in this sector as **difficult framework conditions** for the implementation of possible growth potential. Some interviewees believe that the desire for change comes from the stakeholders rather than the farmers themselves.

Even supporters of positive growth potential generally take a critical view when asked whether implementation can be expected soon. This is due to **political mechanisms** and **regulations** in this sector. **Positive growth effects** are expected from agricultural concepts such as **vertical farming** and **increasing automation**.

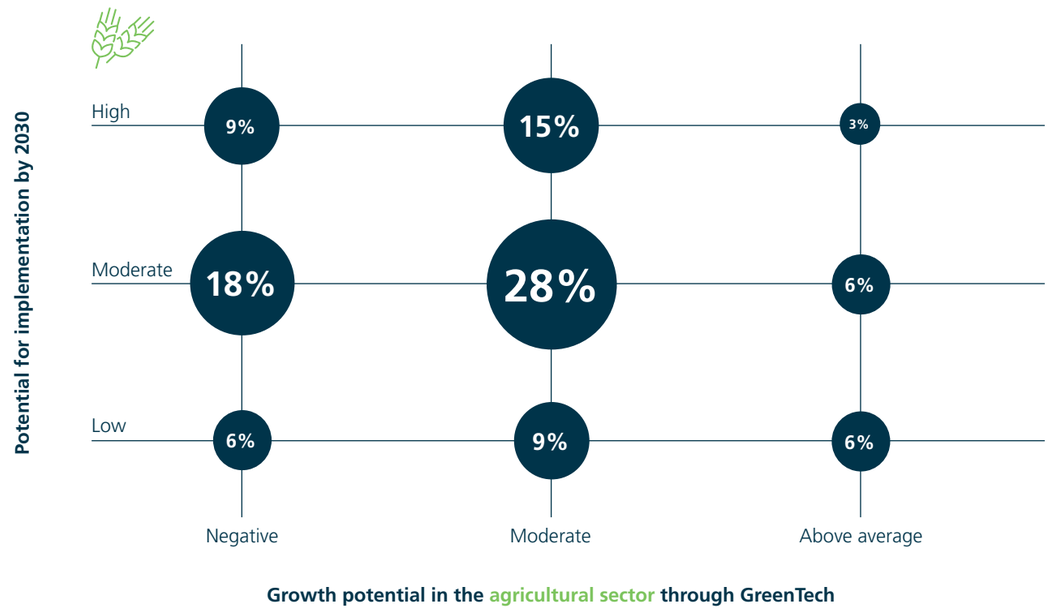


Figure 16: Assessment of growth and implementation potential in the agricultural sector (n=34)

“I think the sustainable energy economy is a huge driver of growth and Germany should definitely be leading the way.“

Kevin Bär,
Senior Manager Sales and Growth Global, E.ON

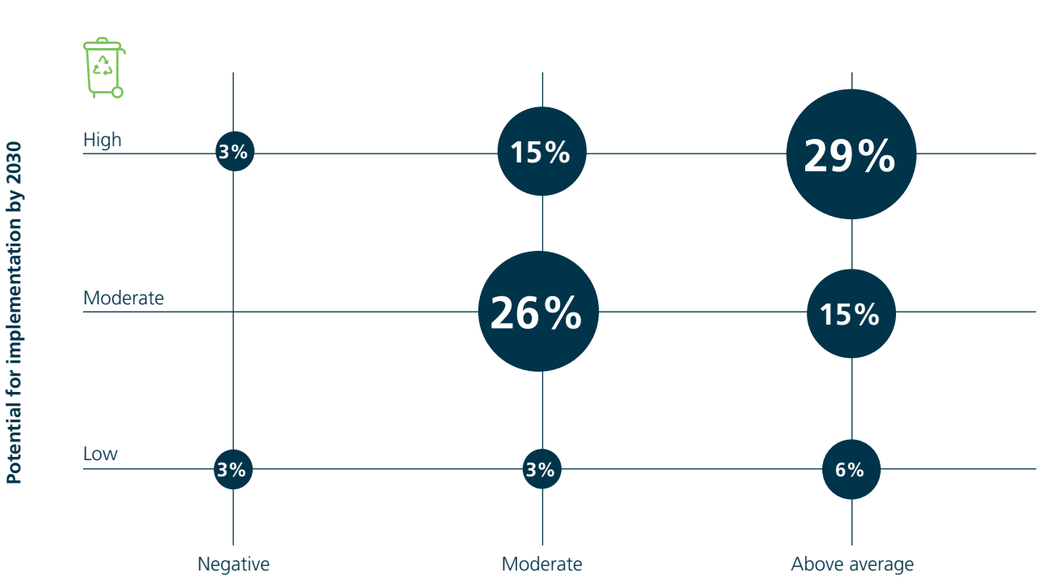
Waste management

About **half of all experts** attest to **above-average growth potential** for waste management. A further 44 per cent forecast moderate growth in the sector. According to the experts, the high growth potential results from innovative GreenTech technologies such as the application of artificial intelligence in waste sorting or the introduction of product passports that can be used in **recycling** and **waste logistics**. Efforts to create a **circular economy** are bringing the waste industry into focus and may generate growth potential. At the same time, it is a conservative sector that has so far been characterized by small and medium-sized companies with numerous public operators and a generally rather low willingness to invest. This makes it **difficult to implement** technological innovations. Most of the respondents believe that valuable and innovative concepts undoubtedly exist, some of which have already been in place for years, but they are not being consistently implemented. Successful recycling efforts also lead to a **reduction in waste generation** in the medium to long term, and therefore to lower or even negative industry growth.

Comparison to the reference model

Overall, the experts confirm the micro and macro-economic growth potential of GreenTech as shown in the reference model. There is a **broad consensus** on the economic effects of GreenTech. According to the experts surveyed, **dynamic growth** in the GreenTech industry can be expected in the coming years. This will lead to the **creation of new jobs** or a relocation of jobs to the GreenTech industry. In addition, GreenTech innovations are likely to make companies **less dependent on suppliers** while business models will tend to become **more robust**. As described in the reference model, these economic effects of GreenTech **interact** with environmental and social effects.

Assessment of growth and implementation potential



Growth potential in the waste sector through GreenTech

Figure 17: Assessment of growth and implementation potential in the waste sector (n=34)

4.5

Social effects of GreenTech

As well as the dimensions of economy and ecology, the experts were asked about the social impact of GreenTech. Multiple answers were possible in this case. In a similar way to the environmental impact, the experts found it difficult to quantify social effects. These effects are often interrelated and are primarily a result of the economic and environmental effects. The dimensions for which social effects were identified by the experts are specified below.

As described in Chapter 4.4 above, the **creation of new and sustainable jobs** is cited as the most important socio-economic effect of GreenTech (42 per cent of experts). Startups in the GreenTech sector are attributed a significant role when it comes to the positive social effects of GreenTech since they provide stable, secure jobs with a long time horizon due to their business models. This effect of startups should be encouraged in the long term in order to create opportunities for new jobs based on GreenTech business models. In Germany in particular, there is great potential for jobs created by GreenTech to be taken on by employees whose jobs no longer exist (e.g. in the field of fossil fuels).

Some 20 per cent of the experts surveyed see great potential for assuming **social responsibility** through GreenTech. Examples were given in which digital solutions enable companies to track their supply chains not only in terms of their carbon footprint, but also in terms of their social footprint. Even if the substitution of fossil primary energy sources with GreenTech is achieved, raw materials will still be needed (e.g. for batteries). These are often obtained from socially disadvantaged regions. Companies that source these raw materials can use GreenTech to create decent working conditions in these regions and combat exploitation and child labor. In this context, companies must take responsibility for ensuring compliance with human rights and environmental standards throughout the supply chain. The experts see this as a key role in the use of GreenTech. The increasing transparency for consumers also leads to an **increased awareness of environmental friendliness and social justice in the purchase decision**.

However, the expert interviews show that regional differences influence the social impact of GreenTech (mentioned by 10 per cent of experts). For example, there are strong **regional differences** in the distribution of GreenTech, which can lead to social disparities. For this reason, a homogeneous distribution should be sought. For example, e-mobility and the substitution of fossil fuels are seen in parts of society as a threat to existing jobs. This can be averted by a regional homogenization of GreenTech jobs. However, it is not only the labor market that is affected by regional differences. The varying distribution of GreenTech across regions is also caused by different perceptions of the social strata in the regions. For example, subsidies for electric cars are much better received in economically strong regions than in disadvantaged regions. The same applies to the distribution of green food trends. An important task for policy makers in the coming years will therefore be to involve all sections of society and regions in the implementation of GreenTech initiatives. The study participants also emphasize the different environmental impact across regions, with GreenTech able to improve people's quality of life, particularly in regions with strong environmental influences.

"GreenTech, in the narrower sense, is not directly aimed at improving social or societal circumstances – that's more of an indirect effect."

Dr. Holger Berg,
Vice Director Division Circular Economy / Co-Head Research Unit Digital Transformation at the Wuppertal Institute for Climate, Environment and Energy

Regional differences are more or less intertwined with **social differences in society** (15 per cent of experts). For example, when setting mineral oil taxes, CO_2 levies, etc., it must be taken into account that socially disadvantaged people can be particularly hard hit. Consideration should also be given to the increase in costs due to the pressure to make a rapid environmental changeover. However, the experts see GreenTech as a way to minimize such follow-up costs and to enable fairness and social cohesion, provided GreenTech is affordable and accessible to all. It is also stressed that green technology can benefit socially disadvantaged regions, provided that this is not just large-scale technology and there are many solutions for low-cost, modular energy systems, water treatment, etc. that can be built in the regions. Above all, the quality of life of people living in regions with strong environmental influences can be improved by GreenTech. The open-source approach to GreenTech solutions is also emphasized. The experts are largely in agreement that all levels of society should benefit from the positive effects, as cities, for example, can be

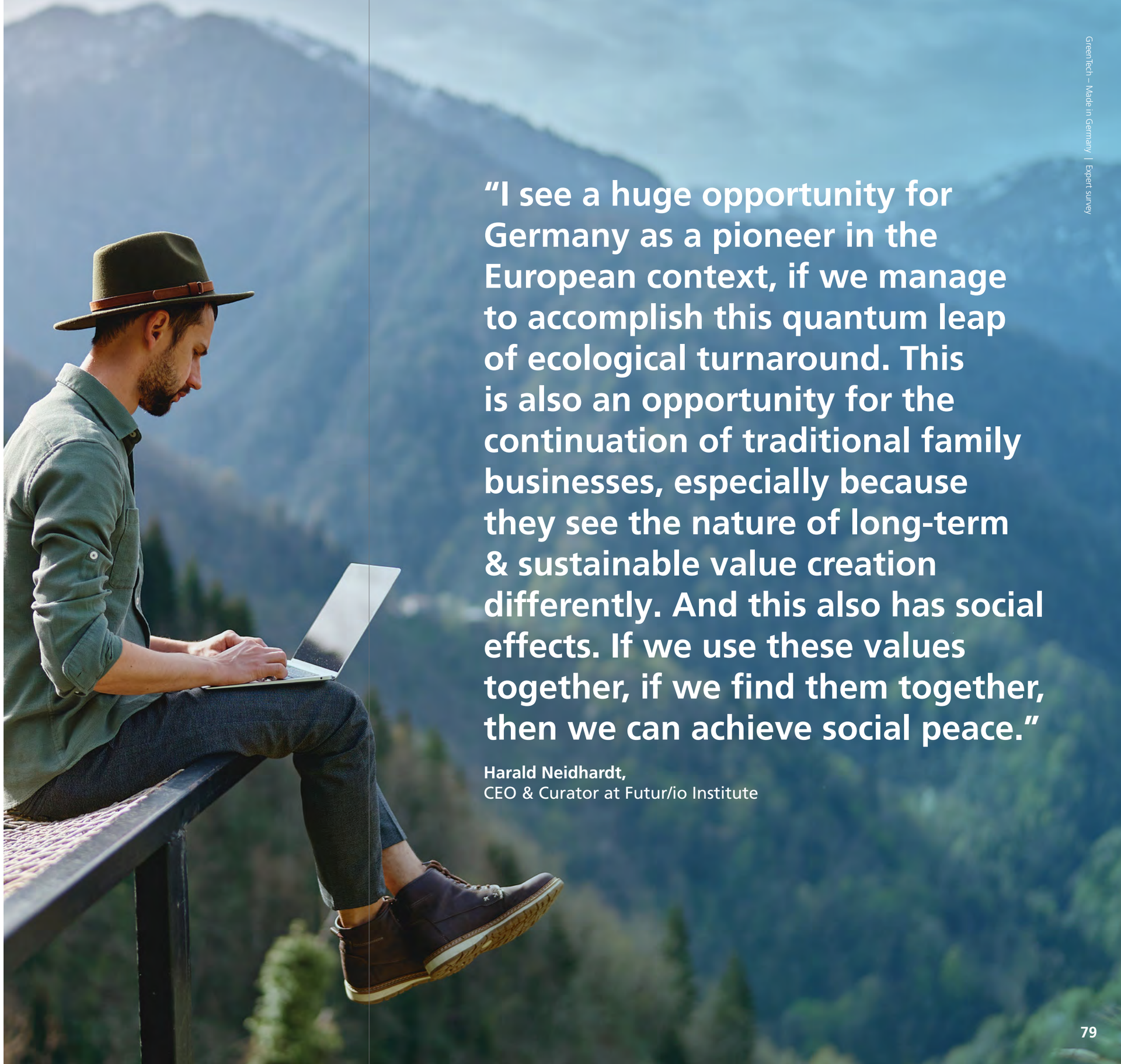
made more resource and climate-efficient, benefiting everyone who lives in them.

In the opinion of some experts, the social effects of a clean environment or a low level of pollution can be just as positive as those of job creation, since an increase in **health** has a positive effect on the social fabric of a society (12 per cent of experts).

In addition, some interviewees emphasize the social effects of digital technologies. Particularly during the COVID-19 pandemic, these ensured the maintenance of social relationships.

The experts also see strong **generational differences** when it comes to the issue of GreenTech. While older generations are still skeptical about electric cars and stick to their large combustion engines, younger generations have a very different attitude toward the use of mobility. This observation is not only made in relation to mobility, but also in relation to everyday activities such as shopping or eating out. In these areas, too, the younger generation is more likely to focus on "trendy" green food products.

Overall, there is a strong correlation between the expert opinions and the social dimension of the reference model described in Chapter 2.3.3, e.g. healthy living spaces, impact on jobs, and social justice, but also environmental awareness in society and the sustainability of our living environment.



"I see a huge opportunity for Germany as a pioneer in the European context, if we manage to accomplish this quantum leap of ecological turnaround. This is also an opportunity for the continuation of traditional family businesses, especially because they see the nature of long-term & sustainable value creation differently. And this also has social effects. If we use these values together, if we find them together, then we can achieve social peace."

Harald Neidhardt,
CEO & Curator at Futur/io Institute

4.6

Evaluation of the political agenda of the new Federal Government

Using a standardized scale from 1 (= not at all) to 6 (= completely), the experts were asked to express the extent to which they agree with the targets and measures of the Federal Government in relation to the promotion of GreenTech. This question was divided into six sub-questions:

- The targets and measures are appropriate for sufficiently promoting GreenTech.
- The targets and measures are sufficiently designed with regard to the substitution of fossil fuels as primary energy sources.
- The targets and measures are sufficiently designed with regard to the protection and efficiency of resources.
- The targets and measures are sufficiently designed with regard to the transformation to a circular economy.
- The targets and measures are sufficient to successfully establish Germany as an export nation among the international competition.
- Up to now, digital technologies have been sufficiently addressed as GreenTech or drivers for GreenTech.

This question was answered by 36 interviewees. The targets and measures of the Federal Government to **promote GreenTech** received the greatest level of agreement. Around **60 per cent of the respondents** gave this a 4 or 5 and therefore consider the targets and measures of the Federal Government to be fundamentally suitable for promoting GreenTech. However, at the same time it is noted that the **implementation of specific measures is still outstanding or has potential for expansion**. Almost 40 per cent of the participants expressed this by giving a 2 or a 3. The majority of the interviewees consider the targets of the new Federal Government to be perfectly appropriate, though they believe that specific measures for implementation are often still lacking. For this reason, there was no complete agreement for this sub-question.

Only 9 per cent of the respondents indicated complete agreement (a 6 on the scale) in response to the sub-question of whether **digital technologies as drivers of GreenTech** are adequately addressed by the Federal Government. In particular, specific measures of the Federal Government to promote digitalization activities and the expansion of the digital infrastructure contribute to this positive assessment. At the same time, **over 40 per cent of the experts indicated little or no agreement** with this sub-question by selecting a 1 or a 2 on the scale. This makes it clear that **much stronger signals** for the promotion of GreenTech at federal level are desirable and, in the opinion of the respondents, necessary.

The experts surveyed assess the targets and measures to **promote the substitution of fossil fuels as primary energy sources** in a similar way to the targets and measures to **promote the protection and efficiency of resources**. Some 36 per cent and 29 per cent respectively agree that the targets and measures in these areas are suitable. However, the majority of respondents still consider the targets and measures to be **far from sufficient** and therefore awarded a 1, 2, or 3 on the scale. This rating was given by 64 per cent of the respondents in the assessment of the substitution of fossil fuels as primary energy sources, and as many as 71 per cent of the respondents in the assessment of the targets and measures for the protection and efficiency of resources. Overall, the targets and measures of the Federal Government for the substitution of fossil fuels as primary energy sources therefore performed better than the targets and measures for the protection and efficiency of resources. Some respondents again differentiate between targets and measures in their assessment. The targets set out in the coalition agreement are viewed very positively, but specific measures are hard to identify.

Currently, the government's efforts to promote the **transition to a circular economy** seem to be the **least** noticed. As many as 86 per cent of the experts believe that the targets and measures are either weak or lacking in this area and therefore chose a 1, 2, or 3 on the scale. Only 14 per cent identify targets and measures and selected a 4 or a 5. There was no complete agreement in this case either. Particularly in comparison with other countries such as Great Britain or France, which have already started introducing regulations on the circular economy, Germany scores poorly in the opinion of the interviewees.

However, targets and measures to **position Germany as an export nation** are clearly discernible from the point of view of the experts surveyed. Almost half (44 per cent) of the respondents could identify the targets and measures, although the targets were more present than the measures. Complete agreement in the form of a 6 was not given.

4.7

Evaluation of the application of GreenTech by companies

In addition, the experts surveyed were asked to assess the extent to which they agree with the targets and measures adopted by companies in general to promote GreenTech, using the standardized scale from 1 (= not at all) to 6 (= completely) mentioned in Chapter 4.6. Again, the question is divided into the six sub-questions shown in Chapter 4.6. This question was answered by 35 interviewees.

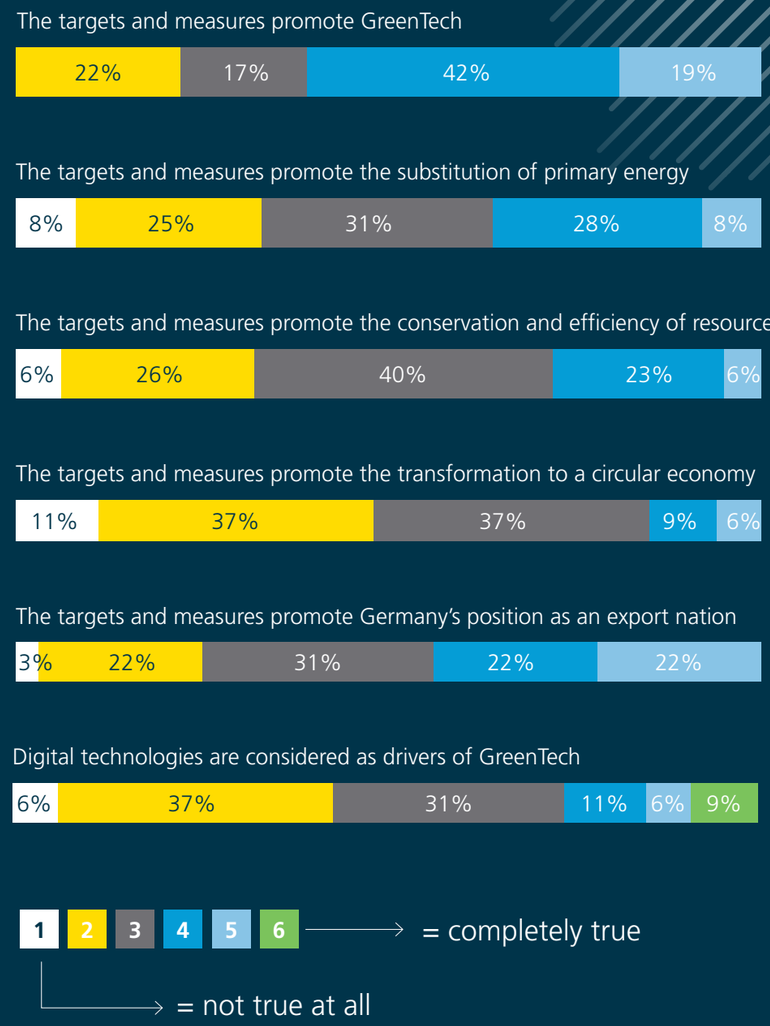


Figure 18: Respondents' assessment of the targets and measures of the Federal Government (n=36)

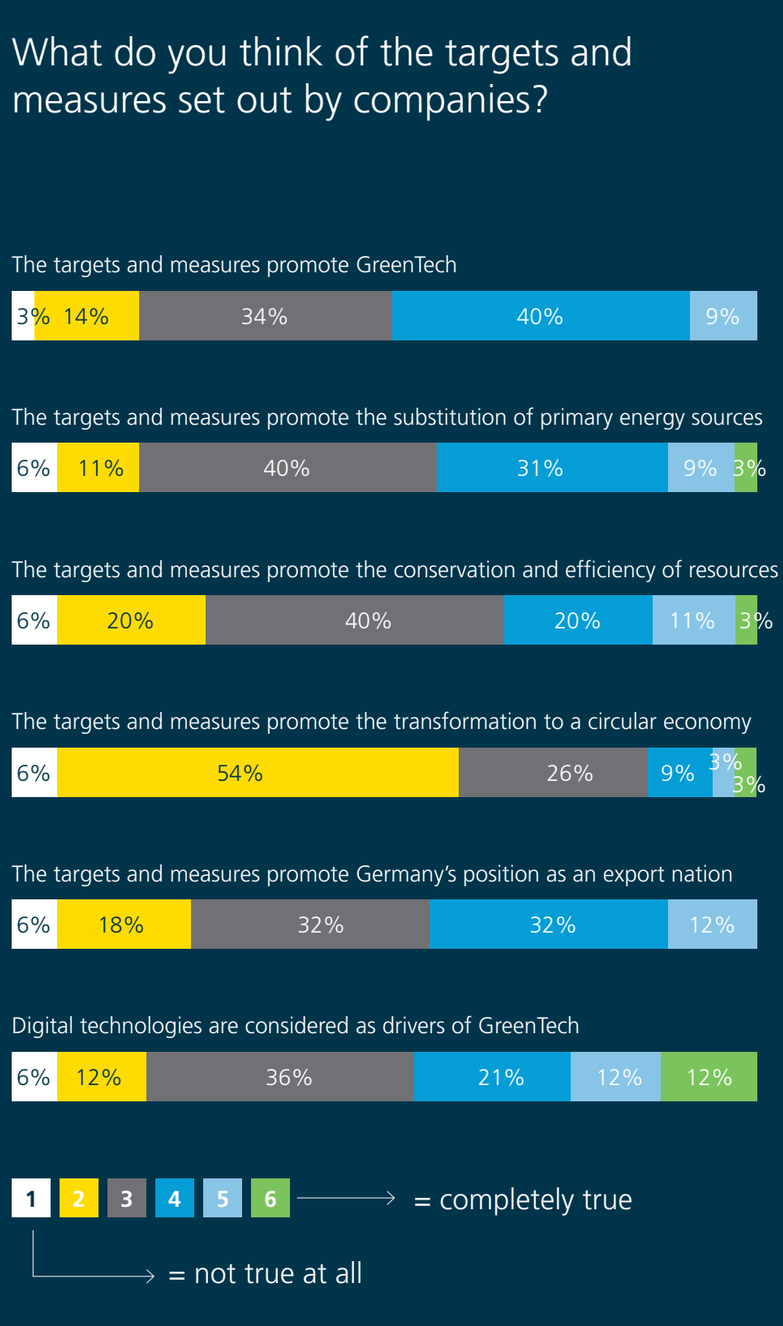


Figure 19: Respondents' assessment of the targets and measures of companies (n=35)

GreenTech in companies today is mostly greenwashing. Name me a brand whose sustainability campaign has really caught on. Where you can say: 'Yes, that's it.' I can't think of any!"
Christian von den Brincken,
General Manager, Sröer Core GmbH & Co. KG

Compared to the assessment of the targets and measures of the Federal Government explained in Chapter 4.6, the targets and measures of companies are rated by the experts as **equally good or better in almost all sub-questions**. Only the **promotion of GreenTech** by the companies is rated slightly worse by the experts. Almost 50 per cent expressed their agreement in the form of a 4 or a 5 on the scale, compared with around 60 per cent when assessing the targets and measures of the Federal Government. With 12 per cent agreement, the experts also rated the efforts of the companies to move toward a circular economy as slightly worse than those of the Federal Government (14 per cent agreement). Complete agreement in the form of a 6 was not given. This cautious assessment was due to the fact that, above all, the small and medium-sized enterprises traditionally anchored in Germany are still doing too little in this area. By contrast, larger companies were confirmed by the experts as having already taken effective measures. In some cases, however, the measures taken by large companies in particular are seen as controversial.

With more **than 43 per cent agreement in the form of a 4, 5, or even a 6**, the efforts of companies to **replace fossil fuels as primary energy sources** are rated much better than those of the Federal Government. In the area of **resource protection and resource efficiency**, targets and measures are also rated better than those of the Federal Government. Nevertheless, 14 per cent of the respondents expressed their strong or complete agreement in the form of a 5 or 6. However, a clear majority of the experts surveyed (66 per cent) can identify no or only a few targets and measures and rated this as a 1, 2, or 3 on the scale.

In terms of the **transformation to a circular economy**, the experts see **as much demand** on the part of the companies as on the part of the Federal Government. For example, 86 per cent expressed a critical view of the activities of companies in this area by awarding a 1, 2, or 3. However, at 6 per cent, the proportion of respondents who did not agree at all and therefore gave a score of 1, is only about half as large as for the assessment of the targets and measures of the Federal Government. Some interviewees made a strong differentiation in their assessment depending on the sector. For example, efforts in **high-production industry** or **trade** are viewed very positively.

The positioning of **Germany as an export nation** by companies is rated very similar to the efforts of the Federal Government in this area. Almost half of the respondents (44 per cent) see that targets and measures are being put in place to strengthen Germany internationally in the area of GreenTech. Here too, trade was once again cited by some respondents as a positive example. In the German automotive industry, on the other hand, some respondents instead see a need to catch up.

The use of and **focus on digital technologies as drivers of GreenTech** are rated best on the company side by the experts surveyed. A whole 12 per cent were able to express their complete agreement in the form of a 6. A further 33 per cent also agreed by awarding a score of 4 or a 5. This means that companies are performing significantly better than the Federal Government on this issue. The reason given for this positive assessment was often that the majority of companies had now recognized the importance of digitalization and had, for example, created their own digital units working closely with the executive board. This was seen as an important step in embedding digitalization throughout the company and as a prerequisite for introducing specific measures.

In addition to the assessment of the targets and measures of companies in general, as analyzed above, the experts were asked to make an assessment of their own company in relation to the sub-questions listed if possible. Due to the position or corporate structure of the respondents, only 19 of the interviewees were able to provide this assessment.

What is striking is that the assessment of the **targets and measures of the respondents' own company is significantly better** than that of the Federal Government or of companies in general, across all sub-questions. For instance, targets and measures to **promote GreenTech** are considered appropriate by over 80 per cent of respondents, while 16 per cent even showed complete agreement by awarding a score of 6. In the assessment of companies in general, this figure was just under 50 per cent, although none of the interviewees expressed complete agreement. This positive assessment can be explained across all sub-questions by the composition of the sample. The assessment of their own company was mainly made by experts who either work in a company in the GreenTech industry or are explicitly tasked with promoting sustainability or similar issues in a large industrial company and therefore represent companies that are, for example, already independently certified in the field of climate neutrality and in whose value system and mindset the topics of GreenTech, climate protection, and sustainability are already firmly embedded. At the same time, some interviewees emphasized that although great efforts are being made within their own company, corporate groups in particular must choose an appropriate speed of implementation due to their size.

Respondents see **the greatest need for clear targets and measures** of their own company in the area of **transformation to a circular economy** (50 per cent), substitution of fossil fuels as primary energy sources (26 per cent), and the focus on digital technologies as drivers of GreenTech (24 per cent). The following figure shows the assessments of the six sub-questions presented in Chapter 4.6 and 4.7 in a comparison of the Federal Government, companies in general, and the respondents' own companies.

50%

of the interviewed experts see the greatest need for clear goals and measures on the part of their own company in the area of transformation to a circular economy.

What do you think of the targets and measures set out by your own organization?

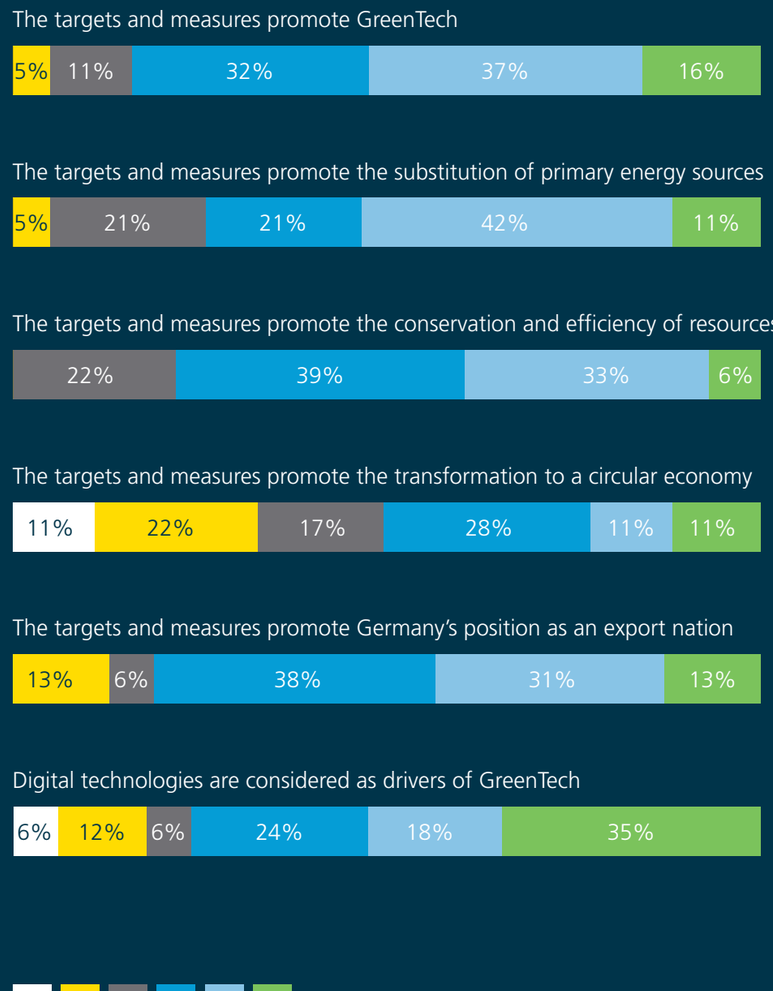
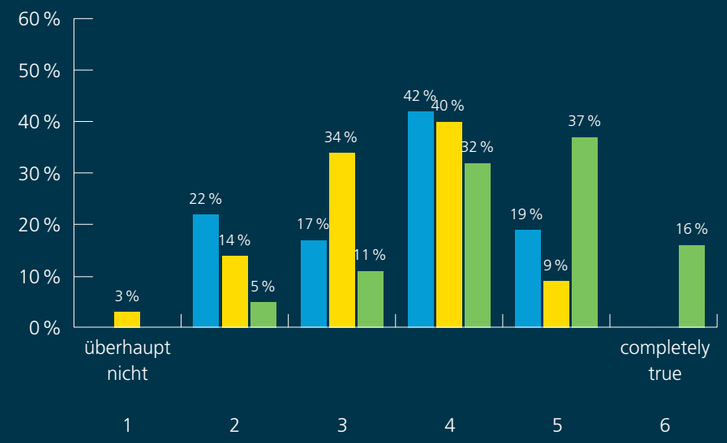


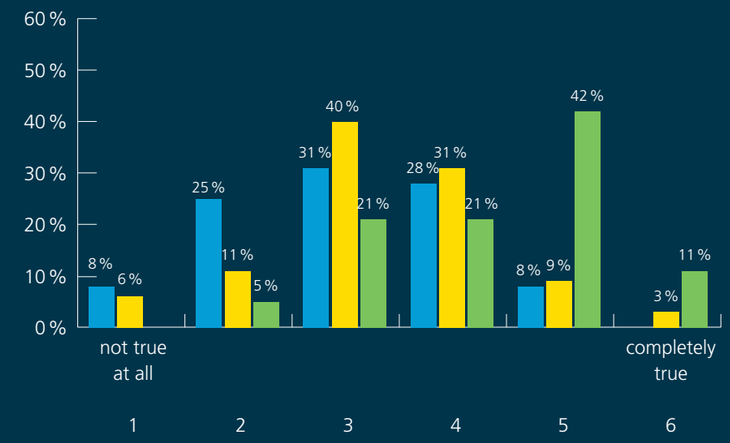
Figure 20: Respondents' assessment of the targets and measures of their own organization (n=19)

COMPARISON

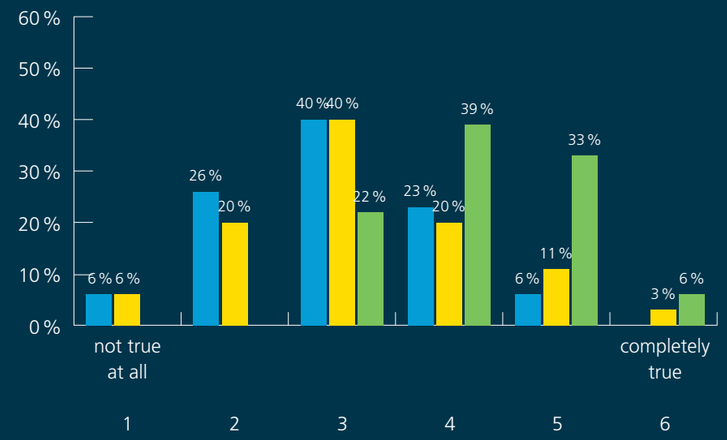
The targets and measures promote GreenTech



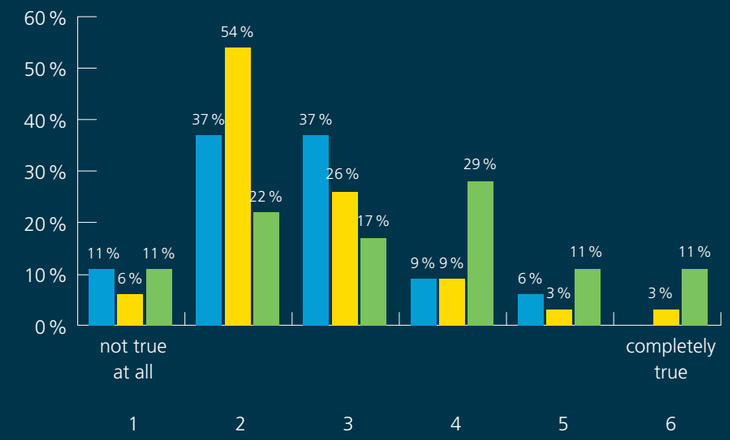
The targets and measures promote the substitution of primary energy sources



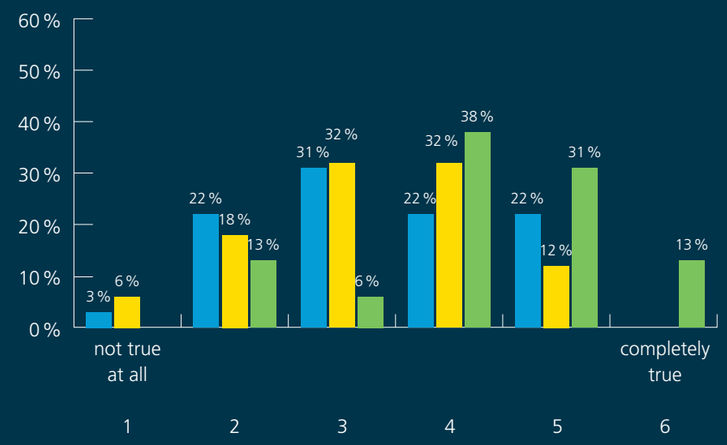
The targets and measures promote the conservation and efficiency of resources



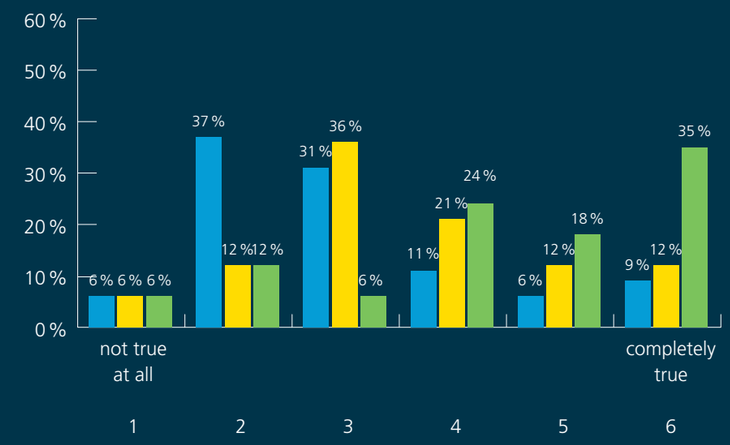
The targets and measures promote the transformation to a circular economy



The targets and measures promote Germany's position as an export nation



Digital technologies are considered as drivers of GreenTech



Companies in general

Ovvn company

German Federal Government

Figure 21: A comparison of the assessment of the targets and measures of the Federal Government, companies, and the respondents' own company.

4.8

Key success factors

Finally, the experts were asked about the most important success factors needed to promote GreenTech by 2030. Most experts identified key success factors, particularly in the areas of finance and funding, policy frameworks, and research and development.

The majority of the respondents see the **financing and funding of GreenTech** as a central design element. The funding sources therefore play an important role in advancing GreenTech innovations in Germany as a business location. The chosen technology does not matter; the experts stress the need to remain open to technology in order to generate improvements. In the opinion of the experts, the importance of the funding requirements now seems to have been recognized by the Federal Government. The complexity of the funding landscape, with numerous funding programs and structures, as well as lengthy and difficult application processes, is viewed critically. The latter is particularly important for start-ups, because with lengthy application procedures in which the answer is only available after six months, agile companies that find their business model dynamically often fall by the wayside. Therefore, state support should not slow things down, but speed things up. In addition to these policies, some respondents highlighted the importance of the private sector. They argue for greater investment by the private sector.

“From an investment perspective, this topic of ‘ESG’ is getting bigger and bigger, definitely.”

Dr. Jan-Claudio Muñoz,
partner at Alter Equity

Even if the success factors in the area of finance and funding are closely linked to the policy framework, the measures of the **policy framework** are mentioned separately by the experts and rank second among the most frequent success factors. The experts hope that policies will include reliable and ambitious goals and framework conditions. The focus is on predictability through a long-term, stable, and calculated political strategy. The **reduction of red tape** is also mentioned as a success factor. As in the field of funding and financing, the experts call for faster decisions. The streamlining of decision-making processes is therefore mentioned across all sectors, for the creation of new companies, for the possibility of new business models, as well as for the operation of renewable energies, and for the area of software/resource efficiency. There are also calls for better access to projects in the GreenTech sector, where there is still far too much nationalization and standardization. Startups in particular often do not get off the ground, even if they have good ideas. That is why it needs to become easier in future to incorporate good ideas from the startup environment into public projects.

“We need to simplify investment and approval processes. It’s unacceptable that we in Germany have three or four-year approval processes for green technologies. We have to move much faster than that.”
Kevin Bär, Senior Manager Sales and Growth Global, E.ON

“We have to get the best founders to come to Germany or we need to make better use of existing potential here.”
Dr. Jan-Claudio Muñoz, partner at Alter Equity

In addition, the experts attach great importance to the major goals that are necessary to drive innovation. The European Green Deal is cited as a good example that helps to achieve a common goal. This is also important to achieve long-term goals. Private and industrial investment decisions in particular need a clearly defined environment and thus a **clearly defined strategy**. This is not only due to political factors and the Federal Government, but also to individual companies that want to position themselves in the field of GreenTech.

However, without the right partners on board, it is difficult to achieve major goals. The experts rely on **players networking with one another** as it is no longer enough to simply be inventive. A common understanding and international partners are needed to enable Germany to compete in the international market. Internationally functioning value chains and models have long been indispensable for success.

In order to combat pollution and the wasteful use of resources, the experts see a need t**o control and put a price on resource consumption**. CO_2 pricing with reliable growth rates is seen as a suitable instrument for this. The carbon footprint of products and companies should also be included in company reporting alongside all of the financial factors, as the environmental impact is just as important as the generated turnover.

For the sustainable success of GreenTech, the experts see the **market-based incentive** as a further success factor, since the products should be able to compete on the market with little or no state subsidies. After all, even the best product or technology is not a product if it is not purchased. In order to be successful worldwide, German companies must be commercially and technically competitive. Political framework conditions such as the Carbon Border Adjustment Mechanism or similar initiatives can help. A market, even if it is politically created and regulated, ultimately provides the framework within which companies can operate. The third most common success factor among the experts is the field of **research and teaching**. Applied research in particular will be placed at the forefront of promotion and intensification. The aim is to invest in smart minds with appropriate further training measures, but also to set up and promote more study courses dealing with the topic of GreenTech. In this way, the experts hope to see a greater transfer of research achievements into the economy. In addition, the experts surveyed see companies as having an important role to play because they can contribute to innovation in the long term by developing the skills of their employees. Although this is primarily associated with expense, the experts see a high return on investment in the successful further training of their own employees. Companies have a major task because the experts consider the promotion of technical training to be the most important aspect. They point out that technical training is increasingly taking a back seat among young people and that companies will soon have glaring knowledge, staff, and skills gaps. If it is not possible to inspire people back into technical professions, then they see Germany as an export nation being increasingly sidelined. Without innovative implementation skills in the country, technology will be bought and used instead of being developed and exported. Germany needs to invest more in research and teaching in the technical field in order to remain competitive.

The fact that GreenTech has a social component has been examined several times in various areas of the study. There are also success factors that affect the social level. GreenTech needs to find **acceptance** within society. This requires a **shift in mindset** in the population. This change in attitude can be achieved by **emotionalizing** the products and through **proper communication**.

“GreenTech needs to generate value and prosperity, otherwise we’ll have an acceptance problem.”

Conrad Hammer,
Head of the Federal-State-Municipal Coordination team,
National Center for Charging Infrastructure at NOW GmbH

This requires social rethinking. The experts believe the topic is evolving into a lifestyle that should establish itself far beyond a social bubble. They think the responsibility lies equally with politicians and companies. Politicians must ensure that they do not ignore the majority and that the topic of sustainability also reaches citizens who have not yet thought about it. The experts note that communication of the topic often takes place in an isolated bubble and does not reach the majority of citizens. Companies should not only present GreenTech on marketing slides, but also make the developed and implemented environmental solutions and systems tangible to people in order to embed the topic of GreenTech in their minds.

The experts also appreciate the importance of **technology openness** to the success of GreenTech by 2030. It is important not to always give priority to one technology, otherwise other technologies will fall by the wayside. It would be conceivable to put out funding applications with the aim of inviting tenders and not with specifications on how exactly something should be implemented.

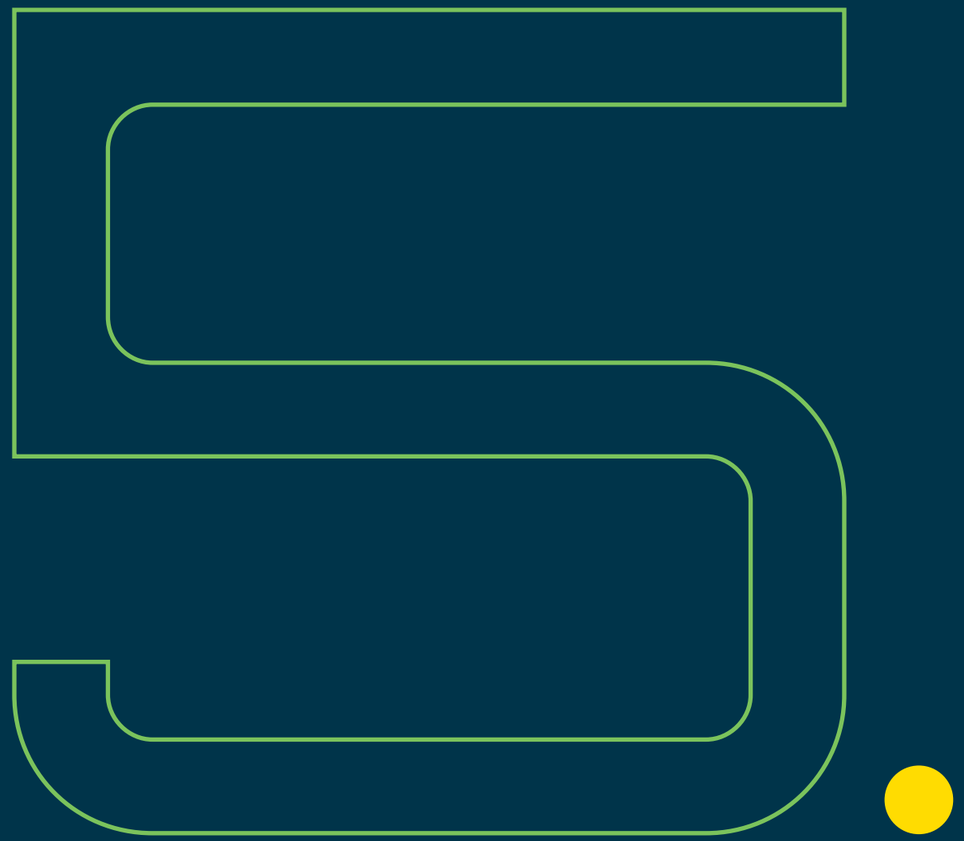
The **creation of a circular economy** is seen as an important lever, so all industrial sectors should focus on the circular economy. A particular focus is placed on the more efficient separating and sorting of used materials. Even though the experts are already seeing measures in this area, more are expected by 2030. Realization of the **energy and transport transition** is given as another success factor. With the energy transition in particular, the experts see cities and municipalities as role models to motivate private households. More **entrepreneurial spirit**, **more courage**, and more **willingness to implement** are required of companies. Companies need to find the right time to take the right action and simply have the courage to take a trial-and-error approach.

Finally, **scalable**, **sustainable digitalization** is seen as a further success factor for GreenTech. The topic of digitalization should definitely be strongly promoted, as it is simply a prerequisite for raising the potential in all areas. This includes the aforementioned personnel development because a technology that hardly anyone can use is not sustainable. The use of data is also attributed a key role. Data is often used only for individual areas, although sharing data could also improve many other processes. Ultimately, the experts see an **integrated economic**, **environmental, and social approach** as a **relevant success factor** in a balanced and joint view.

“We may also need to agree a little more on commonalities and jointly address such issues internationally. Because Germany is too small as a competitive international market, and if we want to be able to compete on an international stage then this requires setting up internationally functioning value-added models based on the existing advanced technology and then being able to stay the course through market power. This may also define a new quality of cooperation, perhaps also national pride, and European pride, but I think this mentality of ‘I’m the most inventive, and that’s why it will work’ is no longer enough.”
Sven Krüger, CEO & Co-Founder, GREENTECH FESTIVAL

“We need to emotionalize GreenTech as an experience, arouse interest in it, and spread the idea of community. Then people will queue like with Apple.”

Frank M. Rinderknecht, founder and CEO of Rinspeed AG



GreenTech – Made in Germany

Recommendations for action

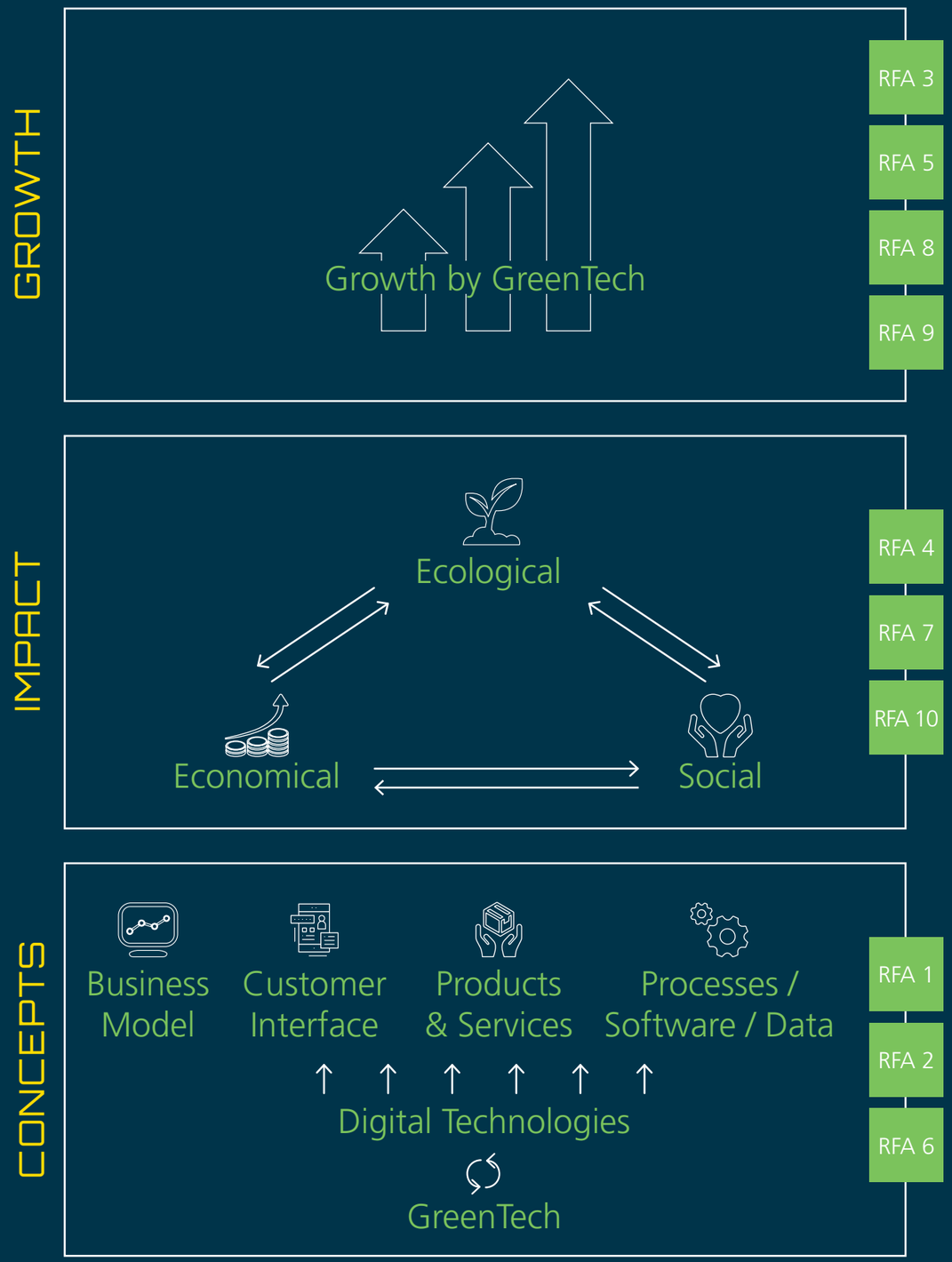


Figure 22: Assignment of recommendations for action to the reference model

Further efforts from the world of politics and business are required to continue the "GreenTech – Made in Germany" success story. This study offers a reference model for this purpose. It sorts the targets and measures of the new Federal Government into the reference model and then carries out an evaluation by means of an expert survey. From the individual components of this study, the following recommendations for action for Germany as a business location can be derived. These, in turn, can be assigned to the reference model in Chapter 2. What is striking is that the majority of the recommendations for action are aimed at the topic of "Growth by GreenTech."

5.1

Technology as a key factor in tackling the climate crisis

RFA 1

Technology is the key factor in tackling the climate crisis. All the experts surveyed agree on this. The transformation into a socio-ecological market economy is also emphasized by the new Federal Government. However, the coalition agreement contains **too few references to the critical role of technology**. The term GreenTech is not addressed by the Federal Government. Nor is the vital importance of digital technologies for the implementation of GreenTech. However, the special role of innovation and technology in addressing the climate crisis and the complexity of decarbonization should be a common thread running through the actions of politicians and companies. If Germany can expand its leading role in the development of GreenTech, environmental goals can be integrated with economic and social goals in accordance with the sustainability triangle.

5.2

Digital transparency as a basic requirement of the circular economy

RFA 2

At various points in this study, it becomes clear that a **fundamental shift from a linear economy to a circular economy** is necessary. The basic requirement for this is **transparency** with regard to the materials used in products, services, and business processes. Digital technologies provide an essential basis for this. For example, the corresponding materials can be documented in the form of **digital product passports**. This will lay the foundation for subsequent recycling of valuable materials, as provided for in the mission statement of the circular economy. The Federal Government should therefore advocate the standardized introduction of appropriate product passports at national and European level and set higher reuse rates for products and services. This should be combined with a comprehensive information campaign to implement a circular economy in order to prepare relevant stakeholders in society for the replacement of the linear economy.

5.3

Vision and master plan for sustainable implementation

RFA 3

The analysis of the coalition agreement and the findings of the expert survey show that the new Federal Government has formulated a **wide range of relevant targets and measures** from the start. However, from the perspective of the experts surveyed, there is no **overall vision** or **concrete master plan** for implementation. Through an ambitious vision, different subject areas can be combined. This also forms the basis for **clear communication** with the stakeholders involved (business, citizens, etc.). However, the survey of experts indicates that the Federal Government's working basis is perceived more as a **collection of relevant individual tasks without a common thread**. In addition, there is a lack of concrete planning for the implementation of individual areas of action. For the further positioning of Germany as a GreenTech export nation, both components are essential in order to clarify the working basis for companies.

5.4

Interaction of the three sustainability dimensions

RFA 4

A further recommendation for action of the present study relates to the **interaction of the sustainability dimensions**. The GreenTech reference model clearly shows that corresponding effects are only possible if the different dimensions of sustainability are taken into account equally. This is confirmed by the expert interviews. The coalition agreement of the new Federal Government places great emphasis on environmental effects and strongly highlights the **energy transition** and the **transformation of the automotive industry**. The economic and social effects of the transformations are given much less attention. However, this is essential for the sustainable growth of the GreenTech industry and the adoption of corresponding products and solutions by companies and individuals.

Therefore, on the one hand, it is important to give greater consideration to the social consequences of GreenTech. On the other hand, it is a question of promoting **viable business models for the integration of economic and environmental interests**.

5.5

Increase in implementation momentum RFA 5

A particularly important recommendation from the experts is an **increase in implementation momentum**. The new Federal Government has recognized this problem area itself and has established some guidelines in the coalition agreement for **reducing bureaucracy** and **speeding up decision-making processes**. From the point of view of the experts surveyed, however, there has been very little sign of this. This applies, for example, to approval processes for the expansion of renewable energies, complex decision-making processes relating to the digitalization of public administrations and municipalities (smart cities), and the availability of venture capital. Germany is **over-structured and too slow in many decision-making processes**. The criticism relating to lack of implementation momentum is also directed at the coalition agreement itself. From the point of view of the experts surveyed, the Federal Government must **speed up the implementation** of its own plans. The fact that the COVID-19 pandemic and the war in Ukraine have also limited the resources of the Federal Government should be taken into account.

5.6

Focus on digital business models RFA 6

Digital technologies are essential to GreenTech. However, these are still mainly used today for efficiency gains through data, software, and adequate control systems. From the point of view of the studies analyzed for the reference model, the greater p**otential of digitalization lies in new business models**. This is confirmed by the results of the expert survey. Business models have an **economic knock-on effect** with regard to the implementation of innovations. If GreenTech technologies are an essential part of such business models, the development of environmental effects can also gain considerable momentum. Ideas for digital business models are emerging in various sectors. In the energy industry, for example, the implementation of virtual power plants, data processing in smart grids, power-to-heat systems, or software-as-a-service for production plant optimization offers relevant business model prospects for GreenTech.

For the mobility sector, mobility platform forums, car sharing, or smart services are relevant as business models for traffic management. Politicians and companies must therefore focus more on **developing, testing, and scaling digital business models**.

5.7

Technology alone is not enough RFA 7

The findings of the expert survey clearly show that significant environmental and economic effects can be achieved with GreenTech. **Technology plays a key role in the transformation of the economic system**. But technology alone is not enough. Politicians need to increasingly convey the message that the **normal production and consumption patterns** in our society are not sustainable in the long term. Therefore, a change of heart within the population is required: A willingness to give things up, conserve resources, save energy, and other key sustainability issues have by no means reached all levels of society. As a result of supply chain problems, the war in Ukraine, and soaring inflation, sustainability has taken a back seat. Therefore, there is a risk of short-term suppression of relevant issues relating to climate development. This is something that politicians must address. Sustainability is not a luxury problem, but a central question of the sustainability of our society.

5.8

Simple financing models for startups and SMEs RFA 8

As a cross-sectoral industry, the GreenTech industry is primarily characterized by small and medium-sized enterprises. A large number of companies are currently creating strong growth momentum. This forms the basis for the development of world market leaders. **Access by the relevant companies to innovation and risk capital** is a prerequisite for this. While conditions for access to risk capital have improved in Germany, more efforts and a **significant reduction of red tape** are needed compared to the US and China. Access to risk and innovation capital needs to become more transparent, simpler, and faster. Corresponding approaches are included in the coalition agreement of the new Federal Government. Overall, a focus is placed on promoting startups. This must be specifically extended to small and medium-sized enterprises in the GreenTech sector. The **promotion of small and medium-sized structures** in terms of the implementation of corresponding technologies is still too weak.

5.9

Review and adjustment of regulatory framework conditions RFA 9

The results of the meta-analysis clearly show that regulatory framework conditions have a strong effect on economic activity. This also applies to the **pricing of unsustainable economic structures or the subsidization and promotion of sustainable economic structures**. The regulatory framework needs to be reviewed and adapted in many areas by the new Federal Government. Many examples of this can be derived from the meta-analysis of existing studies. Starting points are, for example, CO_2 pricing in the European Emissions Trading System (ETS), standardization and certification, the promotion of sustainable finance, and incentives for research and development through suitable funding programs. From the point of view of individual sectors of the economy, further starting points for the **adjustment of incentive systems** can be derived. The Federal Government is encouraged to implement these incentives in a timely manner, where possible in consultation with European partners.

5.10

Specific measurement of sustainability effects RFA 10

The outlined reference model and the results of the expert survey clearly show that there is a lot of evidence that **GreenTech can reconcile economic and environmental effects**. However, the **rebound effect** must be taken into account. Specific measurement of sustainability effects is necessary for individual applications. The **data basis** for this is surprisingly weak in many areas. Important effects cannot be quantified with sufficient precision either from the meta-analysis or from the expert survey. However, since cost-effectiveness is considered to be the central driver of GreenTech, such measurement models are necessary. Therefore, politicians should address the **standardized analysis of the measurement of sustainability effects** and define this as a framework condition for corporate activity. In some cases, corresponding measurement models have already been established at individual companies. The data-based control of companies through digital technologies forms an essential basis for this.

Although the **ten recommendations for action** presented above have been derived from the analysis of the reference model, coalition agreement, and expert survey, the set priorities should not be considered final. From reading the individual results, a large number of further recommendations can be defined that are relevant for politics and business. This demonstrates how the further development of GreenTech is characterized by a high degree of complexity. The density of the relevant design parameters is high. Reference models are an essential tool for presenting complex systems in a simplified way. In this way, further opportunities for sustainable development can be derived from the GreenTech reference model and the results of the meta-analysis and expert survey.

Bibliography

[1] German Federal Environment Agency: "Primärenergieverbrauch nach Energieträgern." [Online]. Available: https://www.umweltbundesamt.de/bild/entwicklung-des-primaerenergieverbrauchs-in-0. [Accessed: Jun-24-2022].
[2] Wirtschaftswerkstatt: "Green Tech: Begriffe A–Z" 2022. [Online]. Available: https://www.wirtschaftswerkstatt.de/Glossar/G/344/Green-Tech. [Accessed: Mar-08-2022].
[3] H. Berrer, B. Dolle, C. Helmenstein, F. Kerschbaum, P. Krabb, P. Pohl, and M. Stadlbauer: "GreenTech Innovationsdynamik," Vienna, 2016.
[4] M. Akbari, M. Khodayari, M. Danesh, A. Davari, and H. Padash: "A bibliometric study of sustainable technology research," Cogent Business & Management, Vol. 7, No. 1, p. 1751906, Jan. 2020.
[5] Talent Tree: "Greentech (Definition)," 2022. [Online]. Available: https://talent-tree.de/glossar/greentech-definition/. [Accessed: Mar-07-2022].
[6] trend:research GmbH: "Potenziale Green Technology in der Region Ostfriesland," 2017.
[7] Stuttgart Region Economic Development Corporation: "Kompetenzatlas GreenTech: Sourcebook of GreenTech," 2013.
[8] Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection: "Klimaschutz in Zahlen," 2021.
[9] McKinsey: "Net-Zero Deutschland," 2021.
[10] T. Hellstern, K. Henderson, S. Kane, and R. Matt: "An executive's guide to climate technology | McKinsey," 2021. [Online]. Available: https://www.mckinsey.com/business-functions/sustainability/our-insights/innovating-to-net-zero-an-executives-guide-to-climate-technology. [Accessed: Mar-17-2022].
[11] Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection: "GreenTech made in Germany 2021: Umwelttechnik-Atlas für Deutschland," 2021.
[12] C. Jin, M. Shahzad, A. U. Zafar, and N. M. Suki: "Socio-economic and environmental drivers of green innovation: Evidence from nonlinear ARDL," Econ. Res. istraživanja, vol. 0, no. 0, pp. 1–21, Jan. 2022.
[13] L. K. Chu: "Determinants of ecological footprint in OCED countries: Do environmental-related technologies reduce environmental degradation?," Environ. Sci. Pollut. Res., Nov. 2021.
[14] R. Hintemann, J. Clausen, S. Beucker, and S. Hinterholzer: "Studie zu Nachhaltigkeitspotenzialen in und durch Digitalisierung in Hessen," Wiesbaden, 2021.
[15] Microsoft: "Digitalisierung für eine nachhaltige Zukunft," 2021.
[16] Bitkom: "Klimaeffekte der Digitalisierung: Studie zur Abschätzung des Beitrags digitaler Technologien zum Klimaschutz," 2021.
[17] S. A. R. Khan, a. S. A. Shah, Z. Yu, and M. Tanveer: "A systematic literature review on circular economy practices: challenges, opportunities and future trends," Journal of Entrepreneurship in Emerging Economies, Jan. 2022.
[18] M. P. Hekkert, E. Worrell, Hanemaaijer, and J. Potting: "Circular Economy: Measuring innovation in the product chain" 2017.
[19] E. Afum, Z. Sun, Y. Agyabeng-Mensah, and C. Baah: "Lean production systems, social sustainability performance and green competitiveness: The mediating roles of green technology adoption and green product innovation," Journal of Engineering, Design and Technology, Jul. 2021.
[20] G. Mazar, M. Kreher, and P. Heidkamp: "Sustainability 1.0 - Warum die Technologiebranche kein Vorreiter der Nachhaltigkeitstransformation ist," 2021.
[21] Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection: "GreenTech Atlas 2021: Deutsche Wirtschaft profitiert von wachsenden Märkten für Umwelttechnologien" 2021. [Online]. Available: https://www.bmuv.de/pressemitteilung/greentech-atlas-2021-deutsche-wirtschaft-profitiert-von-wachsenden-maerkten-fuer-umwelttechnologien. [Accessed: Mar-08-2022].
[22] X. Li and H. Long: "Research Focus, Frontier and Knowledge Base of Green Technology in China: Metrological Research Based on Mapping Knowledge Domains," Polish Journal of Environmental Studies, Vol. 29, No. 5, pp. 3003–3011, 2020.
[23] B. Hartmann: "GreenTech – Nachhaltige Innovationstreiber." [Online]. Available: https://www.marketsinternational.de/wasserstoff-vereinigte-arabische-emirate/. [Accessed: Mar-17-2022].
[24] Fandom: "Green Tech | Megatrends Wiki" [Online]. Available: https://megatrends.fandom.com/de/wiki/Green_Tech. [Accessed: Feb-23-2022].
[25] B. Teufel und C. Sprus: "Wie die Digitalisierung als Treiber der Dekarbonisierung fungiert | EY – Schweiz," 2020. [Online]. Available: https://www.ey.com/de_ch/decarbonization/how-digitization-acts-as-a-driver-of-decarbonization. [Accessed: Mar-17-2022].
[26] M. Schwartz: "How Technology Can Provide A More Sustainable Future For The Industrial Sector," 2021. [Online]. Available: https://www.forbes.com/sites/forbestechcouncil/2021/08/31/how-technology-can-provide-a-more-sustainable-future-for-the-industrial-sector/?sh=4bbb6ab450c1. [Accessed: Mar-17-2022].
[27] D.-H. Kim, Y.-C. Wu, and S.-C. Lin: "Carbon dioxide emissions, financial development and political institutions," Economic Change and Restructuring, May 2021.
[28] T.-T. Shang, M. Tian, N. Tao, and Y. Chen: "Market-oriented green innovation model: conceptualisation and scale development of disruptive green innovation," Asian Journal of Technology Innovation, pp. 1–17, Aug. 2021.
[29] M. Rogers: "These 9 technological innovations will shape the sustainability agenda in 2019 | McKinsey & Company," 2019. [Online]. Available: https://www.mckinsey.com/business-functions/sustainability/our-insights/sustainability-blog/these-9-technological-innovations-will-shape-the-sustainability-agenda-in-2019. [Accessed: Mar-17-2022].
[30] August-Wilhelm Scheer Institute, "Innovation goes green." [Online]. Available: https://www.aws-institut.de/center-for-digital-greentech/. [Accessed: June-26-2022].
[31] T. Losse-Müller, N. Gläser, F. Czernin, S. Ramesohl, H. Berg, and J. Lauten-Weiss, "Zwischenbilanz COVID-19: Umweltpolitik und Digitalisierung," 2020.
[32] M. Hintze: "Green Tech: Deutschland im Dornröschenschlaf," 2021.
[33] V. Frick and A. Höfner: "Was Bits und Bäume verbindet," Munich: oekom Verlag, 2019.
[34] Federal Ministry for Economic Affairs and Climate Action: "Digital GreenTech – Umwelttechnik trifft Digitalisierung," 2021. [Online]. Available: https://www.foerderdatenbank.de/FDB/Content/DE/Foerderprogramm/Bund/BMBF/umwelttechnik-trifft-digitalisierung.html. [Accessed: Mar-07-2022].
[35] Association of German Chambers of Commerce and Industry (DIHK): "Chambers for GreenTech," 2022. [Online]. Available: https://www.dihk-service-gmbh.de/de/unsere-projekte/greentech. [Accessed: Mar-08-2022].
[36] M. Du, J. Antunes, P. Wanke, and Z. Chen: "Ecological efficiency assessment under the construction of low-carbon city: A perspective of green technology innovation," Journal of Environmental Planning and Management, 2021.
[37] Ellen MacArthur Foundation: "Completing the Picture: How the circular economy tackles climate change 2021 Reprint," Ellen MacArthur Found., Vol. 3, No. 26, September, p. 71, 2021.
[38] F. Dong, J. Zhu, Y. Li, Y. Chen, Y. Gao, M. Hu, C. Qin, and J. Sun: "How green technology innovation affects carbon emission efficiency: Evidence from developed countries proposing carbon neutrality targets," Environmental Science and Pollution Research, Jan. 2022.
[39] Boston Consulting Group: "Klimapfade 2.0: Ein Wirtschaftsprogramm für Klima und Zukunft. Gutachten für den BDI," 2021.
[40] Tata Consultancy Services (TCS): "Nachhaltig geht nur digital: Wie Deutschland mit KI und Co. die Zukunft gestaltet," 2021.
[41] K. Wilkinson: "The Drawdown Review," 2020.
[42] G. Bovensiepen, R. Hombach, and S. Raimund: "Quo vadis, agricola? Smart Farming: Nachhaltigkeit und Effizienz duch den Einsatz digitaler Technologien," 2016.
[43] Deloitte and GeSI: "Digital with Purpose: Delivering a SMARTer2030," 2019.
[44] Deloitte: "Nachhaltigkeit trifft Technologie: Sustainability Survey. Ergebnisse für den deutschen Markt," 2021.
[45] J. Wei and C. Wang: "A differential game analysis on green technology innovation in a supply chain with information sharing of dynamic demand," Kybernetes, Oct. 2021.
[46] J. Clausen: "Industrie 4.0 im Kontext von Umweltinnovationen" Berlin, 2019.
[47] German Federal Environment Agency: "Umweltbewusstsein und Umweltverhalten," 2022. [Online]. Available: https://www.umweltbundesamt.de/daten/private-haushalte-konsum/umweltbewusstsein-umweltverhalten#stellenwert-des-umwelt-und-klimaschutzes. [Accessed: May-31-2022].
[48] Ellen MacArthur Foundation, "Completing the Picture: How the Circular Economy Tackles Climate Change," 2019.
[49] M. Tsiodra and M. Chronopoulos: "A bi-level model for optimal capacity investment and subsidy design under risk aversion and uncertainty," Journal of Operational Research Society, pp. 1–13, Jul. 2021.
[50] Bitkom: "Klimaschutz durch digitale Technologien – Chancen und Risiken," 2020.
[51] R. Ullah, H. Ahmad, F. U. Rehman and A. Fawad: "Green innovation and Sustainable Development Goals in SMEs: The Moderateing role of government incentives," Journal of Economic and Administrative Sciences, Sep. 2021.
[52] A. Chelly, I. Nouira, A. B. Hadj-Alouane and Y. Frein: "A comparative study of progressive carbon taxation strategies: Impact on firms' economic and environmental performances," International Journal of Production Research.
[53] X. Chen, H. Yang, X. Wang, and T.-M. Choi: "Optimal carbon tax design for achieving low carbon supply chains," Annals of Operations Research, 2020.
[54] C. You, S. I. Khattak and M. Ahmad: "Do international collaborations in environmental-related technology development in the U.S. pay off in combating carbon dioxide emissions? Role of domestic environmental innovation, renewable energy consumption, and trade openness," Environmental Science and Pollution Research, Oct. 2021.
[55] F. Fusillo, F. Quatraro and S. Usai: "Going green: The dynamics of green technological alliances," Economics of Innovation and New Technology, 2021.
[56] "Koalitionstracker" [Online]. Available: https://fragdenstaat.de/koalitionstracker/. [Accessed: Jun-26-2022].

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