



TACKLING CLIMATE CHANGE IN THE AI ERA

TREND REPORT 2022



CDTM

CENTER FOR
DIGITAL TECHNOLOGY
AND MANAGEMENT



Bavarian State Ministry
for Digital Affairs



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The Bavarian State Ministry for Digital Affairs is a think tank for digitization in Bavaria and takes care of fundamental matters, strategy, and coordination as well as the dig- itization of public administration services. Bavaria is thus underlining the strong im- portance of the digital transformation.

The Ministry for Digital Affairs stands for the determination not only to follow global digital developments and to foster future digital technologies but to help shape them in a sovereign manner. For the Ministry, it is most important that digital transfor- mation must serve the human individuals and our society.

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CENTER FOR
DIGITAL TECHNOLOGY
AND MANAGEMENT

**A project of the Center for
Digital Technology and Management (CDTM)**

The Center for Digital Technology and Management (CDTM) is a joint, interdisciplinary institution for education, research, and entrepreneurship of the Ludwig-Maximilians- Universität (LMU) and the Technische Universität München (TUM).

It offers the add-on study program "Technology Management" for students from various backgrounds, which provides students with tools and knowledge at the intersection of business and digital technologies.

The entire trend report was written by CDTM students under the close guidance of research assistants.

Visit www.cdtm.de for more information.

PREFACE OF THE EDITORS

As Herman Kahn, one of the founding fathers of modern scenario planning, nicely states, it is tremendously important for strategy and policymakers to get a deep understanding of possible future developments to be prepared for them.

The Center for Digital Technology and Management aims to connect, educate and empower the innovators of tomorrow. It is our mission to equip our students with the tools and knowledge they will need to become responsible leaders who actively shape their future environment rather than only react to changes.

This Trend Report is the result of the course Trend Seminar, which is part of the interdisciplinary add-on study program "Technology Management" at CDTM. Selected students of various disciplines, such as Business Administration, Psychology, Medicine, Computer Science, Electrical Engineering, and others, work together on a relevant topic of our time. Over the course of seven intense weeks of full-time work during their semester break, the participating students dive deeply into the topic of the Trend Seminar. Working in several interdisciplinary sub-teams, students apply the knowledge of their main studies and learn new perspectives from their team members. They conduct trend research, develop scenarios of the future, generate ideas for innovative products or services, and detail them out into concrete business concepts.

We would like to take the chance to thank everyone who contributed and made this CDTM Trend Report possible:

We want to thank Bavarian State Ministry for Digital Affairs and the Bavarian AI Council for supporting this Trend Seminar. Particularly, we want to thank Prof. Dietmar Harhoff and Dr. Susanne Klöpping for their collaboration, valuable in

“ **Everybody can learn from the past. Today it is important to learn from the future!** ”

Herman Kahn ”

sights, and feedback throughout the whole project. We hope our findings support you in driving innovation in the context of Climate Change in the AI Era!

In addition, we very much thank all our lecturers, who shared their knowledge and contributed to this project's success:

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Carla Pregel Hoderlein, Anna-Sophie Liebender-Luc and Denys Lazarenko

Center for Digital Technology and Management (CDTM)

PREFACE OF THE PROJECT PARTNER

The State Government of Bavaria is aware that climate change is one of the biggest challenges of our time. Despite other crises like the Covid-Pandemic or a war in Europe, we must not forget: Climate change is here with us to stay. It is crucial that we make an utmost effort to follow the path of the Paris Agreement and keep the global warming significantly below two degrees. Therefore, we must pool the forces and efforts and make use of our scientific and technological potential and competencies to secure our future and well-being. Digitalization and digital technologies can – when used in the right way – provide us with great tools to meet this challenge.

In particular, “Artificial Intelligence” (AI) is a key technology that is very powerful and promising not only for developing new and successful business models but also regarding resource efficiency within production processes, protection of our forests or the shift to more sustainable agriculture – to give only a few examples.

The Bavarian Government is strongly supporting future technologies, especially Artificial Intelligence, with the Bavarian Hightech Agenda and Hightech Agenda Plus: Specifically, we are spending about 3.5 billion euros for AI and other technologies like Quantum Technologies or Clean Tech. For AI alone, we are targeting 100 new chairs in academia all over Bavaria – as many as the national Government is planning for Germany as a whole.

Furthermore, the Bavarian State Government has established the Bavarian Council on AI providing advice in the planning of AI activities. The AI Council consists of 21 leading experts from academia and economy in the field of artificial intelligence with Professor Sami Haddadin as chairperson. I am very grateful that – based on the initiative of the Ministry for Digital Affairs – the AI Council has established a

“ **Artificial intelligence can play a vital role in tackling climate change and its consequences.** ”

Judith Gerlach, MdL ”

new project group headed by Professor Dietmar Harhoff on “AI and Climate Protection” with which we are collaborating closely. The support of the Trend Seminar of the Center for Digital Transformation and Management is the first result of our collaboration.

The 2020 report, “How AI can enable a sustainable future”, is estimating that AI alone can help to reduce up to 4 percent of global greenhouse gases until 2030 – and at the same time could contribute up to 5.2 trillion US-dollar to the world economy. This shows that Artificial Intelligence is a key technology – perhaps even the key technology – to connect both innovation and successful business models of the future with climate protection and sustainability.

In Bavaria, we want to take advantage of the innovative and climate protective potential of AI. Therefore, I am very grateful that we had the opportunity of working with the Center for Digital Technology and Management on this topic. The innovative and interdisciplinary character of the Trend Seminar is exactly the right approach for addressing the questions we have in mind: How can we bring together the business potential and the ecological potential of AI – now and in the future? What are the main trends and drivers in the field of AI related to (tackling) climate change? What are the most promising approaches for the next 10 to 20 years?

I would like to give a huge thank you to all the students who participated in the Trend Seminar, diving deeply into two enormous topics: climate change and artificial intelligence. Thank you for the commitment and thorough effort, for the creativity and ideas that found their way into the trend analysis and the trend report. Of course, I also want to thank the coordinators of this trend seminar for their great work: Ann-Sophie Liebender-Luc, Carla Pregel Hoderlein and Denys Lazarenko.

Having seen the inspiring results of the trend seminar, we are planning to use them as basic and essential information for a larger project which we will pursue with the help of the AI Council as well as the innovation eco-system of Bavaria: to establish the connection of AI and climate protection as a focal point of the Bavarian AI network and to develop a center of excellence for AI focusing on its potentials for climate protection and resource efficiency in Bavaria.

Judith Gerlach, MdL
Bavarian State Minister for Digital Affairs

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METHODOLOGY

For a given topic that is highly impacted by digital technologies, the Trend Seminar pursues three main goals:

- To analyze the status quo and recent developments in order to identify important trends
- To develop extreme but plausible scenarios of the future to be prepared for upcoming challenges
- To develop future-proof product and service ideas and to detail them out into business concepts

These goals are represented by the three main phases of the trend seminar: The Trends Phase, the Scenario Phase, and the Ideation Phase. The Kick-off Phase and the Communication Phase support the introduction into the Trend Seminar journey and the communication of the results in a written and presentation format, respectively.

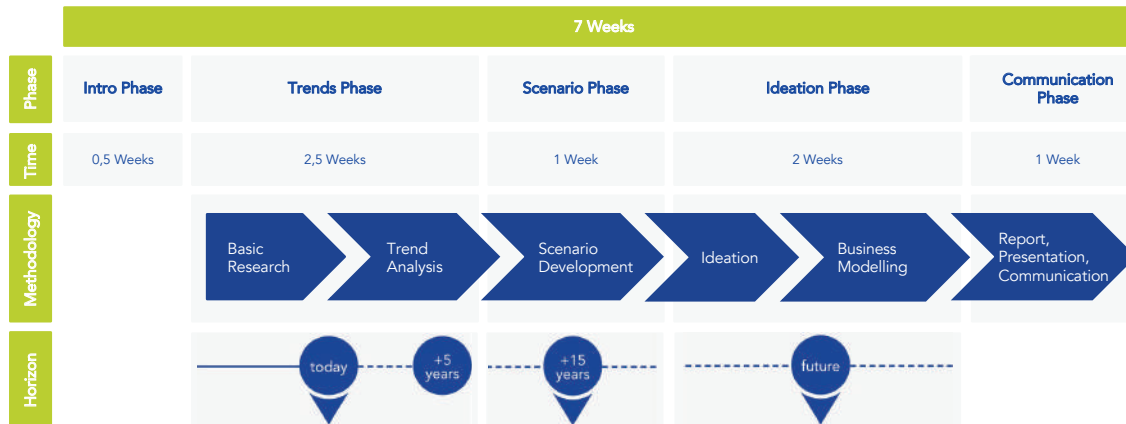
Twenty-six students, supervised by two doctoral candidates, pursue the Trend Seminar in seven weeks of intensive full-time work alongside their project partner. In each phase, interdisciplinary sub-teams are formed, including students from technology, business, and various other backgrounds, to combine versatile ways of thinking.

The **Trends Phase** yields a holistic overview of recent developments and trends in the environment of the overall topic. Based on the commonly used STEEP approach (Social-Technological- Economic-Ecological-Political), the status quo and trends in the fields of society & environment, technology, economics, politics & legal, as well as emerging business models are analyzed. Knowledge is gathered by literature research and expert interviews, preceded by a series of input presentations by experts on the topic. The

class is split into five teams, each working on one of the thematic scopes. At the end of the Trends Phase, the teams present their key findings to each other for everyone to get a holistic view of the topic to build upon in the following phases.

The **Scenario Phase** builds upon the analyzed trends in order to create four scenarios of different futures in twenty years ahead. The driving forces behind the developments are identified and specified as drivers with bipolar outcomes. Once specified, all drivers are ranked according to their respective impact on the overall topic and the perceived degree of uncertainty regarding their outcome. Two key drivers that are independent of one another and have both a high impact and a high degree of uncertainty are chosen. Their bipolar outcomes are used to create a scenario matrix of four scenarios. A timeline for each of the scenarios is created, and the scenarios are sketched out using persona descriptions and visualizations. The Scenario Phase starts with a three-day workshop followed by group work in four teams. The teams are newly formed to include experts from each subtopic of the Trends Phase in each new Scenario Team.

In the third phase, the **Ideation Phase**, the goal is to develop innovative business concepts, which are then tested against the previously developed scenarios. Within a three-day workshop on structured ideation following the SIT approach (systematic inventive thinking) and unstructured ideation methodologies, a large number of business ideas are developed. Out of these, the most promising five ideas are selected and further developed into detailed business concepts. The sustainable business model canvas serves as the base structure. At the end of the seminar, the business model concepts are presented to the project partner and external guests.



LIST OF ABBREVIATIONS

AC

Air Conditioner

AI

Artificial Intelligence

API

Application Programming Interface

ASIC

Application-specific Integrated Circuit

AU

African Union

AUM

Assets under Management

B2B

Business-to-Business

B2B2C

Business-to-Business-to-Consumer

B2C

Business-to-Consumer

BMI

Bavarian Ministry for Internal Affairs

BTC

Bitcoin

CAD

Computer Aided Design

CAGR

Compound Annual Growth Rate

CBAM

Carbon Border Adjustment Mechanism

CBM

Circular Business Models

CCO

Chief Climate Officer

CE

Circular Economy

COP26

UN Climate Change Conference in Glasgow

CSR

Corporate Sustainability Reporting

CSRD

Corporate Sustainability Reporting Directive

D2C

Direct-to-Consumer

DAX 160

Companies listed in the DAX, MDAX, and SDAX

DIY

Do-it-Yourself

EC

European Commission

ECB

European Central Bank

EFSA

European Food Safety Authority

EGDC

European Green Digital Coalition

EIB

European Investment Bank

ESA

European Space Agency

ESG

Environmental, Social, Governance

ESR

Effort Sharing Regulation

ETS

Emission Trading Scheme

EU27

EU Member States Excluding UK

FAIR Data

Findable, Accessible, Interoperable and Reusable Data

FAQ

Frequently Asked Questions

FPGA

Field Programmable Gate Array

List of Abbreviations

GAN

Generative Adversarial Networks

GDP

Gross Domestic Product

GDPR

General Data Protection Regulation

GHG

Greenhouse Gas

GPU

Graphics Processing Unit

GRI

Global Reporting Initiative

Gt

Gigatons

HR

Human Resources

ICT

Information Communication Technology

IoT

Internet of Things

IT

Information Technology

LCOE

Levelized Costs of Energy

LMU

Ludwig Maximilians Universität

ML

Machine Learning

MRI

Magnetic Resonance Imaging

NAFTA

North American Free Trade Agreement

NDC

Nationally Determined Contribution

NFRD

Non-Financial Reporting Directive

NFSR

Non-Financial Sustainable Reporting Standard

NGO

Non-Governmental Organization

NLP

Natural Language Processing

OSS

Open Source Software

PaaS

Product-as-a-Service

PC

Price over Carbon

PR

Public Relations

R&D

Research & Development

SaaS

Software-as-a-Service

SASB

Sustainability Accounting Standards Board

SDG

Sustainable Development Goal

SEO

Search Engine Optimization

SFDR

Sustainable Finance Disclosure Regulation

SINTEG

Schaufenster intelligente Energie - Digitale Agenda für die Energiewende

TCFD

Taskforce on Climate-related Financial Disclosure

TPP

Trans-Pacific Partnership Agreement

TPU

Tensor Processing Units

TSVCM

Taskforce on Scaling Voluntary Carbon Markets

TUM

Technical University of Munich

TWh

Terrawatt-hour

UI

User Interface

UN

United Nations

UNDIO

United Nations Disaster Insurance Organization

List of Abbreviations

UNEP

United Nations Environment Programme

UNASUR

Union of South American Nations

V2V

Vehicle-to-Vehicle

V2X

Vehicle-to-Grid

VC

Venture Capital

VR

Virtual Reality

YoY

Year-over-Year

TRENDS

The following chapter lists current trends that have a strong impact on tackling climate change in the AI era. In accordance with the Trends Phase methodology, trends and related driving forces are structured into five areas: technological trends, societal and environmental trends, legal and political trends, economic trends, and business model trends.

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TECHNOLOGY TRENDS

TACKLING CLIMATE CHANGE IN THE AI ERA

Towards Energy-Efficient AI
Optimizing Distributed Systems
Leveraging Geospatial Image Processing
Accelerating Material Discovery
Making Logistics Autonomous

TECHNOLOGY TRENDS

Influencing Climate Change in the AI Era

Artificial Intelligence (AI) related technologies are increasingly used to tackle climate change. Conversely, the looming issue of climate change significantly impacts the development of AI technologies. As our global conscience shifts toward environmental sustainability, our technological developments need to keep pace, particularly in AI. The following chapter summarizes the five most significant AI-related technology trends affecting climate change.

First, academia and industry are focused on making AI applications more energy-efficient. Research and development follow two complementary approaches: developing new AI algorithms that need less computational operations and developing specialized hardware tailored to the algorithms requirements. Both methods aim to reduce the power consumed by AI applications during training and inference, thus making AI itself more sustainable. Reducing power consumption further enables AI applications on edge devices that currently struggle with their computation and energy requirements.

Second, AI can help us move from centrally controlled resource systems like energy, water, and waste to distributed ones. The greenhouse gas (GHG) emissions that have been fueled by rising urbanization and population growth among other factors can be reduced by managing the mentioned systems, detecting errors early, and understanding the underlying dynamics. In short, more efficient smart grid systems, water management, and automated waste management can all be implemented with AI models and their fundamental driver technologies, such as 5G and the Internet of Things (IoT).

Third, there is a strong trend toward geospatial image processing. More precisely, aerial and satellite images are increasingly analyzed using various AI learning approaches (e.g., reinforcement learning) to estimate carbon stocks, monitor deforestation, and prevent ecosystem degradation. The trend has enormous potential to decrease emissions, enforce data-driven decision-making, and leverage carbon-binding prediction models in terms of these geospatial use cases.

Fourth, AI is revolutionizing the material discovery space, potentially providing sustainable alternatives to the most climate damaging materials of today, such as cement, steel, and oil. Leveraging AI opens new possibilities to combine research in physics and chemistry to support and accelerate discovery when human methods reach their limits.

Lastly, freight trucks account for a significant part of global GHG emissions. Making logistics autonomous offers ample opportunities to reduce emissions with AI. More efficient autonomous eco-driving, avoiding traffic congestion, and the efficiency improvements due to platooning are some technological breakthroughs. However, technological challenges and slow and inconsistent legislation across states and countries impede the implementation of autonomous trucks on public roads.

Altogether, these five AI-related technology trends strongly impact climate change and are central drivers in shaping the climate in the future.



TOWARDS ENERGY-EFFICIENT AI

Improved Hardware and Software are Reducing the Carbon Footprint of AI Applications

As deep-learning models become increasingly complex, computational performance skyrockets – but at what cost? A recent study showed that the training of one of these large deep-learning networks on average produces the amount of CO₂ equal to the lifetime emission of five cars [1]. As industry and academia become increasingly aware of AI's energy consumption, development and research about AI hardware and software are accelerating.

AI Hardware: The general-purpose CPUs currently used in modern computers lack the capabilities for the vast amount of parallel computation that current AI algorithms require. AI hardware combines new electromechanical elements such as graphics processing units (GPUs), field programmable gate arrays (FPGAs), and application-specific integrated circuits (ASIC) with specifically designed architectures, resulting in an efficiency improvement of up to a thousand times [2].

AI Software: So far, significant breakthroughs in algorithm and model efficiency have been made mainly as a side effect of research projects that target high-performance networks rather than computation efficiency itself. However, with increased awareness and rising costs, academia and industry are slowly shifting focus from pure accuracy toward emphasizing efficiency and collective learning approaches [3], [4].

Facts:

- Adoption of AI applications is expected to drive up the energy consumption of the data centers that consumed 200 TWh of electricity and emitted roughly 0.3% of all global CO₂ emissions in 2020 [5], [6].

- Patents for AI hardware have been increasing exponentially over the last decade in the technologically leading countries China and USA [8].
- Computation time needed for neural net architectures halved roughly every 16 months from 2012 to 2019 [9].

Key Drivers:

- Disruptive technologies such as neuromorphic chips [10] or quantum computers enable completely new learning approaches with drastic reductions in computation and energy consumption.
- The focus of academia is shifting toward developing more efficient models and algorithms because of the enormous training costs for new AI models, which only companies can afford [11].
- Research in transfer learning shows promising results for reducing training time and, therefore, energy consumption by repurposing existing models [12].

Challenges:

- Reporting standards for quantifying the carbon emissions for machine learning (ML) models are currently missing but need to be established as a basis for comparison and awareness [13].
- Model growth and the subsequent demand for computing power are outpacing improvements in hardware efficiency [14].
- Fundamental electronic hardware components are approaching their upper physical boundaries, requiring new engineering approaches [15].

Impact on Climate Change in the AI Era:

The more energy-efficient an AI model is, the smaller the impact is on the climate. Depending on the algorithm, the hardware, and the training procedure, the carbon footprint of training ML models can be reduced by a factor of up to a thousand [16]. Making model architectures more compact and cherry-picking the most relevant data saves computation time and energy [14]. Additionally, AI chips' more efficient hardware design can impact carbon emissions massively. For example, Google has achieved an efficiency gain of up to 80 times by using tensor processing units (TPUs) instead of conventional chips [17], while NVIDIA has recently developed a chip that uses ten times less energy than a mobile GPU [14].

OPTIMIZING DISTRIBUTED SYSTEMS

AI-enhanced Management Systems are Optimizing Waste, Energy, and Water Networks

The movement from centrally controlled to distributed resource systems leads to complex dynamics. This causes challenges in operational management, e.g., planning of demand and supply, understanding the underlying resource mechanics, and detecting errors early on. In the context of climate change, special attention is given to waste, energy, and water networks due to their critical impact on reducing carbon emissions or coping with its consequences [18]. Smart devices are currently being infused into these networks, enabling digital management through data generation and remote control. Using this foundation, AI is ideally suited to support by providing valuable information for operators or taking autonomous control in certain areas. The capabilities of AI have already been used to forecast consumption and energy generation resulting in more accurate planning, better pattern recognition in Big Data to understand network interdependencies for control, and precise anomaly detection such as leakages or breakdowns [19]. Due to the ongoing urbanization and rising population, these networks will be concentrated in cities with limited space, rendering their optimization even more necessary.

Facts:

- The smart water, waste, and energy markets have a projected CAGR between 10% and 24% until 2026. The smart energy market is the largest of the three, with an expected market potential of 20bn USD in 2028 [20], [21], [22].
- Pilot projects of smart water systems show promising results, aiming to reduce water loss from leakages by 15% until 2025 [23], which holds enormous potential given a global loss of 35% through water leakages [24].

- Half of the world's population lives in cities, which consume 75% of all energy resources and emit 80% of the carbon [25].

Key Drivers:

- Growing population, socioeconomic developments, and urbanization will increase the domestic and urban industrial water demand by 50-80% over the next three decades, boosting the need for smart management systems [26].
- Legal regulations and policies foster the development of smart networks for water, energy, and waste through standardization, incentivization, or quota specifications like the 'Schaufenster intelligente Energie – Digitale Agenda für die Energiewende' (SINTEG) initiative of the German government to improve the sustainable and intelligent energy supply [27].
- IoT and 5G technologies build the necessary foundation for smart networks, establishing a communication infrastructure that enables the integration of intelligent and collaborative systems and faster data processing [28].

Challenges:

- The manufacturing of IoT devices is expected to increase global energy consumption by 34TWh until 2030 [29], demonstrating a need for low-power devices.
- Connected networks present severe privacy and cybersecurity risks due to the increase in systems and devices that have access to sensitive data on location and private activities [30].
- The interoperability between systems from different domains remains a considerable challenge for the connectivity between other communication technologies [31].
- 70% of the population will live in urban areas by 2050 [25], making city networks more complex due to increased resource flows and nodes.

Impact on Climate Change in the AI Era:

AI can potentially influence water, waste, and energy distributed resource systems toward a more sustainable direction. Water loss management supported by AI algorithms will play a key role in avoiding water leakages early in supply networks and using water resources efficiently [32]. In energy networks, AI can enhance the efficiency and reliability of smart grids by forecasting the power load or analyzing the consumer electricity consumption behavior [33]. To reduce the negative environmental impacts of waste, AI helps to improve automated separation or optimization of waste collection cycles [34].





LEVERAGING GEOSPATIAL IMAGE PROCESSING

AI Algorithms are Increasingly Used to Analyze Aerial and Satellite Imaging

Using aerial and satellite imaging, more and more data is gathered about the earth's surface. This data can be analyzed using computer vision techniques for a variety of climate applications such as estimating carbon stocks, monitoring deforestation and GHG emissions, protecting habitats, detecting wildfires, or predicting environmental events [35], [36], [37], [38]. For example, the Mapping the Andean Amazon Project uses AI and satellite imagery to detect illegal deforestation in the Amazon. They use scalable regression models for wide-area surveys, combined with ensemble methods that detect changes in the landscape [38]. A second example is Climate TRACE, a global coalition of organizations that uses AI to radically improve the transparency and accuracy of emissions monitoring using more than 300 satellites and 11,000 sensors [38].

Aerial and satellite data complement each other; aerial images are collected with drones, balloons, or airplanes and compared to satellite imagery, cover a much smaller field at a higher resolution. Satellite images have larger-scale applications due to their high temporal resolution, while aerial photography is used for more localized applications that maximize its high spatial resolution [39].

Facts:

- The global geospatial analytics market is expected to register a CAGR of 17.6% from 2021 to 2028 and reach 256bn USD by 2028 [40].
- The global satellite data services and aerial imaging markets are projected to grow from 5.9bn USD in 2021 to 16.7bn USD by 2026 (CAGR of 23.0%) [41] and from 2.25bn USD in 2020 to 8.51bn USD by 2030 (CAGR of 14.2%) [42], respectively.

- Various players have entered the geospatial imaging market following a considerable investment movement. A few startups in this space are AiDash, a startup currently using satellites and AI for utility vegetation management [43], and OroraTech, a startup engaging in wildfire detection and monitoring from space [44].

Key Drivers:

- Geospatial data is increasingly available, particularly in open-source repositories such as the NASA POWER Project (a collection of satellite-based climate datasets dating back 20 years) [45].
- Corporate adoption of geospatial image processing further incentivizes the development of this technology. IBM's recently introduced 'Environmental Intelligence Suite' includes a geospatial platform synthesizing earth observation data and AI. This data suite also supports carbon accounting and outlines various climate risk and impact scenarios [46].

Challenges:

- Poor data quality caused by equipment malfunctions or other negative conditions (e.g., clouds covering one portion of the image or visual impairment caused by a forest canopy) causes duplication or missing information. Using ML algorithms such as 'Cars Overhead with Context' could serve as a potential solution [38], [47].
- Siloed data collection in local areas makes it challenging to implement the technology solutions globally [48].

Impact on Climate Change in the AI Era:

Currently, only 17% of the world's forests are legally protected. The rest is in danger of being deforested, contributing to approximately 10% of global GHG emissions [35]. Geospatial image processing to improve carbon stock estimation of forests and peatlands will enable land-use optimization and support regulation enforcement and carbon-binding prediction models. AI-based processing of geospatial images can also help prevent the loss of natural carbon storage like forests through deforestation and wildfire monitoring [38]. According to the United Nations environment program, the world can reduce emissions by 5.7Gt annually by halting deforestation and ecosystem degradation [49].

ACCELERATED MATERIAL DISCOVERY

Using AI to Find New Sustainable Materials Among Infinite Possible Chemical Combinations

To achieve net-zero emissions, breakthroughs in discovering new, sustainable materials, such as fuels, foods, or construction materials, are inevitable. The discovery of new materials is currently slow, costly, and inefficient; human researchers are struggling with the number of possible element combinations and manually applying heuristics to understand physical properties without completely understanding the physics behind the new materials [30]. Cement and steel production, for example, are responsible for 16% of global emissions [50]. AI will play a pivotal role in finding and explaining potential candidates by analyzing large datasets and creating artificial lab environments to run realistic simulations, especially when combined with quantum technology [51]. In such simulations, ML can help guide predictions of future properties from unknown materials or discover new ones [52]. After years of ground-breaking research in Deep Search, Generative Modeling, and Chemical Simulations by leading universities and corporations, the technology is starting to transform material science with a huge potential to combat climate change [53], [54].

Facts:

- Human material discovery research is becoming increasingly expensive, and researchers are becoming less efficient [55].
- In 2015, material production was responsible for 23% of global emissions, and demand for materials is expected to increase drastically, e.g., the need for copper is estimated to increase by 300% by 2100 [56], [57].
- The global advanced material market was valued at 42.76bn USD in 2015 and is expected to reach 102.48bn USD by 2024 [58].

Key Drivers:

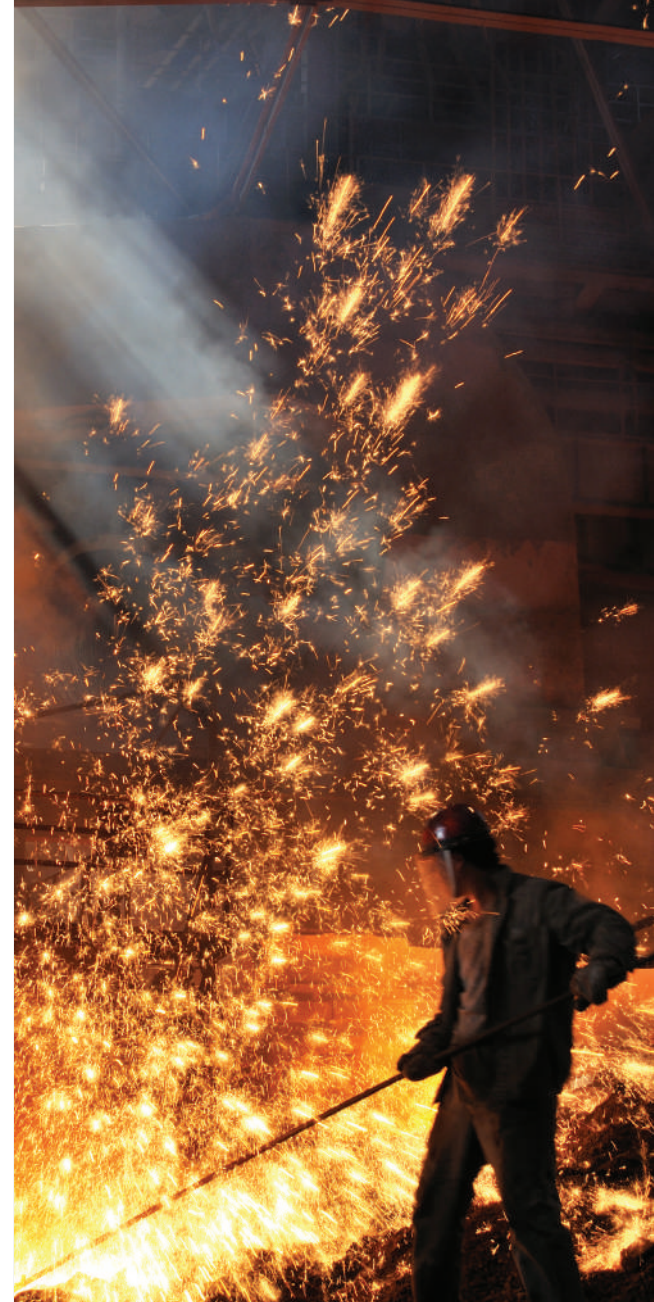
- Sophisticated generative models like generative adversarial networks (GANs) can meet the sustainability design constraints and improve simulation performance. Technology companies have published multiple novel algorithms and researchers, e.g., RoboRXN by IBM [59], [60], [61].
- Several scientific breakthroughs have optimized material discovery processes, including closed-loop material discovery systems [62] and Multiple-Objective Design [63].
- Advances in quantum technology by leading technology companies (including IBM and DeepMind) and universities (primarily MIT and Cornell) are boosting the performance of discovery simulations significantly [64], [65], [66].

Challenges:

- For accurate predictions, datasets need to include millions of data points on atomic structures and previous experiments in addition to physical and chemical constraints [67]. These laws of nature make material discovery drastically more complex than playing or modeling a game of 'Go' [52].
- Computational challenges and energy requirements arising from analyzing billions of molecular configurations need to be minimized, e.g., through building pre-trained networks that include physical and chemical boundaries [68], [69].

Impact on Climate Change in the AI Era:

Researchers, governments, and industry experts know about the dimensions of GHG emissions caused by global cement or fuel production. Given the complexity of experiments and the vast amount of data necessary for ground-breaking discoveries, human intelligence is unlikely to achieve a breakthrough at this point. AI is ideal for solving this human weakness and accelerating the discovery of new materials. For example, the Brazilian company NotCo uses AI to find an alternative to dairy [70], and researchers are close to finding viable solar fuels [71]. Researchers have also used AI to optimize Graphene, a new material 200 times stronger than steel that conducts heat 10x better than copper and electricity 250 times better than silicon [51].





MAKING LOGISTICS AUTONOMOUS

Autonomous Trucks and Optimized Planning and Routing will Reduce GHG Emissions

The freight-carrying truck industry accounts for 3.7% of global GHG emissions and contains ample opportunities to reduce GHG emissions by using AI [72], [73], [74]. Promising applications include more efficient autonomous eco-driving, avoiding traffic congestion, and platooning [75]. ML can be used to optimize routing to reduce traffic congestion and bundle shipments to reduce the number of (partially) empty trips [75]. Recently, transfer hubs have been developed to overcome the technical and operational challenges of fully autonomous driving; humans drive trucks from their origin point to a transfer hub near a highway before driving on the road autonomously. Automotive corporations and startups innovate the sector at a fast pace. The cutting-edge autonomous truck startup TuSimple alone already filed 240 patents [76]. However, legislation lags behind technological advances and increasingly impedes autonomous trucks' deployment [77]. In addition to autonomous trucks, small autonomous vehicles such as delivery robots and drones could further reduce the energy consumption of the logistics sector [30].

Facts:

- Medium and heavy trucks accounted for 3.7% of global CO₂ emissions in 2018 [72], [73].
- Autonomous trucks operate more efficiently and reduce fuel consumption, especially at lower speeds, by 10% compared to manual driving [78]. In addition, platooning reduces fuel consumption by 5 to 20% [79].
- 30% of transport vehicles are (partly) empty during delivery because of demand imbalances, time constraints, or insufficient planning [75].

- In 2020, the total investment of automotive companies (e.g., Volkswagen) in self-driving logistics vehicles startups rose 5 times to more than 6.5bn USD [80].
- The global autonomous truck market is expected to grow from 44.9bn USD to 88.1bn USD from 2020 to 2027 [81].

Key Drivers:

- Vehicles-to-vehicle (V2V) communication technology will be installed by default in new cars by 2023, and vehicle to grid (V2X) communication technology will follow shortly after. This will facilitate vehicle routing and autonomous driving [82].
- Research shows that 70% of end-consumers are willing to pay a 5% premium for green products, eventually increasing green offerings throughout the industry [74].
- Companies can achieve significant cost reductions by investing in more sustainable operations, e.g., fleet optimization and fuel and utility savings [74].

Challenges:

- The technological challenges of autonomous driving are still not solved for more complex scenarios like urban traffic.
- The slow pace and inconsistent legislation across German states and countries hinder the trucking industry's development and adoption of AVs and advanced driver assistance system technologies. Consequently, the legislation congestion stagnates the deployment of autonomous trucks for interstate driving, ultimately the most impactful use case [77].

Impact on Climate Change in the AI Era:

Various aspects of autonomous logistics can reduce GHG emissions and thus impact climate change. First, autonomous driving and platooning reduce the fuel consumption of trucks by up to 10% and 20%, respectively [78], [79]. Additionally, more efficient order bundling and vehicle routing can further reduce GHG emissions [75]. Autonomous trucking can accelerate transportation times, making trucking a viable alternative to air freight but more price-competitive than less GHG emitting rail transport [83].

SOCIETAL & ENVIRONMENTAL TRENDS

INFLUENCING CLIMATE CHANGE IN THE AI ERA

Humanity Is Exceeding Planetary Boundaries
The Challenge of Inequality
Toward Responsible Consumption
Aggravating Resource Scarcity
Increase in Societal Polarization

SOCIETAL & ENVIRONMENTAL TRENDS

Influencing Climate Change in the AI Era

Our planet has always been fundamental in keeping humans alive and providing us with space and nutrients. For thousands of years, humankind has been living in harmony with the environment. Since the dawn of the industrial age, there has been a change in our way of interacting with nature around us. The human drive toward innovation and, for example, more intensive agriculture is one of the key forces behind the growing destruction of the planet we are living on. Changes in our behavior as a society have been the key driver of climate change.

Resource depletion, a major problem in modern society, refers to the extraction of rare-earth metals, freshwater, and other natural resources at an extreme, unsustainable rate. In many parts of the Earth, the consequences of resource depletion manifest as social conflicts because of how scarce the resources are in the first place. The main causes of resource depletion are overpopulation, industrialization, human behavior, and innovative technologies. To avert a global crisis and social tension, AI offers opportunities to prevent the extraction of natural resources by making their use more efficient and helping to find new materials.

Increasing resource scarcity also leads to more inequality. More specifically, it impacts different dimensions of inequality, ranging from job and income inequality to access to education and technology. One key driver behind inequality is climate change. Low-income countries are already significantly affected by it since they have less money than developed countries to adapt to climate change. For them, it is imperative that education, especially digital literacy, is a priority. An educated population enables developing countries to invest in their economies to raise their living standards.

Households are responsible for over two-thirds of CO₂ emissions. Developed countries have been consuming the majority of goods and services and, by doing so, created emissions. With a growing global middle class, demand for consumption increases significantly and puts Earth's resources under a lot of pressure. Humanity must walk a tightrope to support sustainable growth. Raising awareness among consumers is a positive factor because this pressures companies into offering more eco-friendly products and ultimately reduces emissions down the line.

Society is increasingly polarized concerning different challenging topics – the climate crisis is only one example besides the COVID-19 pandemic or migration. Various players fund targeted misinformation campaigns to increase this polarization and avoid or postpone climate action. Concerning the spread of fake news, AI has the power to both defend and defeat the cognitive barriers humans have in recognising these threads.

Finally, there is a planetary boundaries framework that represents nine different dimensions of planetary health. Humanity has exceeded five of them already. Though scientists repeatedly report worsening environmental conditions, society continues to grow and refrains from using resources efficiently. This poses a substantial threat in terms of further deterioration of our ecosystem and human health. If society cannot find a way to change its relationship with the planet, there may be little hope.

HUMANITY IS EXCEEDING PLANETARY BOUNDARIES

Earth is Being Destroyed by its Inhabitants at an Increasingly Destructive Rate

While the destruction of our planet's ecosystem has been going on for a long time, the effects are rapidly getting more extreme. To quantify the destruction, in 2009, an international group of scientists created the framework of planetary boundaries [84]. The scientists proposed quantitative boundaries within which humanity can develop further while increasing ecological sustainability [85]. The framework incorporates nine dimensions: land-system change, freshwater use, biogeochemical flows, ocean acidification, atmospheric aerosol loading, stratospheric ozone depletion, biosphere integrity, climate change, and novel entities [86]. Many dimensions correlate with UN Sustainable Development Goals (SDGs) [87], [88]. Humanity has already exceeded the boundaries in four of the nine dimensions [89]. The activities of our society have pushed climate change [90], [91], biodiversity loss [92], shifts in nutrient cycles [93], and land use [94] beyond what the earth can compensate for. In January 2022, scientists concluded that humanity had exceeded the fifth boundary related to environmental pollutants and other novel entities, including plastics [95].

Facts:

- In 2010, the Convention on Biological Diversity set 20 global targets for safeguarding nature until 2020. None has been achieved [96], [97].
- The Amazon rainforest is estimated to have stored up to 100bn tons of CO₂ [98]. The rainforest destruction is responsible for about 25-30% of annual global GHG emissions [99], [100].
- Overexploitation of resources for production has led to the degradation of 33% of the world's cropland by 2020 [101].

The equivalent of setting five garbage bags of plastic waste (8 million tons) on every foot of coastline is emitted to the oceans yearly [102].

Key Drivers:

- According to the United Nations' (UN) median projection (2015), the world's population will grow to around 8.5bn in 2030. [103]. That growth accounts for the increasing demand for food, water, and natural resources, causing severe biosphere damage [104], [105].
- The amount of people belonging to the global middle class is increasing. Urbanization is on the rise [106, p.2]. As a middle-class lifestyle is more CO₂ intensive, this additionally complicates reaching emission goals [106, p.18]. The need for higher agricultural yield leads to intensified agriculture powered by agrochemicals [107].
- The inefficient use of resources contributes to skyrocketing amounts of water, soil, and air pollution and an accumulation of waste, especially plastics [95], [108], [109].

Challenges:

- The growing pollution results in a vicious cycle of planetary health destruction. For example, degraded soils allow less yield, resulting in higher fertilizer usage and thus more soil degradation [101], [110], [111].
- The increase in frequency, severity, and duration of extreme weather events will place ecosystems at a very high risk of further degradation and biodiversity loss [106], [112]. At the same time, this poses a substantial threat to human health [113], [114], [115], [116].
- Combining sustainable production methods across all sectors while realizing economic growth for innovation is challenging as substantial conflicts of interest arise [117], [118], [119].

Impact on Climate Change in the AI Era:

A part of our planetary health is already irreversibly destroyed with many already extinct species [89], [120]. A multi-level approach to planetary health restoration has to be executed by a global community to stop this. This generates an immense need for socioeconomic change [104]. Innovation, such as AI, could have a big impact, i.e. by distributing clean energy sources efficiently or accelerating the discovery of new technologies [121]. Further, it might play a role in the prediction of extreme weather events or modulation of waste distribution, helping to break the deadly vicious cycle [114], [122], [123].





CHALLENGE OF INEQUALITY

Inequality is Threatening Climate Action

Inequality describes “the state of not being equal in status, rights, and opportunities” [124], e.g., employment and income [125]. Moreover, access to education, healthcare, and societal/political participation is often affected [126]. Technological advances, their distribution [127], and climate justice are highly relevant topics [128].

Climate action comes at a monetary expense. Poor countries are thus burdened the most, increasing inequality overall [129]. Furthermore, new technologies foster a high potential for economic growth. Not everyone is able to profit from these new technologies: the people who lack the skills or access to it are left behind and are more likely to experience income inequality [130].

Different perspectives need to be taken into account when looking at inequality: The global one describing inequality among different countries, the national scale revealing the disparity within the country itself [124], and a personal point of view.

Facts:

- Antigua and Barbuda in the Caribbean lost an estimated 215% of gross domestic product (GDP) in 2017 due to climate change and hurricanes [131, p.83].
- In 2018, Germany emitted 10.3 tons of CO₂ per capita, compared to only 8.9 tons per capita in Austria, even though the GDP per capita is higher in Austria [132], [133].
- It is estimated that between 2008 and 2018, around 24.1m people per year were forced to move due to aggravating weather situations and natural disasters in their country of residence [131, p.83].

Key Drivers:

- Most countries affected by climate change are located in tropical regions. An aggravating climate crisis destroys their livelihood, subjecting them to experience poverty [131, p.83].
- Political and governmental landscapes strongly influence inequality. Countries with high corruption in the public sector are also the most vulnerable to the impacts of climate

change [136].

- The fourth industrial revolution leaves those who have yet to catch up to information and communications technology (ICT) behind. Dependence on high-speed internet and its lack in several regions will reinforce the unequal distribution of tech [137, p.64].

Challenges:

- Developing countries want to close the economic gap with developed countries. This focus on growth will increase emissions, so low-carbon growth opportunities need to be developed and employed [138].
- Access to education and digital literacy [139, p.161] for children of every background [140, p.65] and promoting lifelong learning in adults is a key challenge of meeting changes in the workforce [140, p.116].
- Facilitating financial support and access to loans in low-income countries is needed but not currently happening. The money can be used for boosting investments in health, education, and businesses to accelerate development [141].
- Navigating the impact of AI: 82% of society-oriented SDG targets can be reached using AI, but 38% of targets are negatively impacted [142].

Impact on Climate Change in the AI Era:

The least developed countries profit from structural transformation since they live off their primary sector [143].

In doing so, various technologies and primarily AI could be employed in different fields - one of them being the domain of education [144, p.13-14]. AI-facilitated access to education would improve people's access to the job market and enable society-driven innovation. It then leads to a better understanding of the environment and raises awareness. This changes individual behavior and helps actionism [145, p.56-57].

TOWARDS RESPONSIBLE CONSUMPTION

Rising Mass and Responsible Consumption Influence Climate Change

Changes in personal consumption volume and behavior will be crucial factors for climate action, as households are responsible for two-thirds of all direct and indirect emissions [146]. The underlying trend is twofold:

First, individual consumption and the total number of people that consume are rising. The global material footprint per person has increased by 70% from 2000 to 2017 [147]. Additionally, the overall population is growing and a new middle class is rising in emerging markets [148]. This global middle class has a huge impact, as most of the emissions can be accounted for by higher-income groups [146], [149].

Second, especially in industrialized countries, an environmentally conscious subgroup of consumers is emerging [150]. These environmentally responsible consumers create an incentive for companies to offer more eco-friendly products and services. Companies consequently adapt their business processes in order to position themselves as sustainable brands [151]. The way these two developments influence each other will massively impact how extreme climate change becomes.

Facts:

- 70% of people in industrialized countries are willing to pay a premium for sustainable goods or services [152].
- 64% of surveyed European Union (EU) citizens report that they consciously make more sustainable consumption choices. Out of the respondents, 93% view climate change as humanity's most severe problem [150].
- The UN estimates a total population of 9.7bn by 2050, with three earths needed to support current consumption levels [153].
- While in 2018, only 6% of Germans declared vegetarian, this number has grown to 10% in 2020 [154]. Globally, over 21% follow a vegetarian diet [155].

Key Drivers:

- The middle class is expected to grow by 1.3bn to almost 5bn people by 2030 [148].
- Mass consumption is deeply rooted in society since it was encouraged by governments after WW2. Producers implemented innovative marketing and planned obsolescence to further foster consumer centrism [156], [157].
- A young sustainability-driven millennial generation is increasingly participating in activism [158], [159].
- According to the European Commission (EC), different initiatives such as shared mobility make more consumers consider sustainability and environmental concerns and prefer eco-friendly goods and services [146], [160].

Challenges:

- Climate equality both globally and within societies is a big challenge. Wealthy individuals and countries are mostly responsible for driving climate change, with 61% of the global income generated by 21% of all nations [161].
- It is hard for consumers to recognize negative environmental externalities generated by producers. They might fall for greenwashing if trustworthy certificates or legalization do not exist [162].
- Without dietary changes, food and livestock production would need to increase by 100% to nourish the growing population. This is hard to achieve while limiting the human environmental impact [163].

Impact on Climate Change in the AI Era:

A large-scale shift toward sustainable consumption behavior influences the products companies offer. Changes in the demand could therefore reduce material consumption, waste production, or force more companies to publish sustainability reports [164]. However, it will be crucial that sustainable consumption is adopted across relevant groups, especially the emerging middle class.

AI can play a role in making consumption more sustainable. It can help cut emissions by supporting consumers to track their ecological impact and act accordingly [165]. When facing challenges such as food security, AI helps to model these complex systems [142].





AGGRAVATING RESOURCE SCARCITY

Limited Natural Resources Cannot Cope with Growing Societal Demand

The unsustainable consumption rate of raw materials, water, land, and other natural resources causes resource scarcity. It directly impacts global socioeconomic development, health, and well-being of the environment and humans [166], [26]. The main causes of resource depletion are overpopulation, industrialization, deployment of innovative technologies, and human behavior [167].

The most severe forms of resource scarcity are aquifer depletion, deforestation, fossil fuels and mineral mining, contamination, soil erosion, and overconsumption of resources [168]. On the one hand, global environmental awareness increases, and green concepts are being developed to reduce emissions, e.g., in mobility and urban settings. On the other hand, such measures require an enormous amount of raw materials, further straining the capacity of resource-dependent communities [169, p.11]. Before the earth is left with no clean water, fertile land, and other resources, alternatives to exploiting nature must be found.

Facts:

- The extraction rate of resources such as biomass, metals, fossil fuels, and non-metallic minerals increases rapidly and is expected to double by 2060, reaching 190bn tons [167].
- 50% of all land and 20% of all forests are severely degraded [169]. In 2021 alone, the Brazilian Amazon lost 10,476 square kilometers [170].
- The current supply of raw materials needed for battery production is less than a third of what will be required in 2030 [171].
- Nearly half of the global urban population, 1.7-2.3m people, is expected to face water scarcity by 2050 [166].

Key Drivers:

- The need to support the growing population increases the stress on natural resources [172]. Due to overpopulation, the food, water, and energy demand are expected to grow by 35%, 40%, and 50% respectively by 2030, causing additional pressure on natural resources [173].
- The widespread adoption of digital technologies increased the exploitation of rare-earth metals and led to pollution via electrical waste. The digitization of industry and everyday life further contributes to this [167], [174 p.44].
- Human behavior (e.g., consumerism, eating habits) causes significant environmental depletion [175]. More than half of all world's deforestation is traced back to farming, grazing of livestock, mining, forestry practices, and urbanization [176].

Challenges:

- Communities that directly depend on the availability of natural resources will face difficulties in sustaining themselves, ultimately leading to increasing inequalities and climate migration [169].
- To ensure availability, regional coverage, and security-of-supply, the management and monitoring of information about raw materials will be crucial, both on the EU and global level [177].
- Increased unemployment, inadequate provision of education, and other social services will lead to more social tensions and conflicts because of the economic decline caused by environmental degradation [169], [178]. The extreme scarcity of vital resources could even provoke wars [179].

Impact on Climate Change in the AI Era:

To avoid a global crisis of natural resources, the current rate of environmental degradation must be reversed. AI enables the accelerated discovery of materials and opportunities to preserve natural resources, especially in regulating water security, preventing land misuse, and resource overconsumption [167]. However, technological innovation, global economic growth, and a growing population depend on raw material extraction [180]. The resulting additional depletion of natural resources contributes to the negative flywheel accelerating global warming, biodiversity loss, changing water cycles, and carbon emissions in the atmosphere [181].

INCREASE IN SOCIETAL POLARIZATION

Increasing Societal Polarization and Misinformation Threaten Fact-based Climate Measures

Increasing societal polarization and misinformation threaten fact-based climate measures. Societal polarization on topics such as migration [182], climate change [183], or the COVID-19 pandemic [184] is increasing – a development that is fostered by a crisis in general. But while a pluralism of opinions is considered an essential trait of liberal democracies [185], converging toward a strong alignment along one dimension leads to a perception of groups in terms of ‘Us’ and ‘Them.’ This shift in perception can have severe consequences for democracy and therefore climate policy as well [186]. Targeted online misinformation campaigns funded by corporates and philanthropic actors likely play an essential role in constructing this societal polarization regarding the climate crisis [183]. Social media contributes to the spread of misinformation through algorithmic bias, bots, astroturfers (coordinated fake individuals [187]), and spammers [183]. The institutionalized efforts of the globally active climate change counter-movement have slowed down climate policies by creating the impression of uncertainty in climate science and targeted polarization of climate change both in the general population and political elites [188].

Facts:

- 96% of Germans have had access to the internet and are potentially affected by online fake news [189].
- 52% of American adults got their news or news headlines on Facebook in 2019 [190].
- The top 1% of false news on Twitter reached between 1000 and 100,000 people from 2006 to 2017, whereas truthful posts rarely reach an audience of over 1000 [191, p. 1146].
- Compared to those advocating for it, press releases opposing climate action are twice as likely to be featured on major news outlets. [192]

Key Drivers:

- A counter-movement consisting of corporations, conservative philanthropists, and conservative media spread misinformation and doubts, fund “grassroots protests” and hire public relations (PR) firms to advocate against climate action [193]. The content and language of the discourse are influenced by corporate funding [194].
- People tend to select news aligned with their beliefs which fosters polarization, this phenomenon is known as selective exposure [195]. Differently biased people may assimilate information that fits their bias [196]. Increased exposure to opposing views may even magnify political polarization [197].
- Different crises (e.g., pandemic, migration, economic, or climate) create and intensify political polarization within countries [186], [182].

Challenges:

- According to Jennifer McCoy et al., “Democracies’ survival may depend on their ability to reverse polarization” [198], as polarization can be an underlying cause for populism and post-truth politics [186].
- “Content that arouses strong emotions spreads further, faster, more deeply, and more broadly ...” [199] and false news spreads more than accurate information, making it hard to raise awareness for climate action [191].
- Ensuring that impartial bystanders recognize facts compared to alternative facts will be increasingly challenging, especially as other individuals’ labeling on social media is biased by their political views (e.g., using #fakenews) [200].

Impact on Climate Change in the AI Era:

In a polarized society living in different realities, support for climate policy and societal action varies depending on an individual’s perception of how they perceive the degree of scientific agreement on climate change [201]. People’s political ideology also influences their everyday decisions, for example when picking energy-efficient light bulbs [202]. Companies will run into difficulties communicating the sustainability of their products, as some people might consider labels negatively [202]. AI will be part of both the problem and the solution for fake news: it can contribute to defending and defeating cognitive safeguards [203].



LEGAL & POLITICAL TRENDS

INFLUENCING CLIMATE CHANGE IN THE AI ERA



- A Twin Transition
- Toward Aligned Regulation
- Increasingly Ambitious Climate Targets
- Increasing Sustainability Reporting
- Democratizing Climate Data
- Shaping Ethical AI

LEGAL & POLITICAL TRENDS

Influencing Climate Change in the AI Era

Climate change currently poses one of the biggest challenges to legislators all around the globe: Looking at the EU, its aim is to cut greenhouse gas emissions by 55% by 2030 and be carbon neutral by 2050 [204]. While reaching these objectives requires action across all pillars of society, a major part of the power to drive systemic change lies on the regulatory side. Policymakers are now not only looking into ways to accelerate change, but they are working toward making it more acceptable and affordable. A tool that might be useful to achieve just that is AI. In fact, governments have increasingly used AI in high-impact sectors, such as climate change, over the past years.

Nonetheless, as global temperatures keep rising, the role of AI in fighting climate change is becoming increasingly apparent to the public sector. Governments are aware of the need to lead by example and explore all possibilities that arise with AI. This includes not only making production processes more efficient but also enabling innovative solutions that simply were not possible before. To help businesses innovate in these fields, regulators rethink the legislative landscape around the intersection of AI and climate change policies.

The EU Twin Transition is addressing the interplay between climate and technology. In this twin transition, digitization becomes a key factor in achieving global environmental objectives. Behind this shift toward a twin transition lie two main forces: public investments and policy reforms.

The latter is mainly driven by the general trend toward more and smarter regulation. The EU has especially stepped up to the plate and proposed clear and binding drafts to establish a common legal playground for AI policymakers. Major global AI stakeholders further underline this notion by aligning across borders. In a more fundamental sense, many countries that have signed the Paris Agreement have recognized the need to tighten their climate targets. The EU promotes this by its initiative to expand the emissions trading scheme (ETS) and the effort sharing regulation (ESR).

It is only being made possible by a surge of environment, social and governance (ESG) guidelines as well as corporate sustainability reporting (CSR) guidelines, brought forward in part by the EU.

The push toward open data initiatives further highlights the need for transparent data, both for the public as well as the private sector. This change will be crucial for making environmental AI applications more accessible, understandable, and ethical.

These factors are decisive for the public acceptance of climate policies. Thus, legislators are increasingly looking at guidelines for trustworthy AI.

While these trends are just part of a bigger picture, global implementation of AI toward tackling climate change will heavily depend on them.



A TWIN TRANSITION

Intertwined Digital and Green Policy in Europe Is on the Rise

Digital technologies, particularly AI, are a critical enabler for attaining the sustainability goals of the EU Green Deal across different sectors. As an application of the Twin Transition, the European Growth Model sets the basis for a green, digital, and resilient economy. The fundamental elements of this model are reforms and investments. At the EU level, discussions on the links between digitization and the environment have gained momentum in recent years [205]. Policymakers develop laws that incorporate this twin transition at its core [206]. Combining digital and green targets has also brought forward working groups from the industry which work on the joint EU goals. Lastly, the directions proposed by the EU function as guidelines for EU member states. However, with significant impact come challenges. The adverse effects of AI technologies, such as ethical considerations and the technology's emissions, are critical for society. Likewise, aligning the climate targets of different countries fairly will be a challenging task.

Facts:

- Under the European Green Deal, the EU is allocating an annual amount of 520bn EUR toward environmental objectives [207]. With the Digital Compass, the EU proposes to invest an additional 125bn EUR per year in the digital transition with AI as one of the key technologies [207].
- In 2021, 26 CEOs of European ICT companies formed the European Green Digital Coalition (EGDC) to support the twin transition by investing in and developing green digital solutions, their impact measurement, and co-creating recommendations and guidelines with other sectors [208].

Key Drivers:

- With the European Growth Model, the EU targets three fundamental principles: fulfilling the Green Deal, leveraging the opportunities of Europe's digital economy, and improving political and economic resilience [207].
- The EU officially proposes increased transparency and data-driven approaches, like innovative AI solutions, to execute the Green Deal goals and tackle climate change more effectively across nations [209], [210].
- Governments support research on AI systems by putting the problem of climate change at the core of the development of new technologies [206].

Challenges:

- Standardizing waste regulations is a difficult trade-off between the right level of abstraction, overlapping definitions, conflicting stakeholders' interests, and a strong need for simplicity and cost-effectiveness.
- Countries within the EU have different starting points as well as economic and structural capabilities to cope with uniform waste reduction targets set by the EU.
- Stakeholders at the municipal level often find it difficult to comply with unrealistic targets set at national or international levels [221].

Impact on Climate Change in the AI Era:

The EU is tightening its twin transition targets, with explicit quotas for investments made in digital and green economies being just one example [207]. EU guidelines build a foundation for a broad range of national digital and green strategies. Examples of applied twin transition policies can be found in six EU member states' environmentally-focused AI strategies, including Denmark, Hungary, France, and Germany [206]. Various other guidelines and laws are on the rise to execute the twin transition fairly, especially with regard to sociopolitical and ethical considerations [206]. Lastly, the dual focus is also triggering the interest of the technology industry to collaboratively develop solutions for tackling climate change [212].

TOWARD ALIGNED REGULATION

Legislators Are Shifting from State-Level Recommendations to Implementing Cross-border Regulatory Frameworks

While AI has been on the rise for over five years due to major advances in computational power, legislators around the globe are just now increasingly demonstrating a common interest in providing the necessary legal framework for AI applications. These frameworks will see businesses move away from defragmented self-regulation and provide clear and binding policies for technological development in the future. At the same time, governments, companies, and research institutions are benefiting from cross-border collaborations, with the EU showing particular interest in filling the international gap for AI policy recommendations to safeguard environmental objectives [206]. This effort to harmonize policies between the major global AI players is supposed to enable businesses to operate within clear, legal boundaries. More importantly, however, this harmonization might prove essential in combining all forces toward tackling a global problem such as climate change [212]. However, to reach this goal, policymakers need to be mindful of balancing regulation and innovation to remain flexible in adapting their policies to new technologies, while finding a framework that works toward global objectives.

Facts:

- The EU released the first draft of a cross-border regulatory framework to monitor AI in April 2021 [213].
- The EU decided that a risk-based legislative instrument combined with codes of conduct for low-risk AI applications is the most suitable option [213].
- The total number of AI-related policies passed in 25 European and non-European countries has increased nine-fold from 2016 to 2021 [214].
- In June 2020, the Global Partnership on AI was founded, bringing together technology experts from around the globe to guide the development of AI [215].

Key Drivers:

- The introduction of the SDGs by the United Nations made the establishment and implementation of legal frameworks with a focus on AI necessary [216], [212].
- Stakeholders are increasingly affected by the uncertainty due to the lack of legal clarity in AI [217].
- AI businesses are pressuring toward harmonized frameworks to safeguard their competitiveness in international markets and reduce product changes due to different legal landscapes [218].
- Joint approaches in climate tech allow policymakers to exchange knowledge, resources, and data and are necessary to achieve systemic changes [212].

Challenges:

- Technological advancements already outpace the development of regulatory frameworks [216]. Coordinating these developments on an international level might cause further delays.
- Data sharing across borders is scattered, leading to many data spaces with little relevant data which poses a threat for aligned regulation and cross-border collaboration [206].
- Companies and experts fear that overregulation might hinder innovation and freedom [219].
- While multilayer stakeholder involvement is crucial, there are concerns that interests may differ drastically, making it difficult to find a single right approach [216], [220], [221].

Impact on Climate Change in the AI Era:

In this trend, there are two significant axes for impact. On the one hand, embedding cross-border collaboration into regulatory frameworks could boost climate tech development by facilitating international knowledge and resource exchange while building a shared understanding of the technology itself and its environmental objectives [206]. On the other hand, moving toward regulation can further help push environmental applications to the top of national legislator's agendas, removing the previous legal flexibility provided by non-binding directives and reducing the government's reliance on self-regulation by businesses [222], [206].





INCREASINGLY AMBITIOUS CLIMATE TARGETS

Countries Tighten Their Climate Targets to Fulfill the Paris Agreement

In the Paris Agreement, 195 countries and the EU committed to limiting global warming to well below 2°C. To achieve this goal, governments need to define nationally determined contributions (NDCs) in which they specify how and by how much they will reduce their GHG emissions in the coming years [223].

In the EU, all emissions are either covered by the EU-ETS or the ESR. The EU-ETS was launched in 2005 and covers more than 40% of the total greenhouse gas emissions in the EU [224]. The ESR covers almost 60% of the emissions, imposing reduction targets on EU member countries which need to be fulfilled by NDCs [225]. In this decade, the EU expands the ETS to other sectors and significantly increases the emission reduction rate for both the ETS and the ESR [225], [226], [227].

While there has been progress on the legislative side, current legislation is not compatible with the goals of the Paris Agreement. To address this issue, climate targets need to become even more ambitious in the next few years [228].

Facts:

- In 2021, Germany increased the reduction goal of GHG emissions by 2030 from 55% to 65% [229].
- 22 countries and the EU27 have submitted stronger NDC targets in 2020 than those submitted before the Paris Agreement [230].
- In 2021, carbon taxes and cap and trade systems cover 21.5% of global greenhouse gas emissions, a significant rise from 15.1% in 2020. Of 64 carbon pricing instruments in operation, regulators introduced six in 2021 [224, p. 23].
- At the UN Climate Change Conference in Glasgow (COP26), governments updated their NDCs and pledged to reduce emissions by additional 3.3 - 4.7Gt of CO₂ compared to their previous goals [228].

Key Drivers:

- While there has been a gap between scientific consensus and public awareness, the public is becoming increasingly conscious of climate change, which pushes governments to establish climate targets [231], [232].
- The Paris Agreement forces countries to update their NDCs with more ambitious targets every five years [228].
- The EU aims to lead by example on the sustainable development path guided by the Paris Agreement and the 2030 Agenda for Sustainable Development [233].

Challenges:

- There still is a significant gap between promises and reality: According to the United Nations Environment Programme (UNEP), a 30% reduction on existing global pledges for 2030 is needed to get on track to 2°C [234].
- Currently, “no single country ... has sufficient short-term policies in place to put itself on track to its net-zero target” [228].
- Companies could move production to less-regulated regions, which would not reduce global GHG emissions, also referred to as carbon leakage [235].

Impact on Climate Change in the AI Era:

Climate targets can significantly impact (GHG) emissions and thus limit climate change. Germany, for example, reduced its GHG emissions from 1990 to 2020 by 41.3% due to adapted climate targets [236]. The EU-ETS led to a reduction in emissions of 35% and is on track toward the next goal of 43% [237]. Climate targets started the worldwide effort to reduce emissions, as companies and individuals did not act sufficiently themselves. Regulation is necessary to create a market in which sustainable products are competitive, as it increases the costs of carbon-intensive products. While climate targets have already had a significant impact, with more ambitious targets the impact will increase even further.

INCREASING SUSTAINABILITY REPORTING

ESG Reporting and Corporate Sustainability Reporting are Rising

Reporting of different sustainability measures of companies is getting traction due to, among other things, rising attempts of greenwashing by companies. Focusing on consumer protection, governments are willing to counteract this tendency [238], [239], [240]. The European Commission is developing and planning to implement a corporate Non-Financial Sustainable Reporting Standard (NFSR) in October 2022, building on voluntary existing ESG reporting standards by the global reporting initiative (GRI) and previously published guidelines on reporting climate-related information [241]. AI is seen as a solution to tackle the complexity of sustainability reporting, which was already experienced with ESG reporting standards [242]. Various startups are developing software solutions to support companies to comply with recent and upcoming corporate sustainability regulations by using AI [243].

Facts:

- In 2019, the EC published guidelines on reporting climate-related information, e.g., about the materiality use and the business model overall [241], [244].
- Based on the published guidelines, the EC adopted a legislative proposal for a Corporate Sustainability Reporting Directive (CSRD) in April 2021 [241], [245].
- Currently, 11,000 companies are applying ESG reporting under the Non-Financial Reporting Directive (NFRD) [246].
- In 2020, 85% of companies in the DAX160 applied the GRI standards for NFSR. But increasingly, other frameworks such as the Sustainability Accounting Standards Board (SASB) and guidelines by the Taskforce on Climate-related Financial Disclosure (TCFD) are also applied [247].

Key Drivers:

- The enormous scope of interpretation of wide-reaching regulations like the Sustainable Finance Disclosure Regulation (SFDRs) for the financial industry lead to standardizations and definitions being implemented to increase transparency and support stakeholders in decision-making [248].
- Currently, there is a lack of comparability and coherence of reported non-financial information across the single market and between the NFRD and other sustainable finance legislation [248].
- Companies' increasing greenwashing attempts force governments to establish sustainability reporting standards to guarantee consumer protection [240].

Challenges:

- From the EU's perspective, the recent corporate sustainability reporting does not meet users' needs (investors, civil societies, and others) as it is, in part, lacks accessibility, comparability, and reliability [248].
- Reliable data about emissions in production and consumption of the manufactured products (scope three emissions) is challenging to assess along the entire value chain and might thus hinder accurate reporting [243].
- The costs for companies to fulfill the regulation as well as governmental administrative costs will rise, which affects the national governmental budgets [248].

Impact on Climate Change in the AI Era:

The EU Commission is forecasting that with the first set of corporate sustainability reporting standards, 50,000 compared to currently 11,600 companies are required to report their impact on the environment [246], [248]. Thus, the so-called accountability gap between society and companies can be diminished. In addition, investors' financial resources can be allocated with a more significant impact on preventing climate change, and greenwashing attempts by companies are obviated. Building on standardized reporting, carbon offsetting, for instance, is facilitated and made more transparent as it is based on traceable CO2 emissions along the value chain.





DEMOCRATIZING CLIMATE DATA

Governments Join Efforts in Building Platforms to Democratize Access to Climate Data

Climate change knows no borders, but current data spaces do. As data-reliant technologies such as AI become more prevalent, the availability of usable and high-quality environmental data becomes increasingly relevant. The current data landscape is fragmented across national research institutes [249]. To solve this problem, national governments and the EC are pushing the development of cross-border platforms for sharing climate data. For instance, the Climate Data Store by the Copernicus Climate Change Service (CCCS) makes satellite images by National Aeronautics and Space Administration (NASA) and the European Space Agency (ESA) public for research. [250].

Further, the EC decided to fund a Common European Green Deal Data Space to combine data from all European climate research institutes. These platforms are expected to FAIR (findability, accessibility, interoperability, and reusability) data following the standards established by the Open Data Charter [251]. This enables research teams and private institutions to utilize modern data solutions to leverage existing climate data in four dimensions: improve the modeling of climate scenarios, enhance climate change monitoring, and increase transparency and support decision-making processes [252].

Facts:

- In 2019, NASA and ESA began making satellite data publicly available through the CCCS, which led to a surge in scientific research and supported the development of advanced climate models [253, p. 14], [254, p. 160].
- In October 2021, the 193 member countries of the World Meteorological Organization adopted a resolution, making it mandatory for all to collect and share climate data with fellow members [255].

- In January 2022, the EC committed to establishing a common data-sharing platform, the Common European Green Deal Data Space, to support the development of technical solutions to combat climate change by facilitating access to environmental monitoring data [256], [257].

Key Drivers:

- The amount of climate-related data collected by satellites, sensors, and weather stations worldwide is rapidly increasing at several terabytes per day [258], [259].
- Due to technological advances, climate models have become increasingly capable of processing larger volumes of data. This increases the demand for climate information [260], [261].
- The EC proposed a regulation to harmonize rules on FAIR access to data (the EU Data Act) in February 2022, which includes a budget of 2bn EUR invested in data sharing infrastructure [262].

Challenges:

- Ownership and access to much of the world's data are concentrated in the hands of a small number of technology companies with great power. Public agencies depend on legislation or the willingness of large companies to share data for the greater good [257].
- Open data platforms require large upfront investments and multi-stakeholder engagement, resulting in critical climate-related data remaining locked away or in unusable formats [252].
- Data owners are often unaware of or misinterpret open data practices, such as those agreed upon at a global level in the Open Data Charter [251]. As a result, shared data often does not comply with the FAIR principles or is not published under a correct license [253].

Impact on Climate Change in the AI Era:

Open data initiatives and platforms play a fundamental role in tackling climate change: They allow for enhanced monitoring of policies and programs. Additionally, independent entities can review the progress toward achieving a country's climate targets [263]. Furthermore, open data can facilitate the monitoring of climate funds by tracking the flow and effectiveness of investments [263]. Lastly, open data lays the basis for climate-tech solutions developed by private institutions for tackling climate change [263].

SHAPING ETHICAL AI

Ethical Concerns Become Increasingly Relevant for AI Regulators in High Impact Sectors

The ethical use of AI is currently mostly unregulated, even in high-impact sectors like climate change, where decisions based on climate models can significantly affect people's lives. However, as societal awareness of AI grows, legislators around the world started developing legal frameworks to enforce ethical standards. The EU High-Level Expert Group on AI, for example, has highlighted seven policy requirements to support the shift toward trustworthy AI [264], [238]. While some national governments have started to react by taking these factors into account and drafting non-binding guidelines, the rising complexity of AI models poses several difficulties. On the one hand, introduced biases are becoming more difficult to trace. On the other hand, efforts to further tighten the ethical standards could lead to rigid regulations that cannot adapt to innovation. Legislators are now left with the challenge of balancing innovation-friendly policies while considering ethical concerns, basic human rights, and fostering public acceptance of AI applications.

Facts:

- In 2021, the EC published a statement of intent to investigate the introduction of a legally binding common set of guidelines for the assessment of ethics in the development of AI solutions [239].
- The EU AI Act, published in April 2021, defines four risk groups against which AI applications can be categorized and which require accountability, independence, and continuous reviews [240].
- In April of 2020, the U.S. Federal Trade Commission recommended businesses to validate their AI models and hold themselves accountable for compliance, ethics, and fairness [265].
- Public acceptance of policies to mitigate climate change is key, with perceived fairness and effectiveness being the most important ethical determinants in assessing the public opinion about climate laws [238].

Key Drivers:

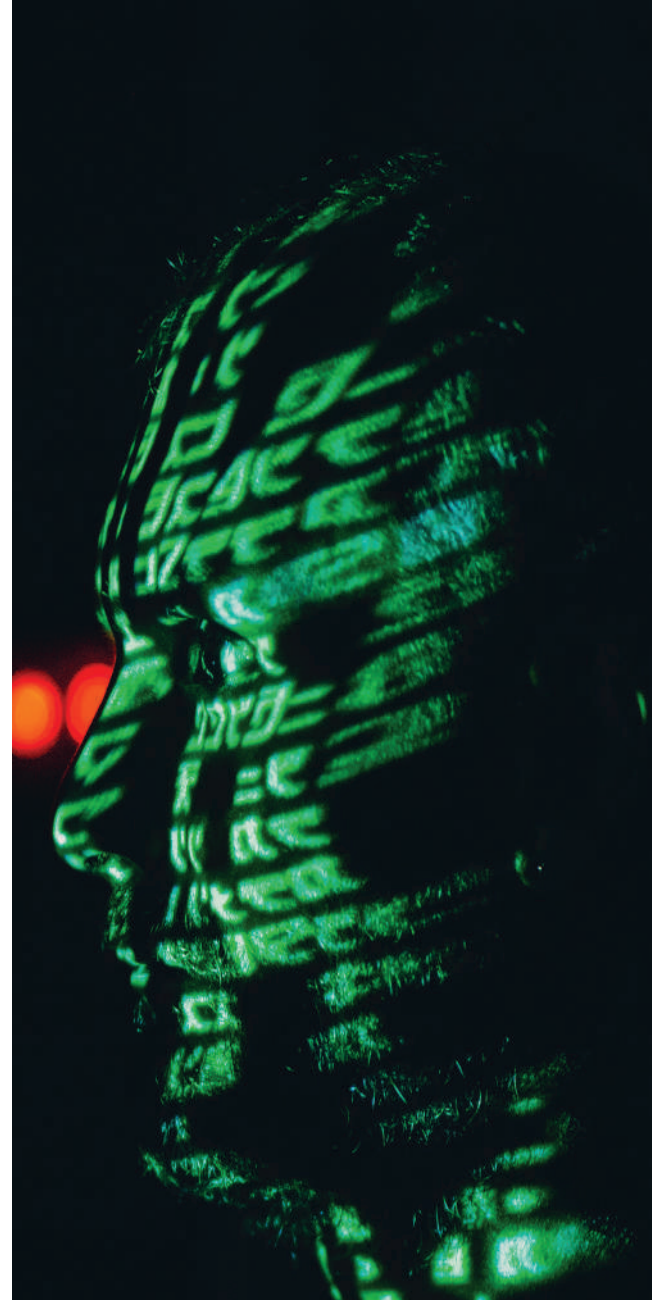
- Businesses seek clear and global ethical categorizations of AI applications to minimize cross-border guideline inconsistencies [266].
- EU member states introduce local regulations that aim at tackling the challenges created by AI [239].
- AI systems become increasingly complex, and humans are less capable of understanding all assumptions made by learned models. Ethical concerns start to rise as models have proven to be at risk of reflecting or introducing bias and discrimination [267].

Challenges:

- Ethical standards diverge across regions and cultures, making one global ethical AI regulation unfeasible [242].
- Risk assessments are being criticized for being too rigid, leaving institutions and businesses worried that the standards will not be able to adapt to new emerging technologies [241].
- The introduction of local regulations leads to a risk of fragmentation in the EU internal market, undermining the objectives of trust, legal certainty, and market uptake [239].

Impact on Climate Change in the AI Era:

Ethical guidelines will play a dual role in the development of AI-based solutions for tackling climate change: On the one hand, they have the potential to increase public acceptance of newly developed solutions, enabling faster adoption and shorter time to impact [268, p. 8]. This can be achieved through trusted and standardized AI frameworks that ensure compliance with local ethical principles and human rights [268, p. 8]. On the other hand, guidelines have the potential to slow the deployment of high-impact AI solutions through policy debates and unaligned ethical frameworks [269].



ECONOMIC TRENDS

INFLUENCING CLIMATE CHANGE IN THE AI ERA



MATURING OF EMISSION MARKETS
GROWTH OF SUSTAINABLE FINANCE
BOOSTING RESOURCE EFFICIENCY
TRANSITION TO RENEWABLES
LOCALIZATION OF ECONOMIC ACTIVITIES

ECONOMIC TRENDS

Influencing Climate Change in the AI Era

Climate change in the past has fundamentally been driven by economic expansion and increasing income across the globe. Squaring the necessity for drastic climate action with the desire for further economic growth will be challenging. There are, however, five trends that together could have an outsized impact on the next few years.

Most economic growth is bad for the environment due to a misalignment of incentives for economic actors. Mature emissions markets tackle this incentive problem by efficiently guiding consumption behavior and investment decisions to reach climate goals. The current global implementation of these markets suffers from a lack of consistent standards for measuring, certifying, and reporting emissions. The increasing expansion of mandatory cap-and-trade systems across regions and the convergence of reporting standards will make the climate-conscious allocation more efficient and effective.

One central area where allocation is becoming more climate-conscious is sustainable finance. It is an essential economic lever when considering how to tackle climate change in a market-based economy. A growing public interest in ESG

and increasing requirements for companies to publicly account for ESG lead more companies to invest in such assets. As a result, business models tackling climate change will have more accessible possibilities to secure investments and work on innovative solutions tackling climate change in the AI era.

These investment possibilities are further fostered by European initiatives which advocate efficient resource usage and increase public awareness to reach the sustainability goals defined for 2050. In 2022, society faces the depletion of resources which is clashing with an increase in demand. Because of that, industry bodies and companies are starting to implement new controlling and measuring instances to transition into a more circular economy that boosts the efficient usage of resources.

Despite reduced resource consumption due to increased efficiency, a transition into renewable energy sources is needed to significantly lower global GHG emissions. Due to the adoption of new legislation which incentivizes investments in renewables and decreasing setup costs, the shift in the energy sector is ongoing and further accelerating. However, the

transition in the electricity market requires a redesign of the electricity grid with a focus on a higher degree of local autonomy and decentralization.

This need for decentralization of the energy sector will have to be addressed by governments especially in light of the transition to renewables and the ongoing trend of economic protectionism. Recent disruptions such as the COVID-19 pandemic, the US-China trade tensions, and the escalation of the Russian-Ukrainian conflict have further raised the economy's attention to the risks related to global value chains. With countries supporting domestic economies and companies betting on supply chain resilience, economic localization as an opposing trend to free trade is gaining importance. With the doubling of production capacity and simultaneously decreasing transport emissions, the impact on climate change can go either way.



MATURING OF EMISSION MARKETS

Emission Prices Are Becoming More Efficient as the Market Expands and Standardizes

The emission of GHG is what economists term a negative externality. Externalities are effects or costs associated with behavior that are not entirely born by the actor but at least partially by society. This cost-sharing creates misaligned incentives and leads to too many emissions. Aligning incentives is the fundamental idea behind the creation of emission markets. As such, these markets are recognized in the Paris Agreement to play a vital role in the fight against climate change. Besides government-mandated emission trading systems, there is also a vibrant voluntary carbon market fueled by zero-emission pledges of companies [270]. However, in 2022 prices between different schemes varied widely, as did reporting and certification standards [271]. Besides higher compliance costs and added friction, such differences between regions and sectors create opportunities for companies to avoid or at least profit-optimize payments for their emissions. The situation is set to improve as new legislation standardizes reporting and certification, new AI-based measurement tools decrease compliance cost, and mandated emissions markets expand to more sectors and regions [272].

Facts:

- In 2021, the EU-ETS covered about 40% of all GHG emissions in the EU [273].
- Between 2005 and 2022, prices for EU-ETS emissions certificates have increased from 8 EUR per ton to about 80 EUR per ton [274].
- Carbon prices in different cap and trade systems globally vary between 1 USD to 150 USD in 2021 depending on the ambition of the system [271].
- The market for carbon credits is projected to be worth more than 50bn USD annually by 2030 [275].

- In 2020, the voluntary carbon markets comprise six significant certification standards grew by 30% [276], [270].

Key Drivers:

- Cap-and-trade systems are expanding globally: In 2021, national governments launched six new mechanisms, and existing ones such as the EU-ETS are expanding to new sectors such as road transport and shipping [270], [277].
- Carbon Border Adjustment Mechanism (CBAM) legislation, adopted by the EU commission in 2021, prices emissions beyond and across European borders [278].
- Certification standards are converging: This applies to voluntary GHG certificates where the Taskforce on Scaling Voluntary Carbon Markets (TSVCM) has proposed quality standards for offsetting projects and corporate emission reporting covered by an EU commission directive on sustainable reporting, enforced starting 2022 [279], [280].

Challenges:

- High emission prices can lead to industry relocation, while fluctuating prices make long-term planning more difficult lowering efficiency [281], [270].
- Measurement of emissions and offsets is difficult, especially when crossing international borders [271], [270]. Reporting requirements exacerbate this: In 2020, companies had to use four different methods on their financial statements increasing compliance costs [282].
- Increasing consumer prices and their regressive effects could lower public support for increasing emission prices [270], thus hindering necessary rapid price increases and making implementation of required policy more difficult.

Impact on Climate Change in the AI Era:

Emission markets will play a central role in achieving the emission reductions outlined in the Paris Agreement by aligning price signals with the externalities associated with GHG emissions. The EU-ETS has led to a decrease in emissions of 35% and is on track toward the goal of 43% [273]. Its expansion to more sectors and regionalities alongside a higher degree of standardization in the mandated and voluntary market will lead to companies' climate-efficient strategic decisions and encourage behavioral change in consumers [283]. AI will play a vital role in detecting and accurately measuring emissions across international supply chains [272].

GROWTH OF SUSTAINABLE FINANCE

More Significant Amounts of Capital Are Allocated to Green Assets

If net-zero targets are not reached, the global economic loss is estimated to sum-up to 10% of the total global economic value by 2050 [284]. Therefore, the question of how to find solutions impacting and tackling climate change arises. In a market-based economy, the financial sector is an efficient system for allocating savings and maximizing returns while minimizing the overall risk. The main concept of sustainable finance is to integrate ESG criteria into financial services to support sustainable economic growth [285]. ESG investing is the dominant form of sustainable finance. It is driven mainly by the environmental aspect and less by the social and governance aspect, underlining the potential for climate-tech businesses [286], [287]. The growing amount of capital invested into these assets is, on the one hand, driven by consumer preferences and, on the other hand, by government policies. Germany aspires to become a sustainable finance hub and has an extensive sustainable finance strategy [288]. Combining these factors, the economic value of markets tackling climate change will increase, and it will become easier to finance climate-tech and ESG conform business models.

Facts:

- Assets under management (AUM) by ESG investment funds have tripled from 2015 until 2021, and ESG funds account for 10% of worldwide fund assets in 2021 [289], [290].
- ESG assets are predicted to increase to 53tn USD by 2025, accounting for a third of global AUM [291].
- The European Central Bank (ECB) expects to see an increasing availability of green finance across all asset classes, e.g., the issuance of Green Bonds by euro area residents increased seven times from 2015 to 2020 and accounted for 75bn EUR in 2020 [290].
- 24 of the 27 EU member states saw an increase in waste

disposal fees over the last years, with prices more than doubling in Poland between 2018 and 2020 [317].

- Europe is a leader in green digital technologies, with 76% more patents registered in the field than the US and four times more than China [292].

Key Drivers:

- Awareness regarding climate change is increasing globally, increasing demand for green products. Google searches for sustainable goods increased by 71% from 2016 to 2020, with 444% in Germany being well above average [293].
- The EU (NFRD, CSRD, SFDR) and German Sustainable Finance Strategy lay the regulatory foundation for ESG reporting, accelerating investments into sustainable assets [288].
- The European Investment Bank (EIB) is one of the most prominent financiers funding digital, green initiatives and covers the entire spectrum from seed capital to senior debt. They are mobilizing 1tn EUR until 2025 [294].


Challenges:

- Global growth is projected to decrease from 5.9% in 2021 to 3.8% in 2023. For the eurozone, an even steeper decline to 2.5% annual growth is predicted for 2023 [295]. This slowing global growth poses a risk to sustainable investments as well.
- Furthermore, inflation is predicted to elevate while monetary policy becomes more restrictive, which will lead to an increase in costs for environmental projects [295], [296], [297].
- A lack of transparency on ESG definitions and corresponding accusations of employees about financial institutions making financial products greener than they are makes conscious capital allocation more challenging [286], [298].

Impact on Climate Change in the AI Era:

Sustainable finance offers the opportunity to accelerate the discovery of climate-tech innovations in a market-based economy. There will be a reallocation of capital toward sustainable companies, and new capital will be invested mainly in ESG conform companies. This shift in capital allocation will make it easier to finance climate-tech businesses and, in turn, harder for non-climate friendly business models to raise capital [299], [298]. Public funding will support solutions that are not classical business cases and will signal to minimize risk for private capital.





BOOSTING RESOURCE EFFICIENCY

Moving Toward a Sustainable Economy Requires Efficient Resource Usage

Natural Capital contributes to the world's gross domestic product by more than 50% [300]. With businesses focusing on profitability and missing natural assets in any economic performance metric, the efficient usage of natural resources was ignored over centuries of commercial activity [301]. This focus has led to resource depletion, aggravating the current rising resource and energy demand [302]. Through the COVID-19 pandemic, factors such as an exponentially increasing world population, steady growing inflation, and an accelerating climate crisis have tightened companies' production capacities by interrupting supply chains and generating resource shortages [303]. Consequently, product prices have risen, making it more difficult for businesses to stay competitive. Nevertheless, these issues have been acknowledged and tackled by recent governmental initiatives, which raised new opportunities to rethink global resource usage, augment society's awareness, and make value chains consider three resource attributes: efficiency, consistency, and sufficiency. Identifying the need for a reaction has resulted in a more conscious implementation of AI and Big Data tools, which paves the way to a more circular economy [304].

Facts:

- The global energy demand is predicted to increase by 50% until 2030 [305].
- By 2100 the global material demand is growing by 300% [306].
- Visible need for efficient resource usage: natural resource extraction and processing account for more than 90% of global biodiversity losses and approximately half of global GHG emissions [307]. Current material use accounts for 20% of CO2 emissions worldwide [306], and predictions report a 40% shortage of freshwater needed to support the global economy by 2030.

- Societal awareness of resource issues and the circular economy (CE) is increasing: Interest increased over 250% in the last four years [308], [309].

Key Drivers:

- Governmental regulatory initiatives and policies incentivize resource efficiency (e.g., Green Deal Initiative, EU Action, and Recovery Plan, European Commission's CE monitoring framework) [310], [306], [311].
- CE is essential to achieve the 2050 goals defined in the Paris Agreement [312].
- AI acts as an efficient catalyst in production and supply chains, augmenting economic growth (an additional 0.5% to the GDP), employment opportunities (700,000 jobs in the EU by 2030 [313]), and a positive environmental impact [314], helping to achieve 134 targets of the 17 SDGs (79%) [313], [315].

Challenges:

- Despite robust policy-making, no specific measurement metrics for CE are defined. Most CE data refers to recycling, which leads to inaccuracies and slow enforcement mechanisms [307].
- Global industry focuses on resilience rather than efficiency [302], with Europe being the main hub pursuing sustainability, whereas the remaining countries follow linear consumption models.
- Increased resource efficiency may result in a price reduction for a good or service, which increases demand (Jevons paradox) [316].
- Waste management contradicts a thriving economy. Further adjustments and regulations are needed to make CE more attractive [306], [317].

Impact on Climate Change in the AI Era:

The current socioeconomic setup allows for 8.6% of circular products and processes, leaving an immense resource and material efficiency gap [318]. AI and technological tools can help to implement policy controlling measures that address specific value chain points. Such measures would lead to a reduction in GHG emissions from mining, production, and trash removal. A doubling of circularity could lead to a 39% reduction in emissions and a 28% decrease in the material footprint until 2032 [318]. At the EU-Level, there is potential for CO2-reduction through CE by 56% [306], [319].

TRANSITION TO RENEWABLES

Renewable Energy Sources Increasingly Substitute Fossil Fuels

The energy sector is responsible for a significant part of global GHG emissions [320]. Political initiatives, driven by raised public awareness, demands from the scientific community, and technical research, have therefore been focused on achieving a transition into renewable energy sources. The first results of these efforts can be observed through an increasing share of renewables in the decade from 2010 to 2020. In Germany, the percentage of renewables in the electricity market increased from 17.1% to 45.3% during this period [321]. The transition, however, is mainly focused on the electricity market, making up only around 20% of the global energy market [322]. Several challenges need to be overcome to further accelerate the transition in the energy market. The transition must mainly be expanded to other energy segments or supported by comprehensive electrification. Furthermore, to maintain energy security while balancing geopolitical power shifts energy grids have to change their mix of energy sources. Despite these challenges, the transition has been accelerated in recent years, leading to a significant reduction of emitted GHG [321], [323].

Facts:

- Renewables overtook fossil fuels as the EU's primary power source for the first time in 2020 [324].
- The cost of renewable electricity has decreased from 2019 to 2020: levelized costs of energy (LCOE) for onshore wind decreased by 13%, offshore wind by 9%, and utility-scale solar photovoltaics by 7% [325].
- The global electricity intensity, measured in gCO₂ per kWh, is expected to decrease from 475% in 2018 to 68.8% in 2040 [322].
- The rise of renewables is mainly driven by the electricity market, with a share of renewables of 45.3% in 2020 in Germany [321].
- In 2016, the energy sector accounted for 73.3% of global GHG emissions [320].

Key Drivers:

- Due to technological advances, renewable energy sources become increasingly cheaper than coal-fired power plants [325], [326]. This cost-benefit of renewables leads to a rise in investments and an accelerated adoption rate.
- Political legislation on the European and German levels is forcing an end to fossil fuels. In Germany, the federal administration put the Act to Reduce and End Coal-Fired Power Generation to phase-out coal by 2038 [327]. The EC similarly implemented the European Green Deal measures to accelerate the energy transition [328].

Challenges:

- Transitioning to an energy system mainly relying on renewables requires a decentralized energy grid allowing for more flexible demand and supply peaks while ensuring energy security. Technological applications and higher co-operation by all players in the energy market are needed to achieve such an energy grid [323], [329].
- Until 2022, the transition to renewables mainly focused on the electricity market. For renewables to gain a further share of the energy market, either alternative renewable energy sources (besides electricity) need to be applied, or significant parts of the economy need to be electrified [322], [330], [331], [332].

Impact on Climate Change in the AI Era:

Due to the high share of energy related GHG emissions, shifting to renewable energy sources will play a significant role in tackling climate change. However, the transition currently focuses on the electricity market, limiting the impact it could have on the global electrification share (around 20%) [322]. During this transition within the electricity market, AI can enable a decentralized and flexible grid, e.g., by better predicting electricity demand [333]. A complete transition of the global electricity market to renewables could lead to a reduction of CO₂ emissions by 40% [334].





LOCALIZATION OF ECONOMIC ACTIVITIES

Geopolitical Events Are Driving the Localization of Value Chains

In the past years, economic localization, which describes the preference of local production, local ownership, local capital flows, and focusing on local needs, has gained significant importance for consumers and businesses [335]. Out of fear of an uncertain world, some of the world's largest economies adopt national-oriented and protectionist agendas to favor their economy. This includes tariffs limiting direct trade and data protection measures hindering the free flow of data. Three recent events have further acted as catalysts for this tendency: the COVID-19 pandemic, the tariff war between the US and China, and the military conflict between Russia and Ukraine. All of them disrupted global supply chains, leading to supply shortages. This has sparked a discussion about global supply chains' fragility and associated risks [336]. But supply chains are not only a concern due to their fragility but also from the view of climate action. The long transport distances enabling globalization also cause large amounts of fossil fuel consumption and harmed the environment [337]. Against this backdrop, the increased localization of some sectors might be beneficial to mitigate climate change [338].

Facts:

- In 2017, the US abandoned the Trans-Pacific Partnership Agreement (TPP) and started renegotiating the North American Free Trade Agreement (NAFTA) to promote domestic production [339], [340].
- In 2018, India started raising import duties on 40 items to protect domestic industry [341].
- The EU adopted the general data protection regulation (GDPR) in 2018, which regulates the data flow to third countries and enforces data storage in the EU [342].
- The COVID-19 pandemic has made relocation approaches more attractive to healthcare, engineering,

construction, and infrastructure sectors. Executives of these industries expect to pursue some degree of regionalization until 2024 [343].

Key Drivers:

- A general geopolitical trend toward nationalism and protectionism is observable as new tariffs and economic sanctions are imposed [344]. Data flow is also affected, with recently enacted localization requirements in the EU, Russia, India, and China [345], [346].
- Due to the disruption of supply chains caused by global events such as the COVID-19 pandemic and the Ukraine conflict, there is an increasing focus on greater supply chain resilience that fosters regionalization [347], [348].
- The green transition will likely lead to shorter and more local value chains in response to the climate crisis [349].

Challenges:

- The high efficiency of global supply chains built over the last 50 years will prevent their undoing in the short term [350].
- Asset-intensive sectors with expensive production sites would need to make significant investments to re-localize their production [351].
- Trade policy will continue to liberalize trade, as free global trade and fair competition help boost economic growth and create jobs. Germany's ministry for economic affairs and climate action sees further liberal trade as essential to secure Germany's future as an industrial hub [352].

Impact on Climate Change in the AI Era:

Economic localization has the potential to reduce the GHG emissions caused by global supply chains. However, the net impact of localization on emissions strongly depends on the type of economy relocated and the relocation strategy. Globalization has led to increased fuel consumption and thus higher emissions [353], suggesting that a localized economy should emit less due to shorter transport distances. Nonetheless, increasing decentralization in supply chains and production would lead to lower efficiency in the manufacturing process, thus suggesting higher emissions [336]. Hence, the answer economic and public actors will find to the current economic localization tendency will decide on its impact on climate change.

BUSINESS MODEL TRENDS

INFLUENCING CLIMATE CHANGE IN THE AI ERA

Rise of Sustainability Management Solutions
Product-as-a-Service enabling Circular Value Chains
Solving Climate Adaptation for Enterprises
Driving Value Creation Through Deep Tech
Open-Source Business Models
Large-Scale AI monetized as a Service

BUSINESS MODEL TRENDS

Influencing Climate Change in the AI Era

Companies produce most goods and services that are used in industrial societies. Therefore, their behavior has an enormous leverage on climate change – and this behavior is strongly influenced by the underlying business model, e.g., their means of value creation and capture. Business models are essential in leveraging the available technologies and commercializing a sustainability-centric solution for everyone. If companies can align their value creation with sustainability goals, they can serve as a vehicle for change. However, companies that are stuck in traditional ways to generate revenue can be counterproductive to climate action or even make climate change worse. Therefore, business models that emerge in the following years will have a significant impact on how well humanity can tackle climate change.

Changing customer preferences and investor priorities drive the growth of sustainable products and services [354]. The startup ecosystem is vital in shaping the sustainability transformation toward a green economy. In 2021, Europe had over 800 climate tech startups, and Germany is home to 252 of them, making it the hub for most climate tech startups [355]. Germany leads in climate tech areas like sustainable

building, green energy, circular economy, smart mobility, biodiversity, and zero pollution [356]. Venture capital (VC) firms and their investors are increasingly attracted to climate tech, with assets under management (AUM) dedicated to the field growing at five times the average growth rate of all industries [396].

This section details six business model trends related to tackling climate change that emerge in the upcoming years of the AI era. First, the rising number of sustainability frameworks and legislations fuels the need for solutions enabling simple compliance, management, and reporting, resulting in a vast market for sustainability management software. Second, an emerging trend are 'X-as-a-service' models that will stay prominent, including sustainability management-as-a-service, circular products-as-a-service, and AI monetized as-a-service. Value creation also extends to material use related to circular economy business models that are growing due to increased population growth and worsening resource shortages [357]. Third, there is a clear trend toward providing climate adaptation solutions. As climate change becomes more widely accepted, climate ad-

aptation solutions increase the preparedness for acute and catastrophic climate disasters [358]. Fourth, a demand for more sustainable solutions amongst customers is furthering the integration of deep tech across the value chain, which may accelerate AI growth further [354]. Fifth and sixth, startups are providing developer solutions in the form of open-source business models and AI-as-a-service, leveraging the advances of other technologies like IoT sensors to further improve data collection [359], [360].

Climate challenges bring new opportunities to innovate and change existing or create new business models. But while the rise of climate tech may be able to decrease GHG emissions by some degree, real change can only occur if there is a shift in consciousness toward environmental awareness.

RISE OF SUSTAINABILITY MANAGEMENT SOLUTIONS

Companies use Software Services to Stay Compliant, Increase Credibility and Reduce Emission

Firms face significant pressure from consumers, investors, and regulators to act sustainably and transparently about their sustainability practices [361]. For instance, companies have to adapt to regulations, like the EU Taxonomy, which provide a framework for classifying sustainable business activities, aiming to prevent greenwashing and increase transparency [362]. To stay compliant and develop an effective climate change strategy, companies need a system to collect metrics on their ESG performance [363]. However, measuring the sustainability of activities is challenging, especially when looking at all three scopes of greenhouse gas emissions. Scope 1 and 2 emissions refer to direct and indirect emissions that are generated from company-managed resources. Tracking them is difficult, but manageable. Scope 3 emissions however are the hardest to monitor. They refer to all other indirect emissions across the value chain that are somehow linked to a company's operations. This monitoring challenge leads to rising demand for solutions that support tracking and reporting emissions [364, p.15]. Consequently, the number of companies offering sustainability accounting software is increasing, and both startups and well-known companies such as SAP are entering the space [365], [366].

Facts:

- The sustainability management software market is expected to grow by 842.76m USD from 2021 to 2026, resulting in a CAGR of 11.93% [367].
- 86% of companies track their emissions manually using spreadsheets, and 91% fail to measure their whole emission scope. Firms name automated footprint calculation, data ingestion, and reporting as desired features to improve their measurements [364, pp.5-14].

- Greenwashing is still largely present. A screening of corporate websites by the European Commission resulted in 42% containing claims believed to be false, deceptive, or exaggerated [368].

Key Drivers:

- The EU Taxonomy regulation makes it mandatory for companies to identify, quantify, and report their carbon footprint [369]. Due to the Corporate Sustainability Reporting Directive, 50,000 EU companies will be obliged to disclose their ESG performance from 2023 onwards [370].
- Blockchain, AI, and advanced analytics make it possible to track the environmental impact of business activities in real-time and across the whole value chain [371].
- Investors and shareholders are paying more attention to ESG criteria. 76% of investors conduct a structured, methodical evaluation of ESG-disclosures [372, p.8].

Challenges:

- Lack of standardization in ESG-reporting. While credit-worthiness ratings match 99% of the time, ESG ratings are aligned only in 6 of 10 cases [373, p.368].
- Scope 3 emissions are challenging to measure due to unreliable data. Complexities arise with international supply chains stretching across continents consisting of intermediary suppliers or consumers not wanting to share information [374].
- The Paris Agreement gives companies freedom in what to disclose to limit brand risk [375]. Additional pressure from investors might push companies toward even more greenwashing to ensure future funding [372, p.17].

Impact on Climate Change in the AI Era:

AI-powered software helps organizations manage sustainability as part of regulatory compliance, investor management, or business operations. Carbon emission transparency alone can reduce an organization's average CO2 emissions by 30-40% by providing the necessary visibility to enable sustainable decision-making [371]. As the regulatory environment becomes more complex, further support is needed to comply with green legislation. Sustainability services rise to serve this growing demand with a CAGR of almost 12%. However, the lack of standardization, difficulty in measuring missions, and loopholes in regulations prevent AI-powered sustainability solutions from prevailing.



PRODUCT-AS-A-SERVICE ENABLING CIRCULAR VALUE CHAINS

Replacing the 'End-of-Life' Concept by Selling Services Instead of Products

Circular Economy (CE) is based on business models which replace the 'end-of-life' concept with reducing, reusing, recycling, and recovering material in production, distribution, and consumption processes [376]. The greater the value locked into a product – whether in terms of brand reputation or resources consumed in manufacturing – the greater the potential for creating a circular business model (CBM) [377]. A circular 'Product-as-a-Service' (PaaS) business model incentivizes companies to manufacture durable, high-quality, and modular products, which circulate in use for much longer, thus conserving the resources used to manufacture them [378]. The goal is to provide a product to as many people as possible, rather than selling as many units as possible [359]. PaaS can be realized with leasing, rental, subscription, or pay-per-use agreements [379]. This business model allows customers to purchase a service instead of buying the product itself and benefit from specific maintenance, repair, or operation services [380]. Core features of circular PaaS like reusability, product longevity, and sharing become drivers of revenue and reduced costs [381], while also saving millions of tons of precious natural resources every year [382], [222].

Facts:

- From 1995 to 2015, GHG emissions from material production alone increased by 120%. As a proportion of global CO2 emissions, material production rose from 15 to 23% [56]. Material demand will grow about 300% until 2100 [383].

- At the EU level, the potential for CO2 reduction through CE concepts like material recirculation, material efficiency, and innovative business models is 56% [383].
- AI can accelerate the transition toward a CE for consumer electronics and unlock the value of up to 90bn USD a year in 2030 [384].

Key Drivers:

- New technologies such as blockchain or AI will enhance and enable many parts of the CE transition, for example, sharing, virtualizing, or managing complex reverse logistics chains [359], [360].
- CBMs enjoy political support due to their many benefits for growth, employment, health, and the environment [385]. The EU-Sustainable Product Initiative, which proposes additional legislative measures and instruments like the EU-Ecodesign Directive, aims to make products placed on the EU market more sustainable [383], [386].

Challenges:

- When designing a PaaS, it is essential to consider that the product can be updated based on innovations and legislations [383].
- Circular PaaS is only sustainable if the product's value can be economically recovered. However, it is difficult to predict how much of this value this business model could unlock [377], as products become more complex and renewing and restoring materials can be highly costly [359].
- Customers are still used to the conventional consumption of material products through sole ownership. Psychological ownership must satisfy consumers' need for possessing a product and substitute for material ownership [387].

Impact on Climate Change in the AI Era:

By 2032, the global GHG emissions could be reduced by 39% and the total material footprint by 28% if global circularity is doubled in the next ten years [388]. Notably, PaaS offers a potential approach to counteract overconsumption, resulting in dematerialization that has already had significant impacts on sustainability performance for many industries [389]. PaaS enables new business opportunities, such as chemical leasing, which successfully combines economic benefits for companies with reduced negative impacts on the environment and health [390].

SOLVING CLIMATE ADAPTATION FOR ENTERPRISES

Diagnostics, Response, and Resilience for Better Recovery in the Event of Extreme Climate Change

Recall the massive destruction of towns and villages in the North Rhine-Westphalia and Rhineland-Palatinate regions in 2021. More than 180 people died across Europe and billions worth of property damage have been caused [391]. This disaster became Germany's worst in over 50 years since the Great Flood of 1962 in Hamburg [392]. Even in our AI era, we did not manage to predict such an unprecedented level of flooding and intensity. Still, with better early-warning and disaster response plans, perhaps such a considerable loss of life and damage could have been avoided [393]. Climate change will become even more extreme, and an integrated portfolio of actions needs both mitigation and adaptation [358]. Mitigation aims to reduce the severity of climate change, and the emission of GHGs is rightly prioritized, but adaptation does not receive as much attention yet [358]. Adaptation acknowledges the inevitability of climate change by increasing human and environmental resilience against the impact of current and future climate change. The market for adaptation is anticipated to grow with a rising number emerging to address the three core areas of adaptation: diagnostics, response, and resilience [358]. The adaptation solutions market provides startups ample business opportunities to sell products to large enterprises.

Facts:

- In 2019, the 215 biggest global companies were estimated to have 1tn USD at risk to their businesses from climate impacts [394].
- It is estimated that climate change adaptation will capture 26tn USD in opportunities and 65 million new jobs by 2030 [358].

- An emerging number of German startups like Wetterheld, Tenevia, Serinus, and others are capitalizing on the climate adaptation demand. Such solutions can include flood tracking, hyperlocal flood warning systems, or automatic underwriting using satellite imagery.

Key Drivers:

- Managing the aftermath or reducing the enormous losses of extreme weather events is a critical driving force as climate change impacts become more intense around the world, considering that global losses from natural disasters in 2020 reached about 210bn USD, of which around 60% some 82bn USD was uninsured [395].
- Climate change litigation and other legal action such as regulatory enforcement proceedings, fines, penalties, and a failure to adapt are driving adaptation-related efforts [399, pp.5].
- Advances in the collection of data via new satellites and sensors, and powerful AI models, offer more detailed insights than ever before [397, .p 28-25].

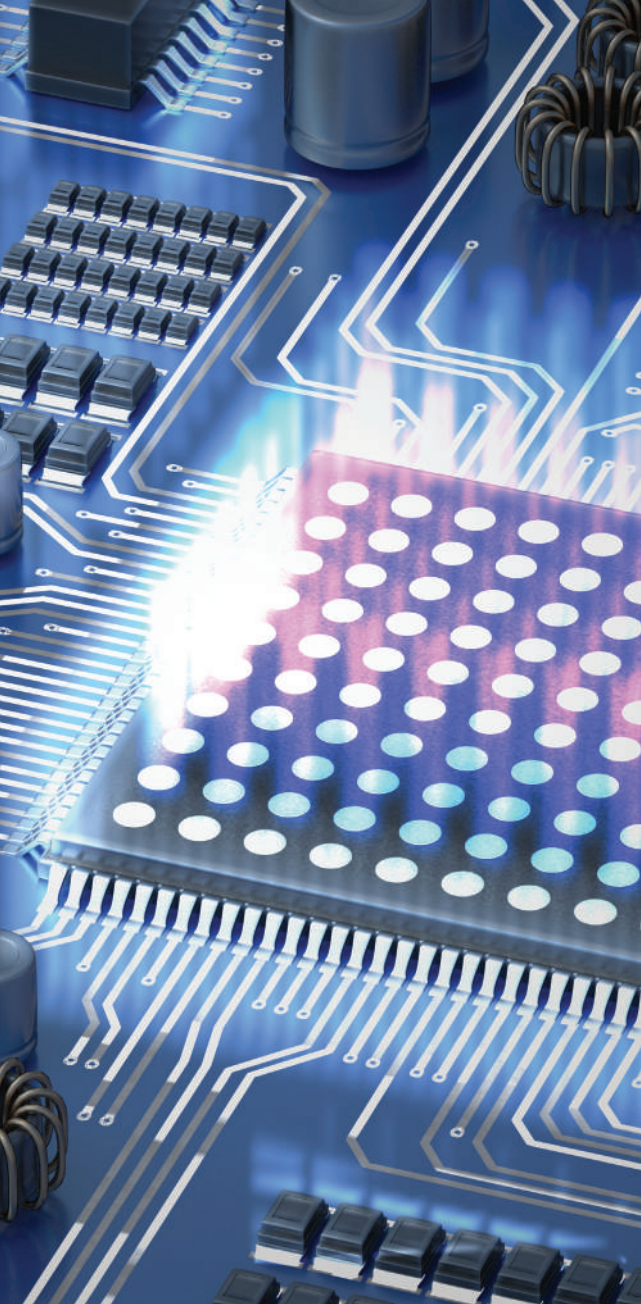
Challenges:

- Data management from multiple data sources, inconsistent data input, and unstructured data can prevent adaptation solutions from running the whole gamut of potential offered by the analytics strategy and data governance frameworks in this thriving data-rich universe [374].
- The lack of transparent scientific validation and public oversight over 'black box' climate models makes it hard for customers to assess the quality of provided data and intelligence [398].

Impact on Climate Change in the AI Era:

Enterprises that lack the in-house capability to meet their climate adaptation can seek the services of startups. How the market for climate adaptation develops will depend on the quality of openly available data collected by governments and researchers. Private companies might be able to get a competitive advantage by using their own satellites, sensors, and custom climate models. By analyzing collected data with new AI models, predictions can detect and confirm threats and disseminate information to responders faster than ever before and open up new plans of action before and after climate change strikes [397].





DRIVING VALUE CREATION THROUGH DEEP TECH

Entrepreneurs and Investors Shift to Deep Tech, Recognizing it as Overlooked

Regulators pressure large companies to reduce their emissions significantly. However, many are struggling to do so [399]. As emissions are produced in the physical world, they cannot be significantly reduced through software solutions only but rather with a combination of hard- and software. When evaluating the different technological areas based on their emission reduction potential, deep tech is the most crucial area as it represents 81% of the overall emission reduction potential [400]. Companies are considered deep tech if they have a solid research base, focus on developing new solutions at the technological frontier, and are usually at the intersection of multiple technology areas [401]. Therefore, they have a high risk of their technology failing [402]. With a lengthy time to market due to the technological development required, deep tech firms rely on a significant amount of funding [402]. However, deep tech companies with disproportionate emission reduction potential are currently underfunded compared to other climate-related businesses [400]. This is both due to a misallocation of capital as well as an unfitness of investors to invest in deep tech [403, pp.4-13].

Facts:

- By 2050, half of the reductions in global CO2 emissions are expected to come from technologies that are only at the demonstration or prototype phase [400, p.42].
- Climate tech investment in Europe has been growing the fastest and most consistent worldwide from 2016 to 2021 [404].
- From July 2020 to June 2021, over 87.5bn USD were invested in climate tech, representing a 210% increase year-over-year

(YoY). However, 75% of the funding addressed technology areas, with only 19% of the potential emission reduction from key technologies [400, p.4].

- Deep tech ventures tend to operate on the convergence of technologies, with 96% using at least two different technologies [401].

Key Drivers:

- Changing customer preferences lead to a demand-pull for low-carbon solutions capable of disproportionately reducing emissions [405], [406, p.2].
- The profitability and valuations of emission-reducing deep tech companies are increasing due to new revenue streams [407] and cost structures [401].
- The barriers to entry for deep tech startups have decreased exponentially and continue to do so due to reducing setup costs, driven by technological [403, p.5], business developments [408], and increased access to financing [400], [409].
- Investors increasingly focus on deep tech, recognizing that it is relatively undervalued [403, p.46], and technology areas with 81% of the emission-reduction potential only receive 25% of the climate-related funding [400, p.44]. However, climate-tech unicorns are concentrated there [410].

Challenges:

- The profitability of emission-reducing deep tech solutions depends on the consistency and rise of carbon prices [400, p.50].
- A potential 'valley of death' appears to arise from a lack of late-stage investors that can finance startups to expand operations [400, p.39].
- VC funds are structurally unfit, provide impatient capital and lack capabilities to invest in deep tech [403, p.13].
- More patient funding from governments and sovereign investors is required to de-risk deep tech companies on a technical level and enable follow-on investment by investors [400, p.13].

Impact on Climate Change in the AI Era:

81% of the overall emission reduction potential arising from key technology areas can be unlocked through increased investment in deep tech companies focused on reducing emissions [400, pp.42-44], which is also likely to yield outsized returns for investors [400, p.4]. Overall, the future emission reductions arising from the development of technologies in the early stages of technological readiness will add up to more than 50% of the reductions in global CO2 emissions by 2050 [400, p.42].

OPEN-SOURCE BUSINESS MODELS

Changing Value Propositions from Product to Service

More and more businesses are pursuing open-source business models, meaning their core product is open-source software (OSS). Software products are open source if their source code is freely available under an open license that allows people to use, modify and redistribute the code for any purpose [411]. This has the advantages of building trust in the product and benefiting from integrating any changes or bug fixes from contributors outside the company [412]. While successful OSS products like the mobile operating system Android have a tremendous impact on the tech ecosystem and decrease the cost to start and scale a business, the question remains for companies that develop OSS how they can also monetize it. The most frequent monetization model is software-as-a-service (SaaS), e.g., offering a managed cloud-hosted version of the OSS product. Other options are support and service contracts, dual licensing (free for non-commercial use, different license for commercial use), marketplaces (e.g. the Android app store), or paid features (just the core software is open-source, but advanced features are not) [413], [412].

Facts:

- The community of open-source contributors is vibrant: more than 56m developers were contributing over 1.9bn individual contributions to OSS projects on Github in 2020 [412].
- OSS is everywhere: the open-source operating system Linux powered 75% of the public cloud workload in 2020, and its share is expected to rise to 85% by 2024 [412].
- Open source is successful: there are several OSS companies that had a multi-billion dollar valuation in 2020, including MongoDB (13.6bn USD), Elastic (9.3bn USD), Confluent (4.5bn USD), HashiCorp (5.3bn USD), and Databricks (6.2bn USD) [414].

Key Drivers:

- Searching for talent: the tech industry finds it harder to find skilled software developers. While in 2010, there were 28,000 information technology (IT) positions to be filled in Germany, the number increased to 96.000 vacant IT positions in 2021, mainly for software developers and system administrators [415]. Open-source products can tap the pool of available developers not only by receiving direct voluntary contributions but also by drawing attention to the company and attracting talent [412].
- Building trust: When tech companies face public scrutiny, going open source with a product can increase confidence in the security of the software [416], create a positive image effect that transfers to the leading brand, and act as a marketing strategy [417].

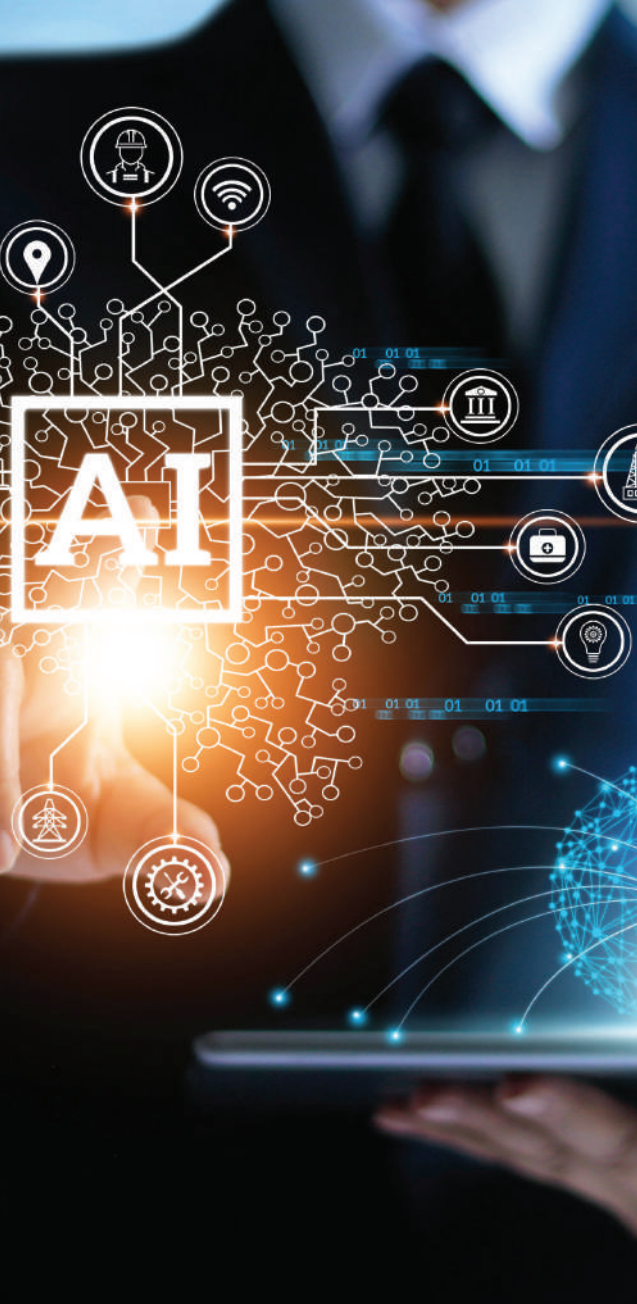
Challenges:

- Besides software development and support, the company also has to engage in community management, as only products with a vibrant community of external contributors can play out the advantages of open-source [418]. Conflict with the community can arise from monetization goals, for example, if core functionality is shifted to paid features.
- Large companies like Amazon Web Services, Google Cloud, and Microsoft Azure can threaten monetization strategies of smaller open-source companies by offering managed hosting for the same product [419].
- Adhering to and enforcing coding standards can be a considerable challenge. Compliance with standards is essential because 90% of software security problems are caused by coding errors [420].

Impact on Climate Change in the AI Era:

OSS is a catalyst for the AI ecosystem and makes rapid development of new technologies on top of the broad available open-source toolset possible. Offering software solutions that tackle climate change as open source can also increase their diffusion and allow rapid iteration on improvements by contributors worldwide. Lastly, for analytic and predictive climate models, it will be crucial that the source code is openly available to make the results understandable and reproducible – the principles of open science [421].





LARGE-SCALE AI MONETIZED AS A SERVICE

State-of-the-art AI Models of Large Tech Firms will be Broadly Adopted

With exponentially rising costs [422] and a lack of AI talent [415], more and more businesses are struggling to develop their own state-of-the-art AI models. Instead, many are looking for plug-and-play solutions that they can deploy in their value chain [423]. Thus, large technology companies have started offering large-scale AI models as a paid service to third parties. This trend is illustrated by the example of OpenAI, which was funded with 1bn USD by Microsoft [424]. OpenAI's state-of-the-art natural language processing (NLP) model GPT-3 can only be accessed for a subscription fee [425]. The emergence of large-scale AI monetized as a service is democratizing access to AI to a certain extent [426]. However, the companies that provide these models have relatively high pricing power over their customers who are often unable to create their own state-of-the-art models [427]. The race for large-scale AI models is showing clear monopolistic tendencies and therefore an increasing concentration of power around large technology companies [427]. As regulators note this, they are putting more pressure on those companies to counterbalance these tendencies [428].

Facts:

- The AI-as-a-Service market is projected to grow at a CAGR of 48.9%, growing from 3.91bn USD in 2020 to 43.29bn USD in 2026 [429].
- A paradigm shift for large technology companies from open-source to monetized Application Programming Interfaces (API) is illustrated by OpenAI's GPT-3 [424].
- The monopolistic tendencies of the technology sector are reinforced by the race for data, as illustrated by the race for autonomous driving: Tesla had collected the data from 3 billion miles as of 2020 [430], eclipsing their closest competitor by more than 150 [431], with the divide rapidly increasing due to differences in fleet size [432].

Key Drivers:

- Data set size drives AI accuracy with predictable benefits resulting from the scale of a data set, favoring those companies with the most data [433].
- Smaller companies are increasingly relying on large businesses providing AI models [434], as the cost of creating state-of-the-art models will grow by a factor of 100 from 2020 to 2025 and is projected to reach 100m USD by 2025 [422] and a talent, compute, and access divide is emerging [435].
- Data monopolies are taking up gatekeeper roles and have increased pricing power as smaller businesses become increasingly dependent on the tools provided by the monopolies [427].

Challenges:

- Open-source initiatives for large AI models are emerging to democratize access to state-of-the-art models, e.g. LEAM [436].
- To mitigate the rise of monopolies, regulators are increasingly pressuring big tech companies in a new wave of anti-trust efforts and introducing new measures [428], with even post-ex merger breakups now being considered [437].
- Increasing the efficiency of large-scale AI model training is crucial to reducing electricity costs and environmental impact [438].

Impact on Climate Change in the AI Era:

Compared to a scenario without AI-as-a-Service models, Emissions from AI training will decrease as fewer companies create their own AI models and instead use the existing models provided by larger players [439]. However, the carbon footprint of large-scale AI model training is still increasing disproportionately to the increase in model accuracy with a growing data set size, resulting in a very high carbon footprint for each large-scale AI model trained [438]. Training such models emit over 284t of carbon dioxide, equivalent to five lifetimes of an average American car [315].

SCENARIOS

The following chapter describes four scenarios of different futures. The scenarios are plausible, relevant, challenging, consistent, and recognizable from the present and near future signals. All of the scenarios are equally plausible and derived from two identified key drivers. They present far-reaching visions of how the future of tackling climate change might look like in 2042. Personal narratives tell stories of ordinary days in 2042 to allow an in-depth look into the future. Finally, identified signposts indicate the progress towards each scenario. They emphasize possible paths from the present to each of the four scenarios.

SCENARIO OVERVIEW

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TOWARDS ONE GREEN WORLD54

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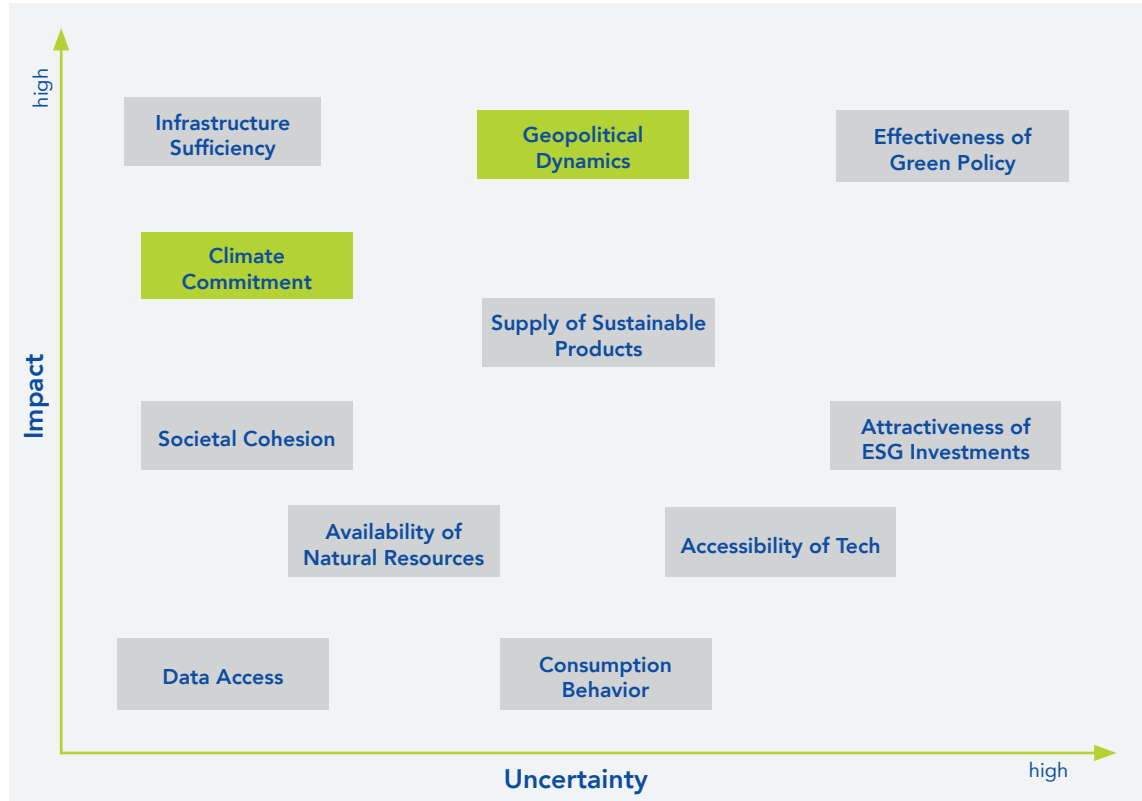
SCENARIO 2
FAILURE OF GREEN COLONIALISM57

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DRIVER MATRIX

The scenario phase follows a structured approach to imagine what life could look like in 2042. Based on the research conducted during the Trend Phase, current drivers and challenges of the different trends are identified. Drivers are the underlying exogenous forces of the trends that shape the way climate change will be tackled in the AI era. All the identified drivers are modeled as bipolar with extreme outcomes.

As a next step, all drivers are ranked in a matrix based on their degree of uncertainty and their impact. The outcome of a driver is uncertain if both outcomes are equally probable. Based on this ranking, two key drivers are identified. Key drivers have a high impact on Climate Change in the AI era and a high degree of uncertainty. In addition, the two key drivers need to be independent of each other and cannot overlap in their definition. After evaluating different combinations, “Climate Commitment” and “Geopolitical Dynamics” are identified as the two key drivers of the four equally plausible scenarios.



KEY DRIVERS

Low Climate Commitment

In 2042 individuals' lack of commitment to climate change action is fuelled by resignation, polarization, and inflation. People believe that it is too late to take effective actions. Instead, hedonistic consumption becomes the social remedy. Increasing prices due to scarce resources hit especially lower classes. This eliminates the willingness to pay a green premium for climate-neutral products. In rich countries, people are hedonistic and do not want to sacrifice their lifestyle. Poorer societies do not sacrifice, as their biggest problem is covering basic needs. Climate commitment is low regarding activism and voting behavior. This leads to countries and companies exploiting all-natural resources. They might mitigate the consequences, but not the root causes.

National Prioritization

In the case of national prioritization, geopolitical dynamics are largely fragmented. Nations are focused on national rather than global survival of the climate crisis, which for some countries could mean not having climate change on their political agendas at all. Legislation (i.e., regulations, guidelines, and sanctions) is unstandardized across the globe. Nations engage in economic protectionism. There is widespread mistrust of supranational organizations, and nations only interact with each other out of explicit self-interest. Not only do nations tend to not cooperate, but they also may be openly hostile towards one another if it serves their needs. There is a widening disparity between developed countries and developing countries, and developed countries practice unfettered extractionism.

Individual Climate Commitment

Climate commitment describes how committed individuals are to taking action in fighting the climate crisis. People widely acknowledge climate change, but their degree of commitment is what influences global development. Individuals' commitment heavily depends on their priorities in life, willingness to adapt, and worldview. It influences their consumption behavior and their participation in activism or elections. How many individuals commit to climate action is an important key driver, as a majority of emissions can be attributed to individual behavior. Further, climate commitment does not focus on companies or government, but on how individuals are also interlinked with legislation. It's people that elect the governments, and it's people that have to bear the consequences.

Geopolitical Dynamics

Geopolitical dynamics describe the scale on which political actors – including nations and supranational organizations– act and interact with regard to geographical issues such as climate change. Geopolitical dynamics go beyond mere climate-related international relations, which traditionally refer only to interactions between nations. As used here, the concept of geopolitical dynamics refers to the larger positioning, strategies, and political power of nations in the evolving environmental landscape. Geopolitical dynamics are concerned with national borders; therefore, the consequences of geopolitical dynamics most obviously involve larger political entities, but shifting geopolitical dynamics can have strong effects on individual citizens and local culture as well.

High Climate Commitment

Individuals are aware of climate change and ready to take action to fight the climate crisis. They take responsibility because they and their children are affected. This leads to a change in social norms; fighting climate becomes cool. People are willing to consume sustainably, even if that means reducing their lifestyle because they realize there is no alternative. They believe that they can change the world through their consumption behavior, voting, and activism. This leads governments to focus on prevention rather than adaptation. Overall, resources are used more sustainably, resulting in a steadily improving situation for everyone. Humanity has a common cause to fight climate change and a vision for a better future uniting people of all nations.

Global Prioritization

In the case of global prioritization, geopolitical dynamics are largely cooperative. Nations are focused on working together to achieve global survival from the climate crisis, which means that all countries have climate change on their political agendas. Legislation (i.e., regulations, guidelines, and sanctions) is standardized across the globe to achieve this goal. Nations happily engage in global free trade. Supranational organizations are thriving and widely trusted, and nations are proud to be members of such collaborative organizations. Nations are only hostile towards one another when absolutely needed to enforce their shared and cohesive goal of environmental sustainability. The disparity between developed countries and developing countries is diminishing, and developed countries provide impactful, developmentally sustainable aid.

OTHER IMPORTANT DRIVERS



SCENARIO MATRIX

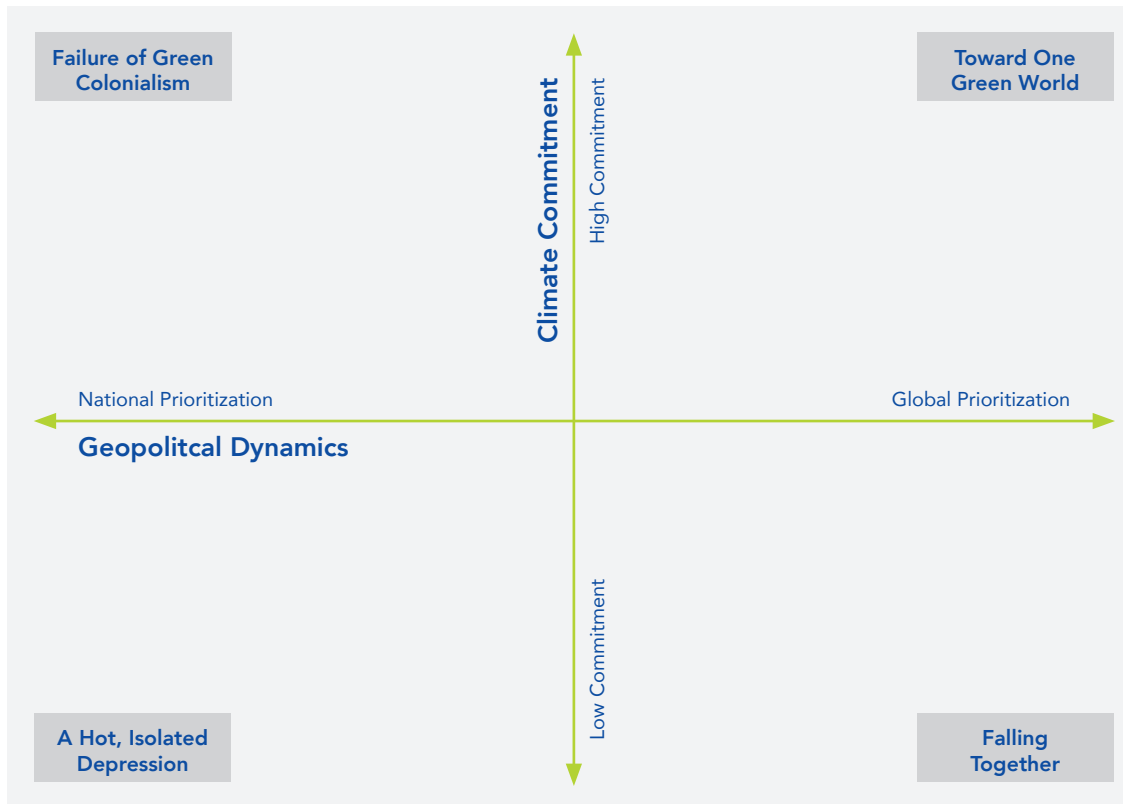
The two key drivers and their outcomes create a scenario matrix. Each key driver represents one of the axes, with the bipolar outcomes on both ends. All four scenarios are based on the extreme outcomes of the two key drivers. Other important drivers are also considered with plausible and consistent outcomes in each scenario.

“Toward One Green World” shows a possible future where most people are committed to climate action in their everyday life as well as political participation. The geopolitical landscape is highly cooperative and supranational organizations like the UN, or the EU have additional competencies such as managing CO2 budgets. While the climate crisis is mostly under control, other challenges like increased surveillance or people being dissatisfied with the restricted lifestyle arise.

“Failure of Green Colonialism” describes a scenario in which individuals display a high commitment to climate action while nations only focus on themselves. Political coordination between countries only occur if there is clear mutual benefit. The democracies in the global north have been able to tackle their environmental objectives due to government action and societal engagement for now. However, the global south has accepted high emissions to make progress, accelerating global warming. The world’s population has started to notice these consequences, causing widespread civil unrest.

“A Hot, Isolated Depression” follows a protagonist through the grim reality in the year 2042. For years, countries have prioritized their own interests, and people have long since lost hope in successfully reversing climate change. Rebecca’s life has drastically changed since her unconcerned childhood – extreme weather events and climate adaptation measures are the new normal. During one of many heat waves, Rebecca is trying to cope with the various consequences of humankind’s disastrous inaction and turns towards her single biggest priority, her family.

“Falling Together” describes a world that is unified and connected yet driven by mass consumption not addressing



climate change. Through global cooperation, peace has spread across most parts of the world and people have unseen opportunities to work and live across the world. However,

due to the unsustainable consumption, the impact of climate change with rising natural disasters is heavily influencing the daily life of people.

TOWARD ONE GREEN WORLD

A Day in 2042

“Good morning, honey!” Mira wakes up to these lovely words and turns to look into a smiling face. She knew Kim since high school and they just moved together to the green town of Weyarn, one of the emerging carbon-zero community villages just outside of Munich. She stands up to take a quick look at the red sunrise out of the panorama window and notices the dimming street lights controlled by the smart grid system. “You wanna join me for a shower?” she turns around and looks at Kim. “Not today. I will support a climate initiative of students in Chile this morning.”

As Mira enters the shower, she sets the water on cold and instantly feels a vibration on her wrist. “You just gained two carbon credits for saving on warm water”, her smart carbon watch prompts the good news. A smile wanders across her lips. She is proud that she gets along so well with her carbon credits since she decided to cut back on the energy consumption in her daily life. After the shower, she puts on an elegant blazer made of recycled plastic yarn and walks over to the kitchen to prepare breakfast. She opens the fridge and gets out her customized granola, curated by her smart assistant to suit her exact daily calorie needs. Sometimes she thinks back to the avocado toast she always used to have when she was still free to choose what to have for breakfast. On the one hand, she misses the subtle buttery taste, but on the other hand, she would feel irresponsible for consuming a product so harmful to the climate. As she grabs her laptop and gets ready to leave, she hears Kim’s voice through the hallway: “Lots of luck, darling, you will rock today!” She leaves the house and takes a deep breath of the fresh air outside with a feeling of confidence.

Mira turns around, looking at the green facade of their penthouse apartment before heading toward the hyperloop station. At the terminal, she walks straight to the platform where the pod toward Maastricht is already waiting. The door slides open smoothly after scanning her



face. The carbon watch vibrates gently, acknowledging that the payment of carbon credits was successful. Mira looks at her budget and realizes that the price must have increased again. Angrily, she thinks that one day the hyperloop will only be affordable for the privileged.

After making herself comfortable, the display in front of her seat turns on, showing the headline from the highly renowned founder magazine Shapers: “WastR in talks with investors for going global.” A feeling of pride overcomes her: all the time and hard work during the last years she has put into her company WastR is finally starting to pay off.

After the Circular Economy Act was adopted ten years ago, the Western world decided to commit to importing waste from developing countries, helping them to improve their living standards and slowly turn green. Mira recognized the opportunity and started WastR, a company specializing in separating and extracting scarce resources from waste.

As the company has proven successful in Europe, investors from the UN invited her for a meeting to discuss strategies to scale globally. While thinking about the investor meeting today, Mira has mixed feelings. She is excited but also a bit nervous about the chance to make the world even greener.

While approaching Maastricht, she looks out the window into the deep blue ocean next to the city. Years ago, the area north of Maastricht, where the rest of the Netherlands used to be, was swallowed by the rising sea levels. After arriving, Mira walks down the promenade and watches how gigantic hydrogen-fueled ships loaded with waste from Africa are approaching the harbor. She enters WastR's large modern office, where her secretary awaits her with a freshly prepared oat-milk cappuccino and notes for the upcoming meeting with the UN representative. Lost in thought on how she wants to structure the pitch storyline, her secretary enters the room: "Mira, he is waiting for you in the conference room." Unsure about her feelings about the upcoming meeting, she pulls herself together briefly and walks through the door. "Welcome, Mr. Olivio! Nice to meet you. I hope you found your way here well." "Thanks a lot, Mira. I am very impressed by your resource separation technology and how precisely your robots can take apart electronic waste." "Yes, indeed! But that's not our work alone, we are collaborating with a wide range of research institutes all across Europe and Africa and utilize the computer vision algorithms developed at the TUM facilities in Nigeria." – "That sounds fantastic. We are always thrilled to hear about global collaboration. As you might have guessed, we see WastR becoming a crucial player in the global resource ecosystem. Therefore, there is an increasing public interest in making it an UN-owned company. Are you open to discuss on that?"

Later that day, Mira heads home. In the hyperloop pod, she puts on her VR goggles to enter THE SPHERE. After the virtual world finishes loading, she quickly looks at her watch. She is late. Hurrying into the Countrymen Cow Club, she notices an old man sitting in the far corner of the dark and smokey place. "He is withering away", Mira reflects, approaching the table. "I got us two rib-eye steaks with guacamole n' some of that good ol' whiskey", he murmurs. "How are you?" Mira asks. "Seriously? Look at this shitty new world. It's not like in the ol' days anymore when we went on a ride around the city with the biker gang. All of this new and so fancy climate tech and big-brother bullshit." – "But Dad!.." Reinhold starts munching. Blood is running down the silver knife. Mira is not hungry. "This climate dictatorship dominates our life." he continues, "I want my freedom back!" "But dad!" Mira argues, "can't you see what we have achieved with this already? I know living today might be challenging from time to time, but we are saving our planet, animals from extinction, and

humanity." Reinhold sighs. "How many coins do you have left?" Mira asks with a shallow voice. Silence. "Oh, dad!" she shouts, "both of us know what will happen if you end up below zero! Don't do that to me!" Nothing. The sound of a completed coin transaction interrupts the noise of the frying pan in the background. "Thanks." Mira pulls off the VR headset. Her pod just arrived at Weyarn Central Station.

The sky was ablaze by the fire of the setting sun. Mira is looking forward to dinner as she hails a hydrogen-fueled air taxi. Minutes pass, and the jet silently descends to pick her up. When she arrives at the restaurant, Mira sees Kim draped beautifully in a sleek dress made out of pineapple leaf fiber. As Kim pecks Mira on the cheek, Mira breaks the big news about the government investment in WastR.

"We make such a great couple", Kim says proudly. She works at the UN, which is growing in power to enforce climate laws and introduce a global GHG emissions market. With companies like WastR collaborating with the government, the circular resource flow is now flourishing globally. She smiles, knowing that if there are even more businesses like Mira's, slowly but surely, all countries will reach the UN's sustainability goal of spending 2% of their GDP on climate action.

Kim tops Mira with an even bigger announcement: "You know that project I've been working on? I'm writing a blockchain smart contract for the UN!" Mira nods in disbelief and tries to digest what she's hearing. Kim explains further, "This is big. The Decentralized Autonomous



Towards One Green World

Organization, known as the UN DAO, is gonna be wild. It will let countries vote with their carbon budget so that people that act greener have more voting power. UN officials then no longer influence decisions any more than individual people!”

While Mira and Kim reminisce on their eventful day, they stroll out of the restaurant. They are greeted by a blanket of stars and the crescent moon that lights up the night.

When the two first met, they could not see such a clear sky due to the horrid pollution. Now everything seems a lot greener as all countries are on track toward net-zero emissions. The Earth is better now than ever before as Kim and Mira move toward one green world.



Signposts

- 40% of EU citizens follow a vegetarian diet, and only the minority eats meat more than once a week.
- Fridays for Future, Extinction Rebellion, and other climate action movements reach 50m supporters on all continents.
- The UN uses its new competencies in climate politics to introduce a global GHG emissions market, consolidating existing local markets like the EU-ETS as well as voluntary markets.
- A standardized CO2-Budget per person is introduced by the UN. People with a low carbon footprint can earn an extra income by selling their excess certificates on a global marketplace.
- All EU countries are led by green party governments, and a pan-European green party coalition is leading the EU.
- The UNASUR (Union of South American Nations) states form an economic and monetary union with a shared currency.
- The AU and the EU establish a climate action agreement.
- EU countries import more waste than they export for the first time as they move towards a more circular economy.
- As a joined global initiative, all UN countries commit 2% of their GDP towards climate action.
- The global CO2 emissions are below 30Gt per year for the first time since they surpassed it in 2005

FAILURE OF GREEN COLONIALISM

A Day in 2042

It is a big day today: The Exclusive EU (XEU), consisting of Europe's five strongest economies, is about to announce its strategy to reach carbon neutrality five years ahead of the original date set in the former Green Deal. Tina, a 28-year-old greenfluencer from Munich, is following the news closely. She and her 23 million followers are gathered in a metastream, reminiscing about how just 13 years ago, this goal seemed far-fetched at best. Today, it seems entirely possible, thanks to the green government's effort to push renewable energies and the US-XEU AI-driven weather machine for climate adaptation.

The conference begins, and all 90 million Germans are watching. Chancellor Robert Habeck gets on stage, and the viewers spam his usual slogan: Green Germany First. He is joined by the Chief Climate Officer (CCO) of Solar, the first German energy company to make it into the Green Unicorn Index (GUX). "What an amazing company! I would love to work there one day!" Tina posts to the chat as their CCO announces that Solar has acquired 80% of the XEU's energy market share after they patented their high-efficiency photovoltaics and opened five new plants in sub-Saharan Africa. Another comment in the chat catches Tina's attention: "Isn't Solar essentially colonizing developing countries and exploiting their workers and land?" She has had this discussion plenty of times in the past and calmly explains the term "Green Colonialism" to her followers. Many politicians and greenfluencers – Tina included – believe that the responsibility of solving the climate crisis lies squarely in the hands of the developed nations that have access to the necessary technology and infrastructure, even if progress comes at the expense of developing countries. "They don't emit as much anyway", she replies. This idea is backed by the fact that the XEU has been continuously hitting its emission targets, Germany has been transitioning to a circular economy, and national carbon markets have been performing well in the Exclusive EU. Just



as she explains this, another comment comes in: "But why are temperatures still ris..."

Her phone starts ringing, and Tina wakes up. It's her boss from Solar calling. The conference she dreamed about was seven years ago, and things have changed. She looks at the clock with a groan – it's 5:45 a.m. She picks up the phone, mentally preparing for what comes next. "Tina! Hurry up, it's important! We need to meet at the office in 10 minutes! Something important has happened!" Tina's stomach drops, and thinks to herself: "Oh, Mama!" Going downstairs, she picks up her VR glasses and logs into the metaverse.

Her whole team is already logged on, sitting around their big conference table and waiting for her.

Tina's boss looks tense but immediately starts speaking to the meeting attendees: "You all know how fast things have been evolving the past few months...we have known for quite some time about difficulties with our contractors, but the situation has suddenly worsened. The countries we have been producing our energy in have stopped accepting our business conditions, and last night they collectively used military force to take control of our power lines. We have already talked to the other XEU branches, and no one saw

Failure of Green Colonialism

this coming. I believe energy farm countries barely have the necessary infrastructure to survive, let alone the knowledge and technology to manage our plants. The technology they are used to is carbon positive. Their emissions are comparable to India 20 years ago! They need us!" her boss exclaims. "Now the UK is worried that their contractors will also take over. We expect massive layoffs and maybe even shutdowns. I'll keep you updated on this ongoing and critical situation. I'm sorry."

Tina cannot grasp what just happened. She had seen what was happening on the news, but she would never have expected her job to be in danger. After all, Solar never meant to exploit any sub-Saharan countries – they were doing something positive: saving everyone from the climate crisis! She logs out of the metaverse, feeling a bit paralyzed. "About time I meet Maja for lunch", Tina thinks. "I seriously need to talk to someone now."

Arriving at the restaurant, Maja is waiting for her at a table in the corner. "I already ordered the usual. They said something about a change in the dressing, though, so we should scan the dish just to be sure". Tina smiles. She loves that nowadays, everyone is so focused on ensuring that the products she eats are truly sustainable through the supply chain. Three years ago, when the smart glass feature that offered consumers the possibility to scan and thus track emissions of grocery store products and restaurant dishes were announced, Maja and Tina were the first to buy and download it for their glasses. A few years ago, the two met at a conference when Maja had to move to Germany from her hometown Amsterdam. Due to rising sea levels, she simply couldn't continue living there and moved to Munich instead.

"I need to tell you something..." Tina starts, spending the next two hours bringing Maja up to speed. "Wow", Maja replies. "Well, it's kind of was to be expected, though, wasn't

it? Those countries canceled multiple contracts with German companies in the last months. Why should they make an exception with Solar? In fact, I read on the news yesterday that Germany already had to minimize the amount of energy that can be exported to the US. The Americans aren't happy and are currently discussing which sanctions they will impose.

Most probably, they will cut Germany or even the whole XEU off from the climate satellite data stream. That would result in a disaster. Without the data, the weather machine would not be able to function properly. Can you imagine living in a city where it's storming or, worse, polluted? Thinking about it, I can kind of understand why Laura got addicted to the metaverse and spends literally all her time there. With things going sideways, virtual reality might be the best reality we have." Tina shivers. She cannot imagine spending her whole life in the metaverse. It completely contradicts her guiding belief of being one with nature. "Thinking about it that way, it would probably make the most sense to get out of here as fast as possible", Maja continues. "Thinking about development, we should probably go to Congo, right? Aren't they an up-and-coming country, especially with their plentiful resources?" "We should hurry though with our visa application then. I just went to the embassy and tried to get one for France. Even that takes 4-6 weeks despite them being in the XEU!" Tina pushes her quinoa burger away. "Ugh, I'm not hungry anymore. I'm going to call a robotaxi."

Tina has a 30-minute ride ahead of her, even with the streamlined traffic patterns made possible by autonomous vehicles. She tries to stare aimlessly out the window when something catches her attention: a large group of people dressed in all black, walking toward the city center. "What's going on?" she asks the taxi supervisor. "Haven't you heard?" He says, "There's a demonstration today against Germany's continued policies of Green Colonialism. Hundreds of activists are saying we made the climate crisis that much worse and are now even going to the streets. I haven't seen an in-person riot in years." Tina hears a loud crash a few dozen meters away, followed by the smell of smoke. "Don't worry. I'll instruct the taxi's algorithm to drive faster. You'll be home safe in no time."

Tina walks down the corridor of her apartment building, and her face recognition door swings open in anticipation of her arrival. Gaia, her smart home assistant, greets her by name. It feels good to be cared for after the day she's just had. She thinks back to the good old days and recalls fondly the

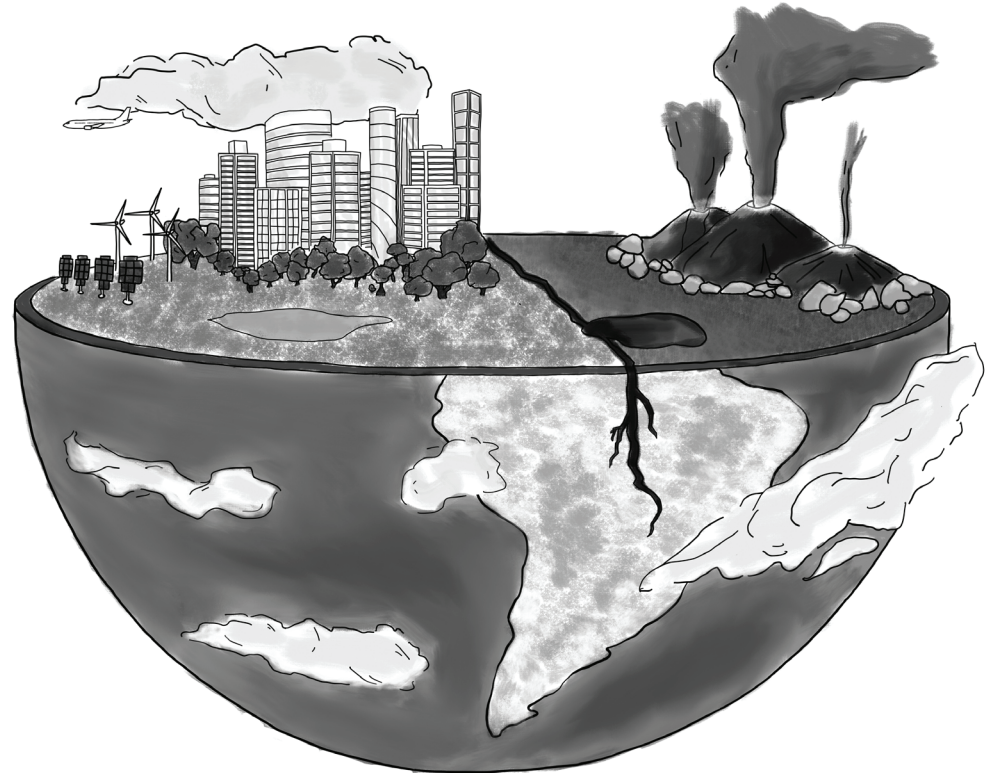


Failure of Green Colonialism

personal commitment people made to tackle climate change. The German national policies seemed to genuinely foster a better world. But she suddenly wonders if maybe things were not as good as she thought. Had life in the German green bubble prevented her from seeing the truth? The past 20 years, had it really been one for all or just all for some?

Signposts

- Fridays for Future movement reaches 20m followers.
- Major changes for EU companies: Price over Carbon (PC) becomes the most important valuation criteria. Also, an obligatory Chief Climate Officer is introduced.
- EU Free Trade Agreements are amended and the XEU (Exclusive EU) is established, only including Europe's five strongest economies.
- NATO & UN are dissolved.
- The Green Olympics, a competition for sustainable nations, starts only China, the US, and the XEU participate.
- "Carbon Polarisation – Europe on track to be carbon neutral while a new industrial revolution skyrockets emissions in Africa".
- XEU-US cooperation develops a "nice weather machine" heavily relying on AI.
- XEU reaches net-zero 10 years ahead of time.
- Global temperature rises and hits 1.5°C. Amsterdam and other cities have become uninhabitable.
- The Republic of Congo, Brazil, and Kazakhstan end resource trading with XEU countries.



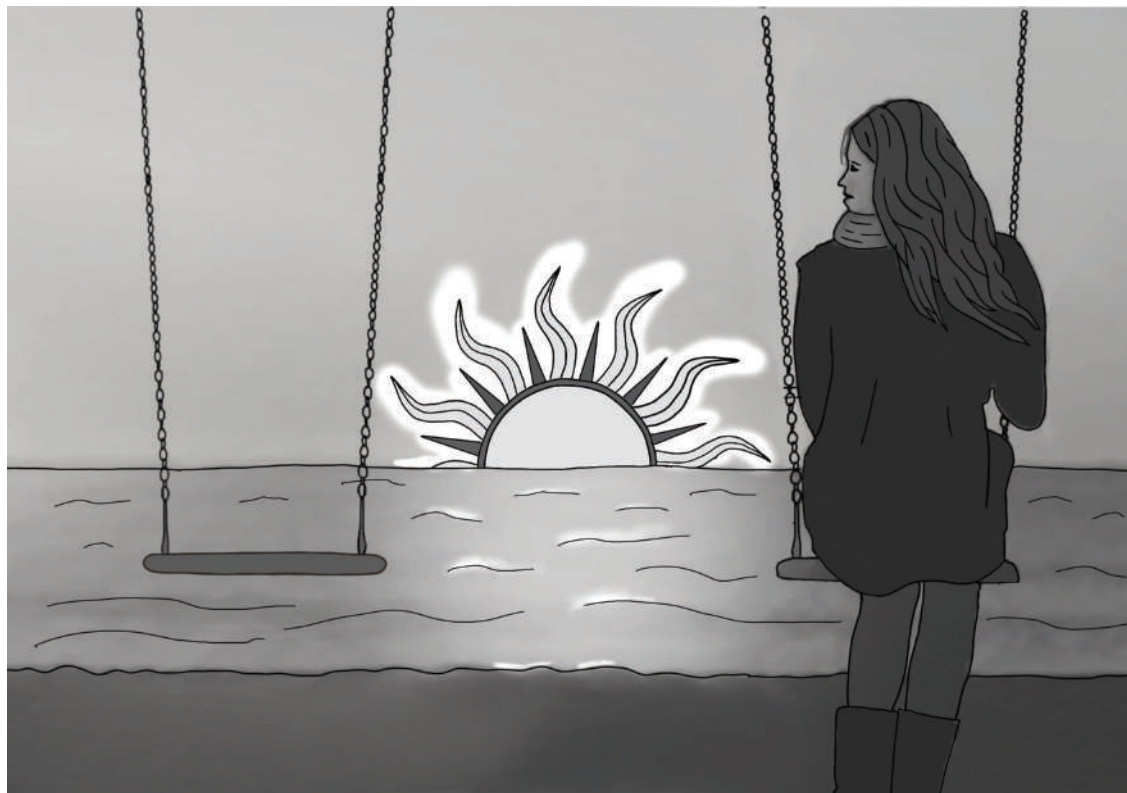
A HOT, ISOLATED DEPRESSION

A Day in 2042

Shortly after the sun hits Rebecca's face, she wakes up from the heat on her skin. Even though the air conditioning was running all night, it could not combat the heatwave outside. She turns around and makes a sluggish hand movement toward her smart alarm. The news headline "10th anniversary of the dissolution of the Paris Agreement – a reflection" is projected on the wall. Rebecca is annoyed by the reminder of the past. Back then, countries moved away from international collaboration, and organizations like Fridays for Future stopped protesting after scientists published the unlikelihood of saving the earth from human-made global warming. That was also when Rebecca lost all hope to solve the climate crisis in time. Today, her main life goal is to cope with the quickly changing conditions and take care of her loved ones. Luckily, Rebecca lives in a relatively wealthy country with access to climate adaptation technology. The early AI-based predictions about the current heatwave and swift adjustment of the energy system to avoid blackouts like in earlier years worked well this time.

She walks into the kitchen of her apartment. Rebecca and her family live in an old building block, which is in desperate need of a climate-adjusted renovation – two ACs are defective, making those areas barely habitable. Due to a significant increase in energy prices, the family had to leave their house in a better neighborhood.

Her 12-year-old son is sitting on the table passively watching the last five minutes of the daily therapy session, which now commences virtual school every day. Triggered by the increased suicide rate of climate-depressed teenagers, the government made preventive mental health sessions mandatory. Rebecca's 80-year-old mother, living with the family, is struggling with dust in her lungs after living in a highly polluted city for many years. Due to the collapse of the pension system in 2035, they could not afford a retirement



home and professional care for her. Rebecca is usually supported by her husband, who also lives in the apartment. However, in the last months, like many men, he has been mandated to support the Climate Response Force in building a big new dam in the Baltic Sea to prevent flooding.

In the past, Rebecca would head toward her work after breakfast. However, like many people in the current economic depression, she lost her job. After the government revoked the ban on combustion engines due to drastic resource scarcity, the electric vehicle sector collapsed. Rebecca is angry every time she thinks about it, but so are many of her friends who have been working in the tech industry. Most

multinational companies went into bankruptcy due to high import tariffs or were disintegrated by self-serving regulators.

Today, Rebecca rushes to catch the cheap, old autonomous bus heading to the supermarket. While the ride was not very pleasant, at least it did not break down this time. She immediately heads into the air-conditioned building. For a second, she considers ordering her groceries via drone delivery next time but quickly remembers her tight budget. Her gaze hits the locked glass cabinet with avocados and mangos in the fruit section – more a display of luxury than an actual offering to her, as only the richest can still afford them. A bitter smile appears on her face as she thinks back

A Hot, Isolated Depression

to the days of her childhood when local products were sometimes even more expensive than the cheaply imported goods from all over the world. Nowadays, tariffs and the horrible situation in many former exporting countries in the south drive the prices through the ceiling. She looks through the shelves of genetically modified and domestically grown fruits and vegetables and finally decides to get some non-genetically modified apples for her beloved son. They were probably cultivated on an air-conditioned vertical farm. The usual climate outside has proven increasingly hostile to most unmodified domestic plants. She further picks up some deep-frozen tuna pizzas – of course not with real, extinct tuna, but with a tuna-flavored substitute. On the way, she passes the phone charging stations that the supermarket offers to attract customers. Some people come here during the blackouts, as the quantum-powered AI managing the unstable electricity grid prioritizes system-relevant buildings like supermarkets. Finally, in the pharmacy section of the supermarket, she gets two boxes of antidepressants and new face masks against the high air pollution. At the checkout, she sighs when she remembers that many people now spend more than sixty percent of their income on food, and the increasing inflation is not improving the situation either. Nowadays, only people earning way above average can afford the carefree, consuming lifestyle she got used to as a teenager and had therefore long seen as usual. As the checkout queue is not moving forward, she decides to pick up two more packs of toilet paper before the price increases again.

Back at home, Rebecca's smartphone starts ringing. iPhones became too expensive after the tariffs were introduced but selling her data to the domestic phone producer earns her a bit of money every month. Her cousin Dave is calling. Decades ago, Dave and his family moved to Ghana for business, but he cannot come back home due to the tight visa restrictions against climate refugees. In the past, Rebecca and Dave chatted every couple of weeks about life and how their kids were doing. But for years now, she was primarily concerned with checking they were alive. Dave tells her about his situation in Ghana. He could not shower for three days because the government rationalized water usage. Ghana's water availability is forecasted to decrease by 70% until 2080, which Dave says justifies the measures. Many of Dave's friends fight hunger because of the crop losses on the dried-out fields. Dave is lucky. He used to work as a strategist for a multinational steel corporation. However, after the company had to close operations in Ghana due to



regulatory restrictions, he had to find work elsewhere. After years of struggling to stay afloat through day jobs and some money sent by Rebecca via crypto networks, he is now working 14 hours a day in a lithium mine owned by a Chinese car manufacturer. Every day, colleagues collapse at work due to the unbearable heat – the number of heat-related deaths has increased by a factor of 4 in the last decades. As usual, Rebecca ends the call, wishing him “good luck.”

Exhausted from the day, Rebecca sinks down on her couch, where her mother is already waiting for her, coughing heavily. Although she does not expect anything to lift her up, Rebecca turns on the 8 p.m. news. It's a habit that has prevailed in the family for decades. Due to the perfect deep fake technology and data coming from biased AI algorithms, she knows that the news is not always real, but she watches it anyway. Rebecca is relieved that the news about the EU

break-up faded in the past few days. Of course, she is sad about the failure of this utopian project, but everybody saw it coming. Especially after the highly praised Emission Trading System failed embarrassingly, and three countries followed the UK to leave the alliance.

The news anchor announces that the national health insurances finally recognize climate depression as an illness—which is coming late, considering how many people are already unable to work today. The following section is about a big tech company that stopped its research program into carbon capture technologies – a lot of people had high hopes for it in the 2020s, but ultimately it proved infeasible. Finally, there is some good news for the economy: a manufacturer of autonomous weapon systems had record sales in the last quarter. The police use armed drones to crack down on environmental extremists and apocalyptic religious cults.

A Hot, Isolated Depression

Rebecca turns off the TV and wonders: Maybe the researchers who flew toward Mars five years ago will finally send the signal for us to follow them into a new, better future. Until then, Rebecca will keep avoiding the usage of plastic straws to do her part.

Signposts

- The majority of scientists agree that runaway climate change cannot be stopped anymore. They recommend undertaking climate adaptation measures.
- The electric vehicle industry collapses and millions of people are unemployed. The reasons for that are resource scarcity, high tariffs on lithium and missing charging infrastructure.
- Annual inflation rates hit two digits. The government lifts taxes on fossil fuels and allows fracking in Germany, shifting the balance even further away from green investments.
- The German right-wing chancellor decides to close borders to climate refugees.
- The national consumer protection agency concludes that more than 60% of food products consist of genetically modified organisms.
- Google is split up and nationalized due to drastically increasing protectionist regulations. This also reflects a trend away from global solutions to local data silos.
- After a series of disagreements among nations, the severe conflicts about climate refugees and climate mitigation resulted in the EU being dissolved.
- Climate depression is officially recognized as an illness by national insurance companies, affecting a half of the population.
- The German government agreed to spend 50,000BTC on nuclear weapons to compete in the international arms race.
- China occupies the Democratic Republic of the Congo. General resource scarcity is the trigger for an autonomous drone war over resources.



FALLING TOGETHER

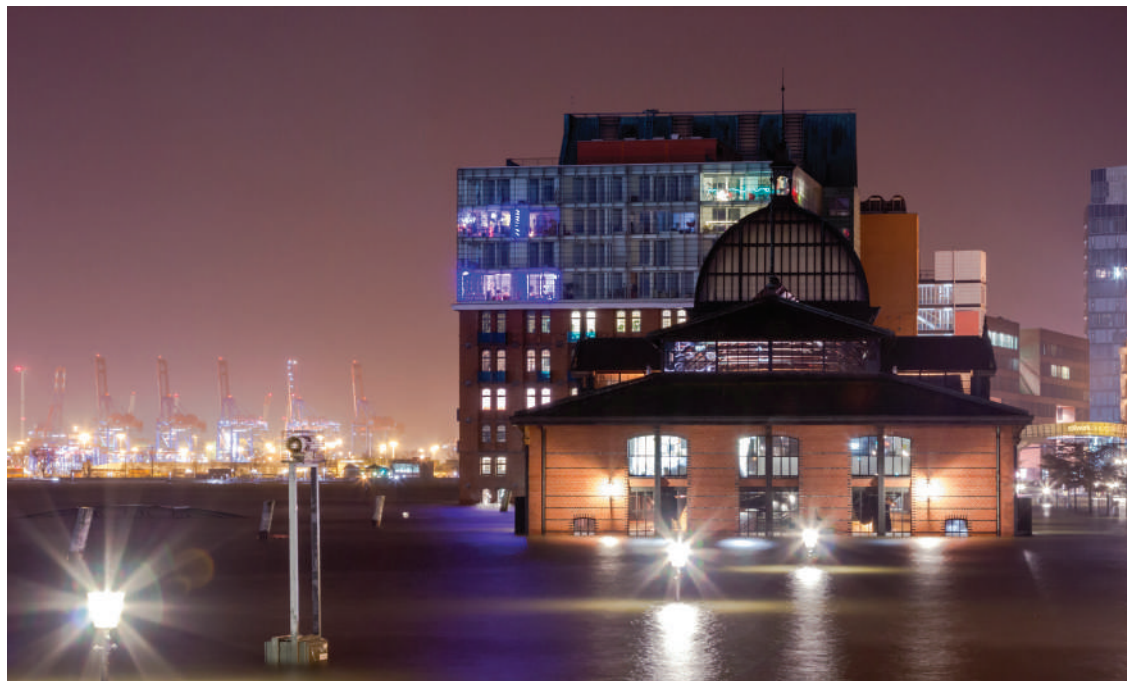
A Day in 2042

The gloomy sun slowly rises over the Elbphilharmonie and breaks through heavy clouds into Akila's room, softly waking her up.

Still astonished from seeing the first sun rays after such a long time, she hears a known voice coming out of the stereo system. "Good morning! How are you feeling this morning? Would you first like to hear about your sleep statistics or today's news? Is there something I can already organize for you?" "Good morning, Sunny", says Akila to her personal assistant system, "first the news, please." – "Let's start locally. Germany just announced the transfer of its national army to the United Nations Forces. On the global level, the top tech leaders announced another gigantic solar farm in the Sahel region which will further decrease the cost of electricity." The stereo system keeps telling the news while Akila gets out of bed and gets ready to start the day. "Alright, Sunny, what is the plan for today?" – "You have exactly 43 minutes before the first meeting", responds Akila's virtual assistant", then..."

Sunny continues planning while Akila gets ready to start the day. Sunny continues: "Your fridge is running out of food. I made you a list of groceries that can be delivered at lunchtime today." She looks over the list suddenly appearing on the first TV screen: Only 17 Union coins for a week's food supply! Ever since the global currency has been adopted, shopping has become even cheaper. Systems like her personal assistant always check grocery providers for the best prices leading to a price decay. Sunny jumps in again: "Only 10 more minutes until the first meeting. The meeting notes are already up to date!" Akila would probably be lost if she was going through life without the personal assistant that handles all her virtual belongings, home apps, and interactions with the world. It takes care of her appointments, places orders, and controls a home cooling system that ensures clean air and social apps.

The hologram call starts and Akila sees her colleagues from the United Nations Disaster Insurance Organization (UNDIO) appearing one by one. Akila struggled a lot to find a way to help others and find meaning in working for large monopolists



that dominate today's job market. Throughout her childhood, she had heard stories about how in the past, machine learning algorithms and satellite imagery were not only used for making human life more convenient but also to predict and monitor wildfires, pollution, deforestation, and much more. However, with a global organization such as UNDIO, she finally feels like she is doing something significant and redeems a strange missing part in her. UNDIO is a global organization funded by taxpayers, basically every citizen of planet Earth. It supports people in recovering from natural disasters, for example, when their housing is destroyed due to bad weather conditions or when their area becomes uninhabitable.

"Hey, how is it going?" Akila asks in Arabic, her mother tongue. In new communication systems, a speech recognition system processes the voice data in real-time. Such that working with people from other parts of the world becomes even easier.

"I'm good, thanks! What time is it in Hamburg?" her colleague from India answers in Hindi. After all colleagues have dialed in, they start discussing the new strategy of UNDIO. As local governments lost their regulatory power after people became more self-centered and interested only in boosting their virtual social score, UNDIO plays a crucial role in ensuring economic and social stability and security of essential resources.

As many regions of the planet became or are increasingly becoming uninhabitable due to extreme droughts, floods and wildfires, UNDIO launched the UNDIO Relocate program to help people move to other, safer places on the planet. However, as such events are becoming more frequent, the costs of running the program are skyrocketing. UNDIO must consider more cost-efficient ways of ensuring people can still work to contribute to the global economy and enjoy the benefits of the meta world. Akila proposes investing in

Falling Together

huge research projects for synthetic food production, which Sunny informed her about the other day. Apparently, the global population will reach 10bn people by 2050 and at this consumption rate, the food production system cannot cope with demand. Already 90% of the world's fertile land is used for food production and a steady decrease in soil fertility worldwide. Akila talks about in-vitro meat and presents old research papers about vertical farming. The research had been conducted in the sustainability wave in the 2020s, but people turned out to be unwilling to pay the premiums for green products. However, they could now become

relevant again as the world population is faced with a rapidly growing famine.

A well-known squeaky noise interrupts the discussion. Push notification of the UNDIO app covers the screen of Akila's personal device with the headline "Extreme floods will hit Hamburg within 5 hours. Relocation planning loading..." A few seconds later, a new message appears. "The quadrocopter will be ready for take-off at the hub of your building in 30 minutes. Press the Connect button to access the UNDIO support team." "Alright, it seems like a few of you will have to relocate today.

"Shall we postpone our discussion?" the boss asks to break the silence. "No need, actually, we have quite some time. Let's finish off this topic first", answers another colleague who also lives near Hamburg. New notifications keep popping up, giving more details about the new relocation process. Ever since floods and other extreme weather conditions became a regular occurrence, the world got used to life on the go. Especially those born after the 2020s do not have trouble keeping up with life within four walls with remote education, work, friendships, and virtual systems controlling all the intelligent home devices that replicate utopian conditions. Akila mutes the notifications and decides to focus on the meeting.



After finishing the meeting, Akila packs her bags and makes sure that she has all the important things for her move to Munich, the new location suggested by UNDIO Relocate. She thinks of her first relocation: Three years ago, Akila already had to leave her home country of Egypt. It felt so paradoxical - the global trade system and cooperation had led to developing countries closing the gap with western countries. Shortly thereafter, the effects of climate change made the region uninhabitable. Through her first relocation, UNDIO gave her the chance to find meaningful work. Fortunately, with the opening of the markets and increased cooperation across countries, it has become less complicated to migrate across the globe and settle anywhere. She had hoped that Hamburg would remain safe for a little longer, but floods had already become common within the last months leading to Akila mentally preparing for another relocation.

Sitting on her packed bags, Akila quickly grabs a bite to eat and takes a brief look over her apartment. She hasn't seen much of Hamburg over the past years as air pollution is at a dangerous level, but air machines that create a fresh air feeling. Air machines combine filters and humidifiers with natural scents, making Akila's life a lot easier. She begins to imagine a new life in Munich when a new notification pops up: The autonomous air taxi arrives to pick up Akila. After reaching 200 meters of altitude, she can see the Elbe River quite well, which has changed a lot in the last few months and is now as wide as the Amazon River. She notices the engine noise slowly changing in frequency and getting louder. Apparently, the air taxi transitions from take-off to high-speed travel and accelerates to 500 km/h. Next to Akila, an old man with horn-rimmed glasses has opened a holo-book and is reading about how China has completely opened its economy to the international public. The opening of China and the fall of the

Falling Together

regime in Russia after the Ukrainian war had been key drivers on the way toward global cooperation and the possibility of strong international networks like UNDIO.

Upon her arrival in Munich, she is eager to get to know other people in Munich. Luckily, UNDIO organizes so-called “welcome dinners” with other refugees and locals. Since people started collaborating globally, they have become more open to different cultures, and discrimination related to ethnicity has increased. During dinner, Akila meets people from other parts of Germany and people from the global south who arrived in Munich throughout the last few days. Having conversations with these new people is easy, as AI-driven translation services are also helping in the offline setting.

After a long day, Akila heads home to get some rest and she is happy to see that her bed and furniture have already arrived in her new flat. After brushing her teeth and hearing the latest news about Hamburg from Sunny, she falls asleep.

Signposts

- Solar and wind energy surpassed 50% share of global electricity due to its cost efficiency, replacing fossil fuels.
- The EU-ETS was dismantled after rising prices led to a recession.
- A global free trade treaty was ratified.
- Yearly global GHG emissions surpassed 45bn tons in CO2 equivalents due to the rise of the global south.
- The last island of the Maldives disappeared due to rising sea levels.
- The United Nations Disaster Insurance Organization (UNDIO) was founded as a specialized agency of the UN.
- Global warming surpassed 2°C compared to pre-industrial levels.
- One billion people migrated due to the effects of climate change.
- The majority of countries adopt one global currency.



IDEATION

The following chapter describes five novel business models in the field of tackling climate change in the AI era. Each of the business models is described using the Osterwalder Business Model Canvas.

TEAM 1
CITYTWIN.AI67

TEAM 4
VERDEO91

TEAM 2
MEAT.AI75

TEAM 5
REDROP99

TEAM 3
SAVEVA83

CITYTWIN.AI

Empowering Urban Planners to Improve the City Climate Using Digital Twins

Regardless of where you live in Germany, citizens all have one thing in common: Infrastructure and society heavily affect every person's daily life (and climate impact). As you move through a city or village, you are indirectly impacted by urban planning policies. Climate change is an ever more pressing matter. As seen by the 2021 flood in the Ahr Valley, infrastructure needs to adapt to effectively keep citizens safe and happy but there is a high need for a solution to help citizens and governments make these plans. Microclimates in cities are especially influenced by urban planning: On an average summer night, Maxvorstadt is a lot hotter than the English Garden. After a hot summer day, buildings radiate heat and thus increase the temperature at night.

CityTwin.ai offers an all-in-one solution to evaluate urban development concepts, emphasizing the city climate. The product first creates a digital twin with the help of AI.

Then the algorithms empower urban planners to make informed decisions: They can discover opportunities for emission reduction and evaluate options for climate adaptation. CityTwin.ai aims to eliminate decision uncertainty by making it clear and quantifiable what impact specific policies or buildings would have on the climate of a locale. This helps users iterate more quickly between ideas, allowing for more effective policymaking with less risky implementation. The product can be used both in small contexts, such as the impact of a park on an area's microclimate, and at a large-scale, e.g. redeveloping all old buildings in a city.

CityTwin.ai has more than just benefits for local governments; CityTwin.ai's platform provides increased transparency for other relevant stakeholders (such as citizens), allowing for universally higher buy-in on various green policies. CityTwin.ai believes that on top of assisting with urban



planning, CityTwin.ai can be used powerfully to increase social support for effective green policies if the data behind specific green policies is released. This will ultimately further aid in combating climate change.

CityTwin.ai is the digital twin solution that empowers urban planners to improve the city climate.

Business Model

 Key Partners

- City departments
- Game engine companies
- Pilot customers
- Network of climate experts
- Connections with local politicians and lobbyists

 Key Activities

- Creating the digital twin
- Using the digital twin to make informed decisions
- Expert consulting service

 Value Proposition

- Help cities struggling to create digital twins:
- Facilitate the expensive, and complex process
- Develop models that can be used for several applications and not only for climate modeling
- How the city climate changes without intervention
- Which intervention and measures are most effective
- Model all aspects

 Customer Relationships

- Personalized onboarding
- High level of software service:
- Personal customer service
- Consulting as an option

 Customer Segments

- City planners
- Architecture offices
- Regional and national governments
- Large construction companies

 Key Resources

- Urban data
- Simulation algorithms
- Digital infrastructure
- Developers and consultants

 Channels

- Offline channels such as trade fairs and conferences
- Online channels such as a web application

 Cost Structure

Initial investments

- Developing the algorithms
- Data acquisition

Fixed costs

- Research and development costs
- Employees
- Office
- Marketing

Variable costs

- Data storage and acquisition
- Data scientists for consulting

 Revenue Streams

- Basic services, implementation and setup fees
- On-demand services, higher-fidelity simulation and interpretation support

 Eco-Social Costs

- Cost in energy usage
- Cost in terms of privacy

 Eco-Social Benefits

- Climate change mitigation and adaptation
- More transparent and effective urban planning

Value Proposition

Cities Struggle to Create Digital Twins: City planners need to consider various factors when deciding on new urban development concepts. Currently, this information is hard to obtain. Creating a climate model of a city is complex and expensive. It, therefore, requires significant planning and management overhead. While a few pilot projects have been funded by the Federal Ministry of Internal Affairs (BMI), most cities and rural areas lack the resources and expertise to create such a model.

CityTwin.ai Makes Creating a Digital Twin Easy: CityTwin.ai allows public administrations to evaluate urban development concepts without in-house modeling and climate expertise. The customers of CityTwin.ai provide the data they have, and CityTwin.ai measures the missing information. This data is then used to create a digital twin of the customer's city. Different data sources are merged using AI, leading to a mostly automated process with little manual work. This allows CityTwin.ai to simplify the creation of a digital twin.

The CityTwin Helps in Evaluating Urban Development Concepts: After creating a digital twin with the help of AI, the algorithms allow urban planners to make informed decisions: they can discover opportunities for emission reduction and evaluate options for climate adaptation. With the product, city planners can quickly assess the impact of different measures on the city climate and other relevant metrics, for example, traffic flow. This allows city planners to optimize many things at the same time. Because testing a concept is so easy, it is feasible to evaluate many scenarios. This leads to better policymaking results. In the end, urban planners can confidently make more significant steps toward a better city climate.

Customer Segments

Targeting Customers in the Domain of City Planning: CityTwin.ai's target customers are in the industry of urban and rural planning. One central pain point is data fragmentation, making it challenging to analyze available information as a whole and then deduct measures from it. CityTwin.ai solves this problem by gathering data from scattered sources and integrating it into an all-encompassing model. As city planning is mainly performed by public institutions, these are

the primary target customers, with related companies as a secondary target group.

Urban Planners and Local Government Departments: CityTwin.ai gives urban planners and local government departments the tools to shape the city of the future. Their CityTwin can simulate changes in a city's environment to uncover consequences. Thereby, they can assess how one decision impacts the microclimate in the city and the general impact on the climate and the environment. Furthermore, they can use the model to educate citizens on the actions taking place in their city. This understanding of measures incentivizes people to support the change process.

Architecture Offices: CityTwin.ai's core product is a high-definition simulation of a city; architecture offices can equally profit from it. New regulations and customers' demands drive the need to construct buildings with the highest sustainability standards, including the impact on the city climate. Additionally, visualizing a building in a 3D model shows how it integrates into the vicinity, therefore ensuring that a city's aesthetic is kept.

Regional and National Governments: The force of climate change and its impact propels the transition toward sustainable cities. Governments can therefore evaluate and compare regions on a large scale regarding sustainability.

Large Construction Companies: As the construction industry is a massive contributor to GHG emissions, finding ways of improving the emissions during construction and the emissions of a building over time is inalienable.

Customer Relationships

Personalized Onboarding with Intense Collaboration: CityTwin.ai's customers value the high degree of collaboration as the climate model is built together with CityTwin.ai. This intense collaboration is characterized by high contact during the initial analysis. CityTwin.ai wants to know the purpose of the city's twin and the goals that are to be targeted with it. Additionally, there is an inquiry about the customer's knowledge of handling the model. CityTwin.ai wants every single customer to feel comfortable with the model. Therefore, the model is tailored to the customer's knowledge, so using the model can be a pleasant experience for everyone.

Provision of a City's Individual Twin: In this phase, all relevant data is acquired and then built into the model. The digital twin is shaped until the customers' expectations are entirely fulfilled. With CityTwin.ai's model, customers can efficiently simulate any planned changes in their city.

High Level of Software Service: CityTwin.ai provides a constant software service. If the model does not work correctly, the issue can be resolved quickly. Offering this service makes sure that customers do not have to wait for a long time and can instead work with the model at any point.

Personal Customer Service: Additionally, there is a unique customer service level 1 to level 3. CityTwin.ai's customer service team can assist with content-related questions regarding the model and its usage. This is reinforced through quick access to the exports that will be modeled in the simulation.

Consulting as an Option: CityTwin.ai offers consulting as an add-on service. Customers who wish to get an in-depth analysis of their model and recommendations from climate experts can do so.

Channels

Offline Channels: Due to the complex product and the long lead times until a contract with a government entity is signed, partnerships with CityTwin.ai are concluded exclusively offline. The product is presented and promoted by experienced consultants at trade fairs and conferences. This allows interested institutions to directly get in touch with the product and learn how it can facilitate their urban planning process. In addition, partnerships are established with public administrations and city councils to provide case studies for other interested institutions. Customer acquisition is performed through cold calls with city officials or product demonstrations to politicians. Finally, public tenders present an opportunity for CityTwin.ai to respond to existing demand and offer a product tailored to the needs of its customers. After purchase and during the onboarding phase, multiple onsite workshops will be conducted with the customer to familiarize planners with the tools and support in modeling their first scenarios.

Online Channels: CityTwin.ai's product will be delivered online via a web application available from any device with a strong focus on desktop layouts. One side of the product, the

city modeling and simulation tool will be accessible only to the customer and is protected by a secure multi-level authentication. The other side of the product, the simulation dashboard, can be shared with stakeholders or citizens as a public-facing interactive website to make the impact of a specific change transparent. A city can publish multiple dashboards on different products under their chosen domains.

Key Activities

Creating the Digital Twin: First, the existing data of CityTwin.ai's partners, mainly the city administration, needs to be integrated into the system. This involves finding relevant data and converting it to a format compatible with the proposed solution. Afterward, CityTwin.ai would run an automated analysis to check if all relevant data types (buildings, roads, etc.) are available in sufficient resolution. Otherwise, CityTwin.ai will expand the existing data with additional measurements. Using CityTwin.ai's AI, this data is merged to create a high-fidel-

ity digital twin of the city, which can then be used for further analysis. CityTwin.ai also offers a visualization with which their clients can explore the digital twin using a 3D interface or virtual reality (VR) headsets.

Using the Digital Twin to Make Informed Decisions:

CityTwin.ai's customers can easily manipulate the city in the visualization described above to create different development concepts. Suppose CityTwin.ai's customers want to evaluate the impact of replacing a residential area built in the 1960s. To simulate the effect of such a measure, they would delete it in their digital twin and place new buildings, trees, and parks using the intuitive drag and drop feature. The simulation then evaluates the impact of this urban development concept. CityTwin.ai's customers choose one of the available climate models from academia or CityTwin.ai's own proprietary AI algorithm to model the city climate. CityTwin.ai also offers multiple models for other predictions, such as traffic or public transport usage. Once they have selected the algorithms, the desired fidelity, and the simulation time-

frame, CityTwin.ai's servers will calculate the results. Once the simulation results are available, CityTwin.ai's customers can explore them with the visual interface or export the data using their tools. CityTwin.ai's AI also provides basic recommendations for actions based on the results.

Expert Consulting Service: After reviewing the simulation results, city planners can request an individual consultation with climate experts to get a more in-depth analysis and recommendations for action.

Key Resources

Urban Data: Large amounts of precise data are essential to create the digital twin of an environment. CityTwin.ai fuses multiple sources of information, such as satellite imagery data, geospatial data, and sensor data to create a 3D simulation model. Satellite images of populated areas can be obtained from satellite data providers, such as Up42 or SkyWatch. For even higher-fidelity imagery, drones are deployed locally to map specific areas within a city. Geospatial data can be obtained from city governments, NGOs, or the customers themselves. This includes information on the locations of buildings, the mapping of streets, and geo-positions of recreational facilities. Further, sensor data supply essential information on the current traffic flow and the climate and air quality within a city.

Simulation Algorithms: A team of data scientists develops state-of-the-art modeling algorithms that assess the impact of measures and actions on the ecosystem of a city. The algorithms allow users to simulate scenarios, such as transforming a building into a recreational area and investigating the changes in the city's climate or traffic flow.

Digital Infrastructure: The digital infrastructure is the backbone of CityTwin.ai's product. A lightweight web application architecture is leveraged for the customer-facing product, running on a serverless cloud infrastructure. The compute-intensive city simulations are performed batch-wise on scalable compute clusters leveraging a data lake architecture.

Developers and Consultants: Experienced developers are needed to build CityTwin.ai's core product. On the one hand, software engineers need to build up the infrastructure and web application; on the other hand, data scien-



tists need to develop and integrate simulation algorithms. Further, a team of consultants needs to be built up to support customers during the onboarding phase that can support the modeling of complex scenarios.

Key Partners

City Departments: CityTwin.ai cooperates with city departments to access already existing data sets. This entails development plans for specific areas, waterworks, transport routes as well as current construction plans. Furthermore, available data on greenhouse emissions of buildings and



transportation systems are advantageous as they can then be directly integrated into CityTwin.ai's model.

Game Engine Providers: One of CityTwin.ai's key partners is situated in the domain of gaming design. This could, for example, be Unreal Engine (Unity). Building on existing game engines allows CityTwin to leverage the visual representation of modeled scenarios. As a result, a vivid and exciting simulation of the city is ensured, which can be tailored to incorporate changes and suggestions.

Pilot Customers: As CityTwin.ai proposes a novel city planning solution, working hand-in-hand with pilot customers is essential. CityTwin.ai aims to form close partnerships and directly integrate product feedback and suggestions. Thereby it is validated that once the final product is offered to a wide range of customers, the product suits their needs and demands.

Network of Climate Experts: To leverage the latest models and frameworks from research, CityTwin.ai collaborates with several climate experts. They assure that all ecosystemic dimensions are considered when creating simulations. Furthermore, they can take up consulting roles should a client need expert advice or support.

Connections with Local Politicians and Lobbyists: As CityTwin.ai's product is targeted mainly at the governmental sector, partnerships with city officials play an essential role in the product's success. Therefore, CityTwin.ai focuses on building relations with local politicians and lobbyists to create awareness of the product.

Revenue Streams

CityTwin.ai offers its product based on a typical SaaS pricing model: Cities can acquire the core product for their local area by paying an initial setup fee as well as a yearly base subscription fee with a minimum duration of 5 years. On top of this base subscription, dynamic usage-based fees are levied, which enable cities to add third parties to the platform.

Basic Services: In its most basic form, revenue is generated in the following two ways: After a city decides to buy CityTwin.ai, it has to cover the costs for the data acquisition, setup, simulation, and fine-tuning of their CityTwin. Then it

needs to finance the educational workshops on using the tool as well as a project management fee. After this initial setup, the city will pay a fixed base subscription fee for the maintenance of their CityTwin. In addition, it charges a usage-based, dynamic fee that enables cities to add third parties to the platform, such as architects or officials from other institutions. This usage-based fee covers hosting, computing power, as well as customer support.

On-Demand Services: Building on the core software product, CityTwin.ai offers a range of additional services. The services cover technical offerings such as higher-fidelity simulations of a specific aspect of a chosen scenario or project, as well as expert input on the climate impact of particular elements of a planned project. Any consulting service is priced individually depending on the required skill set of the consultant and the number of person-days required to complete the project.

Cost Structure

Initial Setup Costs: In the beginning, a significant initial investment is needed to develop the pipeline and integration tools. Developing the CityTwin.ai product requires the data to be processed in many formats. This subsequently requires a mix of skilled software developers with experience in web development and in working with game engines, data scientists for setting up the data pipeline, and a range of experts in climate and urban modeling. Besides the cost of acquiring the datasets, the salaries of these experts are the primary cost driver. Until revenue of over one million dollars is exceeded, licensing the Unity game engine required for visualizing the product for clients is free of charge.

Fixed Costs: CityTwin.ai has three main cost drivers on the fixed cost side. The first one is the workforce and R&D spending. Building and maintaining highly complex products requires highly skilled experts, independent of the number of customers. The second factor is the office space and equipment needed to operate, including the amenities required to attract top talent. The final aspect is the promotion of the product. Due to the typically long lead times on public procurement, CityTwin.ai invests in a strong presence at industry fairs and other such events, without seeing an immediate return on investment.

Variable Costs: The variable costs split into two buckets. The first one is technical maintenance. Each CityTwin requires large amounts of data storage and computing power to run the necessary simulations. Additionally, city specific data such as newer satellite imagery will have to be purchased and ingested regularly to keep predictions and simulations up-to-date. The second bucket is expenses related to the consulting side of the business. These costs are mainly driven by employing experts and climate consultants, depending on the number of such engagements that CityTwin.ai's clients request.

Eco-Social Costs

Cost in Energy Usage: According to a Nature article published in 2018, data centers use 200 terawatt-hours (TWh) per year, which is more than the national energy consumption of some countries, including Iran [439]. Therefore, it is essential to track the energy usage of the data centers where CityTwin.ai stores its data. Specifically, CityTwin.ai is committed to combating climate change, so it will use renewable energy for their data centers



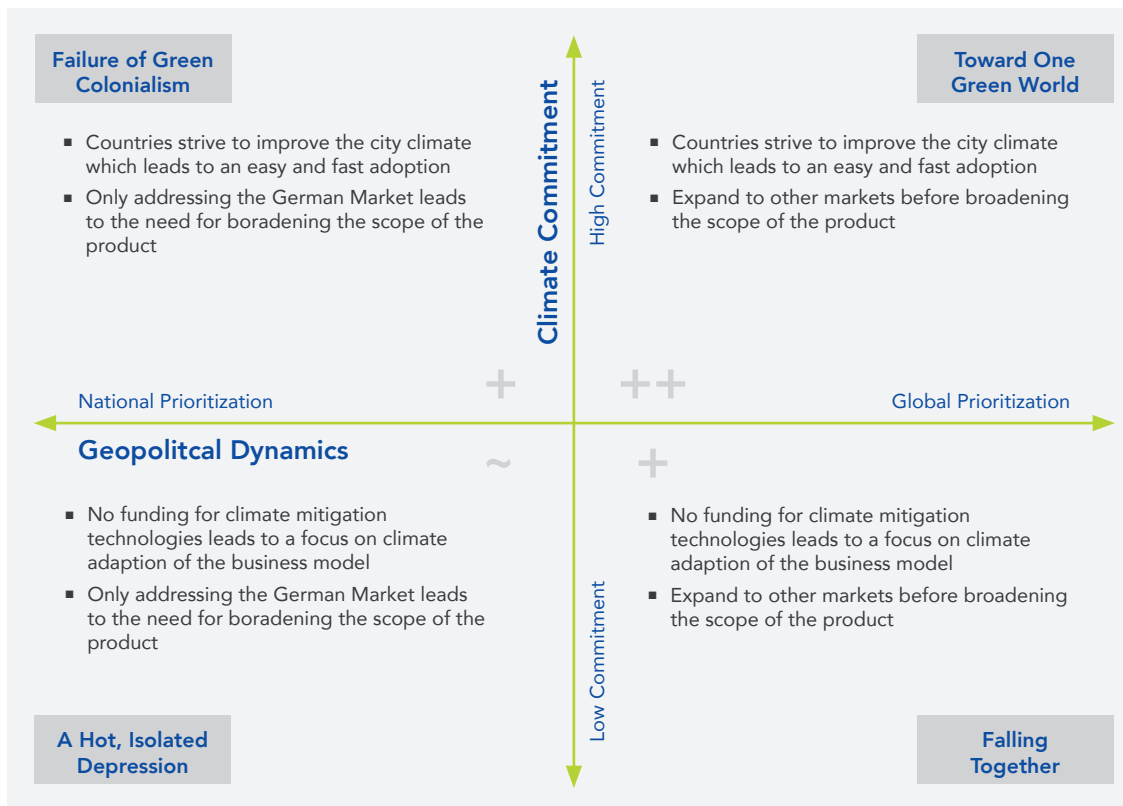
when possible and offsetting the carbon emissions of their affiliated data centers in all other cases. CityTwin.ai aims to be a net-zero company by offsetting all its emissions.

Cost in Terms of Privacy: CityTwin.ai requires a lot of information to function effectively. Its model's thoroughness is one of its most essential features, but this thoroughness creates a great responsibility for data protection. In the EU, GDPR outlines strict guidelines for data storage and processing. The most relevant restrictions GDPR imposes are the consent of participants, the data storage timeline, and motivation for data processing. More advanced legal research is required to determine precisely how CityTwin.ai's open-source data collection fits within this framework. In addition, CityTwin.ai's data collection presents another potential cost – the average citizen's perception of privacy within society. As demonstrated by the adverse public reaction to the release of Google Street View in 2007, citizens can be very sensitive to perceived breaches of privacy. Therefore, it would be necessary for CityTwin.ai to mitigate the potential adverse public reaction and emphasize that the data is not being used for excessive surveillance.

 **Eco-Social Benefits**

Climate Change Mitigation and Adaptation: CityTwin.ai is primarily concerned with climate change mitigation and adaptation. Compared to traditional policy implementation, CityTwin.ai allows testing of many potential measures allowing for more impactful climate policies with a lower environmental risk. This can result in a more significant environmental impact. Additionally, the digital twin enables the discovery of unknown emission sources. For example, creating a digital twin of a city could reveal previously unknown pockets of traffic congestion, shining a light on less apparent sources of GHG emissions. This empowers governments to tackle climate change effectively.

While reducing GHG emissions in cities is desirable, it is also rather abstract and cannot be felt directly by the inhabitants of a town. Compared to that, measures that improve the city climate, such as avoiding heat accumulation in the city center, can be felt directly. It is also necessary, as the rising global temperatures lead to an increase in heat-related deaths without further climate adaptation. CityTwin.ai empowers urban planners to take the measures required before it is too late.



More Transparent and Effective Urban Planning: The potential for increased policy transparency provides a potential uptick in the feeling of well-being and safety for citizens. An example of this is as follows: imagine a historic building is identified as a significant source of GHG emissions, and the local government decides that it must be torn down and rebuilt. Without CityTwin.ai, citizens may feel confused and mistrustful of the government. With CityTwin.ai, the government would be able to publish a transparent emissions report to provide the public with relevant information that would mitigate the potential adverse reaction. CityTwin.ai also makes urban planning faster and easier, with less potential for negative externalities.

Scenario Fit

Toward One Green World: In this scenario, CityTwin.ai's business would flourish. As people demand climate action, cities would strive to improve the city climate, leading to an easy and fast adoption of the available solution. Cities would especially use the software to identify emission sources to limit climate change. But as global temperatures have already risen by 1.2°C, they also profit from CityTwin.ai's climate adaptation recommendations.

Due to the global collaboration, the scope of the product would be kept as described and there would be a focus on a fast expansion to the global market. With that, CityTwin.

ai could sell the product to more customers with only slightly increased costs for the internationalization of the product. The climate models CityTwin.ai uses could be global; thus, no changes are required. Cities worldwide would also profit from data sharing, making the simulation even more accurate.

Failure of Green Colonialism: If countries strove for a green future but did not collaborate, CityTwin.ai's business would change compared to the first scenario. The adoption in Germany could still be fast and easy; however, the national prioritization would make global scaling impossible. In this scenario, both the climate mitigation and the climate adaptation aspect of CityTwin.ai's product would be required.

As global scaling is not possible, the focus would be on expanding the scope of the product and adding many more features. The traffic and city climate models would be refined, and new models would be added. Additionally, new types of simulations would be added. For example, the product would use the traffic flow analysis to recommend optimal car charging station positions. Similarly, the demand for bike-sharing stations would be predicted by the implemented models.

A Hot, Isolated Depression: To keep cities inhabitable, a solution like CityTwin.ai would be required in this scenario. Without CityTwin.ai, heat-related deaths could reach barely acceptable levels. Cities that adopt CityTwin.ai earlier are at an advantage, as the simulations with different climate change scenarios allow them to make informed decisions. These cities have considered global warming early in their city planning concepts and can therefore sustain a habitable environment, even in harsh conditions.

Citizens of other cities that have not yet used CityTwin.ai would demand immediate action from their public administration to improve the city climate. While they do not prioritize climate change mitigation in general, they see that more and more people struggle to keep up with extreme weather events. Therefore, urban planners would start using CityTwin.ai's product to improve the climate adoption and resilience of the city. While they can't reverse global warming, reducing the average temperature within cities using the digital twin is still possible.

Falling Together: If the scenario "falling together" were to happen, CityTwin.ai would still strive. As global temperatures rose, the demand for climate mitigation techniques would also rise. Even though some cities might have been abandoned in this scenario, most public administrations would try to find a way to keep their countries and cities habitable. As local measures are the easiest to implement, CityTwin.ai's product would be helpful to mitigate climate change consequences and therefore demand would be high in 2042. In the 2020s however, because of the peoples low climate commitment, only a few cities include climate adaptation as a goal in their urban planning. These cities could still profit from the product and would finance the early development.

As soon as temperatures reach a tipping point where most cities have to care about climate adaptation, CityTwin.ai can quickly scale globally. Because of global collaboration, cities across the world benefit from data sharing.

Challenges

- Collect and maintain the data to create a digital twin: CityTwin.ai's first challenge is scraping and storing the massive amount of data a digital twin simulation requires.
- Build an AI algorithm to predict the impact on emissions and people: Due to the complexities of urban planning, it takes considerable effort, brainpower, and time to create algorithms that accurately model the surrounding environment.
- Establish and maintain partner relationships with various local, state, and national governments: To establish its product in the public sector, it will be crucial for CityTwin.ai to have those relationships and provide a product that the important stakeholders in the public sector love to use.
- Build a strong reputation of transparency and accuracy among global citizens: CityTwin.ai aims to bolster trust in governmental policies, which could prove to be challenging. CityTwin.ai will share processes early on with citizens affected by their platform to build trust and confidence.

Outlook

In consideration of possible future developments, CityTwin.ai has a strong future ahead. As effective climate policies become increasingly crucial in the next 10 – 20 years, effective urban planning will be of the utmost importance. Additionally, as the demand for government transparency grows, CityTwin.ai will be able to provide a powerful tool for governments and urban planners alike. CityTwin.ai aims to empower more successful climate mitigation and adaptation – tasks of the utmost importance in the coming years.

What does the timeline for this look like? By 2025, CityTwin.ai hopes to have the pilot launched in Bavaria, with a focus on Munich. The plan is to expand the product to the DACH region by 2027 and incorporate rural and suburban areas into the model. By 2030, CityTwin.ai plans to expand fully through the EU and begins offering large-scale consulting services, including architecture and other recommendations. The biggest target is to be fully global by 2032, with the ultimate goal of consulting for the UN as they shape future climate policies.

CityTwin.ai has a bold vision for the future, but it's not impossible to achieve. Digital twins, if appropriately implemented, could revolutionize urban planning and climate mitigation, and the hopes are to achieve that with CityTwin.ai.

MEAT.AI

Healthy, Tasty and Carbon Negative Beef Alternative From Ambient CO₂

The United Nations estimates the world population to increase to 10bn by 2057. With an increased demand for resources but yet steady decrease in the agriculturally cultivable area due to human-induced land degradation, erosion, and pollution, humankind is steering into a food crisis. An increasing number of air-based protein companies are emerging, due to the fact that agriculture emits at 9.3bn tonnes of CO₂ equivalent worldwide, with animal-based foods contributing to more than half. Meat.AI aims to capture the business opportunity in the rising demand for meat by sourcing products from existing air-based protein companies and creating a well-textured alternative meat.

Building on producers that transform CO₂ from the air into nutritious protein with the help of microorganisms, Meat.AI provides a solution to combat the climate effects of meat con-

sumption. Meat.AI produces a beef alternative, called AirMeat, with a refined sensory experience similar to natural beef by committing to research and development. Using AI algorithms on magnetic resonance imaging (MRI) scans of beef steaks to build optimized computer-aided design (CAD) models for the beef alternative, resulting in a real beef-like texture. Being only dependent on the supply of air-based protein derived from CO₂ in the air, this technology has the potential to increase the food security of nutritious and healthy meat alternatives while at the same time binding CO₂ from the air. AI in food manufacturing can monitor every step of the process through price and inventory predictions that help track the sourcing of ingredients from where they are procured to the final place where consumers receive it – either online or at the organic supermarket. Meanwhile, the vegan product removes ethical issues associated with slaughtering living animals.



The AirMeat steak is a sustainable product created with CO₂-based protein that is affordable for big consumer groups within the population, as it is sold at a competitive price. The final high-quality textured beef steaks are produced and packaged at Meat.AI's facilities and sold to consumers via organic supermarket chains and Meat.AI's e-commerce Shop. Mainly, Meat.AI focuses on middle-aged consumers with a high income in Germany that are conscious about their health, climate change risks and animal cruelty in conventional industrial meat production. They are willing to pay for a high-value meat alternative. Meat.AI provides them with a vegan cruelty-free beef alternative that is not only carbon negative, but also engineered to be healthy.



Key Partners

- Universities for research collaborations
- Air-based protein powder suppliers
- Renewable energy suppliers and green logistics partner
- Food approval authority in Europe
- Organic supermarkets



Key Activities

- Research and development
- Physical production
- Packaging and shipping
- Build and maintain sales channels



Key Resources

- Production facilities and office space
- Highly skilled workforce
- Upfront investments into R&D and machinery
- CO2-based protein
- Renewable energy



Value Proposition

For the Organic Supermarket Chain

- An unique meat substitute to add to the existing product mix of bio foods
- Carbon negativity of the beef alternative is favorable for supermarkets
- Security of supply through independence from crop failures

For the End Consumer

- Providing a carbon negative beef alternative
- Cruelty-free way of consuming meat
- Competitive price with AI-based monitoring



Customer Relationships

- Food retailers
- Online customer service
- Online communities



Channels

Direct-to-consumer (D2C) Online

- Meat.AI's e-commerce website

Business-to-business-to-consumer (B2B2C) Offline

- Delivery to selected organic supermarkets



Customer Segments

Climate-aware Flexitarian Consumers

- Diet centered on plant foods
- Considerate about climate change and animal cruelty
- Attracted to the sustainability of Meat.AI's beef steak

Health Aware Consumers

- Healthy diet based on low meat consumption
- Drawn toward the health benefits of Meat.AI's beef steak



Cost Structure

Fixed Costs

- Rent for the production site and offices
- Employee salaries
- R&D costs
- Machinery, equipment costs

Variable Costs

- Costs for carbon negative protein powder
- Maintenance costs
- Shipping costs of the product
- Marketing and sales expenses



Revenue Streams

- Food retailers with organic focus
- Online retail shop for committed customers



Eco-Social Costs

- Emissions from production and operations
- Renewable energy consumption for powering machinery
- Displaced jobs in the real meat supply chain
- Conflicting eating norms



Eco-Social Benefits

- Reduction of used land for animal husbandry
- Abolition of animal cruelty and factory farming
- Ensure food security in terms of protein nutrition

Value Proposition

Meat.AI produces a high quality, healthy, tasty, and well textured beef alternative based on carbon negative air-based protein derived from CO₂.

For Organic Supermarket Chains: Meat.AI expands the supply of vegan, organic beef alternatives for organic supermarkets. Currently, food retailers are offering either soy or vegetable-based meat alternatives, as artificial meat is not mass-produced yet. Using air-based protein in combination with high-tech production methods, Meat.AI aims to enrich the product portfolio with a much more realistic beef steak alternative for everyone. As only renewable energy is used for production and air-based protein binds CO₂, carbon negativity of the end product can be ensured, making it favorable for the upcoming mandatory carbon accounting of supermarket chains. Due to the product's high durability with innovative production methods under a protective atmosphere, products can be stored well and bought in large quantities. In addition, these beef alternatives provide security against threats to food security such as crop failures or animal diseases, which are predicted to increase due to climate change.

For the End Consumer: As climate awareness in the population increases, carbon negative and vegan beef alternatives for consumers become increasingly attractive. But aside from its carbon negativity, the beef alternative is more nutritious and tastier than comparable products thanks to the newly developed and proprietary process of Meat.AI. Packaged in an elegant container made of reusable material, opening the container provides a pleasant experience. The Meat.AI "beef" is optimized by using a digital CAD twin sourced from MRI images and an AI optimized fiber alignment technology called FIB-AI-lign. In addition, Meat.AI can ensure affordable prices due to process optimization along the production chain.

Customer Segments

Channels to access customer segments consist of both B2B2C (organic supermarkets) and D2C. The focus in this section is on customers that eat the end product.

Climate-aware Flexitarian Consumers: These consumers prefer to eat vegetarian, but still enjoy the occasional meat dish. They are conscious about climate change risks

as well as animal cruelty. These customers know that they can make a meaningful difference with their diet, but are still on the verge of switching to being fully vegetarian because they are not satisfied with the texture, nutritional value and environmental benefits of available meat alternatives. Existing soy-based substitutes have a smaller carbon footprint than animal-based alternatives, but still harm the environment due to soil degradation. Meat.AI meat substitutes taste similar to meat and is also climate-friendly. They make it more attractive for this customer group to consume even less meat. They are willing to pay for a high-value meat alternative such as Meat.AI and even the standard subscription of Meat.AI, which provides a sustainable delivery.

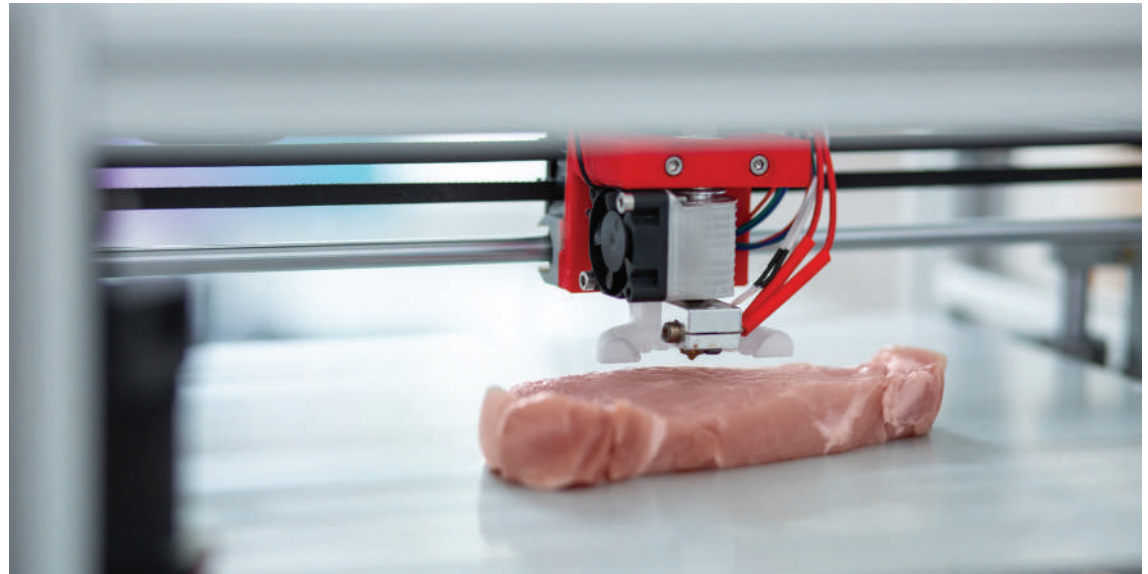
Health-aware Consumers: These consumers are interested in a healthy diet, thus have a low meat consumption. Such consumers are at the same time aware of the downsides of vegetarian diets, so they try to combat that by not eating vegetarian junk foods like french fries and try to reduce the intake of unhealthy foods. The main driver behind this customer behavior is the current and future well-being of

their body, and not necessarily climate action. If they buy meat, they prefer more expensive organic options to avoid the hormones and pesticides. Health-aware consumers will buy Meat.AI because they believe in the health benefits of the product, and miss the taste of meat.

Customer Relationships

Meat.AI's online shops offer an assortment of alternative meat so that customers can select which seasoning they want on their beef. They benefit from the convenience of not having to go to the grocery store, and the online shop can provide a subscription so that customers can get supplies of the "beef" twice a year delivered to their front door. For customers that go to the organic grocery store, they find Meat.AI products in the familiar grocery aisles. With the reliable supply chain network of Meat.AI, it is expected that there will be a steady stock of goods in partnering organic grocery stores.

Food Retailers: Key partners distributing Meat.AI's beef steak alternative are managed by account management





teams that take care of the sales process and logistics. They are also responsible for finding new bio-supermarkets to sell to or for expanding to other cities. Account management teams are also key to maintaining and nurturing existing relationships with procurement teams of key partners.

Online Customer Service: Customer representatives are available to support end customers by getting help during the sales process or after purchase. Also, IT support is provided in the event users face issues on the online channels. In the event of unsatisfied customers, Meat.AI offers 100% money-back guarantee and quick customer service to address any issues.

Communities: Through an online community of like-minded Meat.AI enthusiasts, members can exchange experiences and knowledge. The online community allows customers to exchange recipes and organize culinary events. The community can also help Meat.AI gather feedback and better manage customer expectations. Another benefit of the community is that Meat.AI can address common customer questions or comments at the same time, and customers can share solutions with each other.

Channels

D2C Online Channel: Various online channels such as an e-commerce website and third-party channels such as social media and food blogs will be used in Meat.AI's digital strategy. Customers can order online and have Meat.AI's products shipped to their homes. Such customers might not have time to go grocery shopping or are not located near a grocery store that offers Meat.AI products. The e-commerce website of Meat.AI will employ performance marketing and SEO to garner a larger online presence. With the large number of online users, Meat.AI also intends to have a strong social media presence on Instagram, TikTok, and LinkedIn to reach the maximum number of potential buyers. Meat.AI also plans to partner with culinary influencers and celebrities who can give product reviews and further establish brand awareness. Additional promotions on food blogs and online magazines in the fields of health and climate can further market the usage of Meat.AI's products and inspire its use in a diverse range of recipes.

B2B2C Offline Channel: With a reliable supply chain network, the products can be delivered in large wholesale quantities to selected grocery partners. The partner network of grocery stores would include selected bio-supermarkets that embody the same climate values of Meat.AI. The supply chain should operate using the lowest carbon routes and function according to Meat.AI's goal of being carbon negative. Customers can then purchase Meat.AI products in their local grocery store. Partnerships with supermarkets could also offer the opportunity for in-store events and offer tastings. Such events can provide a direct interaction with supermarket-shoppers to gauge their reactions when they taste the product and get valuable customer feedback.

Key Activities

Research and Development: In the first years, Meat.AI shall focus on universities as critical partners to optimize the texture of the beef alternative. Supported by MRI technology, the CAD model is created based on data of several thousand MRI images. Algorithms will also be used to create a special CAD model of the meat, serving as a blueprint for the protein fiber alignment process. Besides the CAD model creation, the focus of Meat.AI is scaling the beef alternative's electrospinning and fiber alignment production methods (FIB-AI-lign).

Physical Production of the Beef Alternative: After R&D-intensive years, Meat.AI's emphasis shifts toward the physical production of the beef alternative, thereby scaling and optimizing production processes to cover the demand of organic supermarkets.

Packaging and Shipping Products to Organic Supermarkets and End Consumers: Packages used for the beef alternative are produced from 100% recycled plastic to enable carbon neutrality. Used packages are integrated into a deposit system to be recycled by a specialized partner. In addition to packaging, Meat.AI invests in optimizing the shipping process, emphasizing fast, but sustainable delivery. Supermarkets and end consumers are incentivized to buy large quantities to minimize the need for transportation.

Build and Maintain Sales Channels to Organic Supermarkets and End Consumers: In the beginning, Meat.AI must build up strong relationships with its customers, organic supermarkets, and end consumers. Implemented feedback loops on the website allow the integration of further product improvements to make the beef alternative even more attractive.

Key Resources

Production Facilities and Office Space: Meat.AI needs to rent production facilities and office space to produce high-quality meat alternatives. The production facilities must fulfill certain industrial production site requirements, such as sufficient floor stability and electric power supply. The site would be located in Germany to keep GHG emissions for transportation low and meet the goal of carbon negative production. Also, the offices will be rented from a tenant company providing facilities certified for carbon neutrality.

Highly Skilled Workforce with Specialists in Food Technology, Manufacturing, and Computer Science: The first years of an intensive R&D phase would require specialized skills in food manufacturing, mechanical and electrical engineering, and computer science with a focus on AI. When scaled production starts, organizational roles such as project managers, sophisticated human resources department and controlling will be required.

Significant Upfront Investments into R&D and Machinery: The R&D phase requires significant upfront investments in the technology development for the 3D fiber alignment that



would be optimized and scaled for mass production. Also, there will be a lot of specialized hardware needed that will further increase the initial costs.

CO2-based Protein: As air-based protein powder is the primary substrate of the final beef alternative, large quantities of this raw material are needed. CO2-based protein manufacturers such as Solar Foods use purified CO2 and other air components, such as nitrogen, to feed microorganism cultures that metabolize them into protein structures.

Renewable Energy: Due to the extensive air-based protein processing, large amounts of electricity are required. This energy is only sourced from renewable energy suppliers.

Key Partners

Universities for Research Collaboration on MRI Scans of Beef Texture and AI Optimized Fiber Alignment: Meat.AI collaborates with research institutes at the Ludwig-Maximilians-University of Munich (LMU) and the Technical University of Munich (TUM) in the first years of research and development. This collaboration will include joint supervision of student's master thesis, as well as incorporation of PhD candidates into Meat.AI's team.

Air-based Protein Powder Suppliers: The main component of the beef alternative is air-based protein powder from suppliers like Solar Foods. Due to the significant dependency on the supply of air-based protein, long-term partnerships with suppliers need to be established. Meat.AI also needs to be aware of the partner's potential choice of producing meat alternatives themselves, which would turn them into competitors.

Renewable Energy Suppliers and Green Logistics Partner: For the production process of the beef alternative, electricity is needed. To ensure overall carbon negativity and not diminish the positive carbon footprint of the air-based protein, energy must be obtained from renewable energy sources like solar or wind. Besides relationships with renewable energy suppliers, partnerships with green logistic partners are established to avoid potential greenhouse gas emissions resulting from transportation.

Food Approval Authority in Europe: Obtaining approval on new food products by the European authorities takes

time. In the early stages, a relationship with the authorities is established. To achieve this, food regulation experts that are well-connected in this environment will be hired.

Organic Supermarkets: With organic food retailers being the main B2B partners, Meat.AI focuses on establishing long-term contractual relationships with organic food retailers to ensure continuous sales for the upcoming years. Meat.AI's first steps in the market entry strategy involve supplying organic supermarkets at selected locations based on the lowest carbon routes. Further expansion to other sites will follow in subsequent steps.

Revenue Streams

Meat.AI's main revenue streams are wholesale to organic supermarkets and an online retail shop for committed customers. The sales team will reach out for partnerships with supermarkets before production starts and an IT service company will be engaged to set up the online shop as soon as the alternative beef steaks fulfill food regulation requirements.

Food Retailers: The main offline revenue stream of Meat.AI are food retailers. They are the main channel for selling Meat.AI's products by distributing Meat.AI's beef steak alternative as part of their organic product portfolio. The product is distributed under Meat.AI's brand for 40 EUR/kg fixed list price. This price covers all costs of Meat.AI until delivery to the supermarket facilities, e.g., research and development, ingredients, production, and logistics. Also, it is the average price of a beef filet in Germany, positioning Meat.AI's alternative steak as a high-quality product. Meat.AI is interested in selling large quantities at once to the supermarkets to run efficient logistics. Thus, Meat.AI offers special promotions for wholesale buyers that aim to increase the ordered quantities. In the research and development phase, pilot projects will be set up with future food retail partners to test the product and convince them of Meat.AI.

Online Retail Shop: The online retail shop is aimed at committed customers looking to order from Meat.AI directly. The price of the products in the online shop is equal to the consumer price in the supermarket to avoid direct price competition with the retail partners. To keep logistics overhead low for orders related to the online shop as well, customers are incentivized to order larger quantities. An example of such incentive is benefitting from promotions such as a bulk discount when buying more than 20 steaks.

Meat.AI

Online shop customers are further incentivized to purchase large quantities with subscription plans automatically shipping 40 steaks at a discounted price twice a year.

Cost Structure

Fixed Costs: One major expense is the rent for the production site and offices. Meat.AI plans to establish one production site in the center of Germany to ensure the most carbon friendly transportation routes to supply every German region. Besides rental costs, employee salaries pose another significant amount of fixed costs. In particular, highly-trained employees specialized in food science, but also computer science, biochemistry and biotechnology are necessary. Given the shortage of people with sufficient technical skills, recruiting and hiring costs should also be accounted for. In the early stage, large R&D costs will occur for dataset creation, experiment labs and patent applications. Also, special machinery and equipment tailored to Meat.AI's requirements needs to be manufactured for the alternative steak production processes. In particular, machines for electrospinning, fiber alignment, and UV crosslinking are necessary.

Variable Costs: To be able to produce the beef alternative at a large scale, Meat.AI is largely dependent on long-term contracts with suppliers to stabilize prices of the air-based protein powder. Besides the costs for the raw material, air-based protein powder, additional costs for maintenance of the production site, offices and machineries occur on a regular basis. Furthermore, sustaining the online shop requires outsourcing to an external IT services company to keep the shop attractive and appealing to the end-consumer and ensure stability and safety. Moreover, as Meat.AI promotes their beef alternative as carbon negative, shipping costs for green logistics are rather high and occur frequently. In addition, marketing and sales expenses are initially high to develop a well-known and strong brand image. Launching successful marketing campaigns that could reach a large audience is key in early stages and could be expensive considering the costs for research, design, social media, and employees.

Eco-Social Costs

Societal and environmental externalities caused by Meat.AI's products and operations should be considered, as Meat.AI wants to provide truly sustainable meat alternatives. During

production and manufacturing upscaling, environmental costs could be accounted for with carbon offsetting strategies. However, Meat.AI will work with significant effort toward its long-term vision: producing carbon negative meat alternatives.

Environment: The environmental costs are expressed in CO₂-equivalent emissions resulting from the company's activity. Two direct emission sources are the protein powder texturization processes and the computation of AI models. These two sources use significant amounts of electrical energy, so electricity from renewables is used to reduce emissions. Also, as Meat.AI aims for carbon negative food production, resource efficiency and process optimization to tackle emissions are the highest priority. Further emissions arise from the supplied protein powder, which is of minor concern (0.2kg of CO₂ equivalents per kilo protein powder), and the material and machinery used for R&D and production. To account for them, Meat.AI will offset the amount of carbon emitted.

Society: Providing a high-quality, environmentally friendly meat substitute further supports the ongoing trend toward fake meat consumption. As actual meat producers and processors lose market share, jobs in this sector and the related meat supply chain will be displaced, as these jobs shift toward alternative meat production. On the other hand, butchers, animal farmers, and feed producers will need to retrain and obtain unemployment subsidies, thus stressing the public budget. A feeling of an unjustified cut of jobs might arise and lead to public discontent.

Eco-Social Benefits

The beef alternative produced by Meat.AI is in itself sustainable. The resulting benefits for the environment should show the possibilities of modern food production and be a guiding star for consumers and society to pursue a sustainable lifestyle.

Environment: The Meat.AI solution provides a beef alternative based on the protein produced out of CO₂, leading to a 100x reduction of emissions compared to conventional beef. The technology enables meat with a negative carbon footprint in the future. Furthermore, decoupling meat production from animal breeding enables location-independent production. It reduces the land use for growing fodder plants, which accounts for a major part of all land used for agriculture, especially in the tropical regions of South America and Africa. Meat.AI can help to save thousands of square kilometers of rainforest from deforestation every year.

Consumer and Society: Air-based protein is independent of agricultural areas and crop failures, therefore improving food security in terms of protein nutrition. In addition, Meat.AI consumers can enjoy eating meat substitutes that have a similar taste and texture like real meat but have no carbon footprint. This allows them to reduce the emissions of their consumption behavior and have a guilt-free conscience. In addition, Meat.AI's meat substitute is healthier than conventional meat. This is on the one hand due to the lack of hormones, antibiotics, and pesticides in the supply chain, and on the other hand due to the mix of healthy amino acids and fats that are used to manufacture the Meat.AI beef substitute. Also, no ethical concerns are raised because of no critical animal husbandry. Meat industry experts could help engineer an even better meat substitute. Finally, society might appreciate meat substitutes as equally valuable as real meat and foster a shift toward a sustainable meat-eating culture.

Scenario Fit

Failure of Green Colonialism: In this scenario, nations would prioritize their local economies, imposing high taxes on imported products. Most air-based protein suppliers are headquartered outside Germany, so it would be difficult and expensive for Meat.AI to cover its supply of protein at first. The German government, which is committed to climate action, could offer financing through subsidies for sustainable food production which Meat.AI could use for the acquisition of the protein on the one hand. On the other hand, the German government and Meat.AI itself would be interested in producing air-based protein locally as well, so further public financing could be used to develop the necessary technology in Germany. Regarding the consumers, a highly committed society strongly demands meat alternatives to lower their individual carbon footprint. High demand would allow Meat.AI to establish high prices for its beef steaks, resulting in Meat.AI being a profitable business.

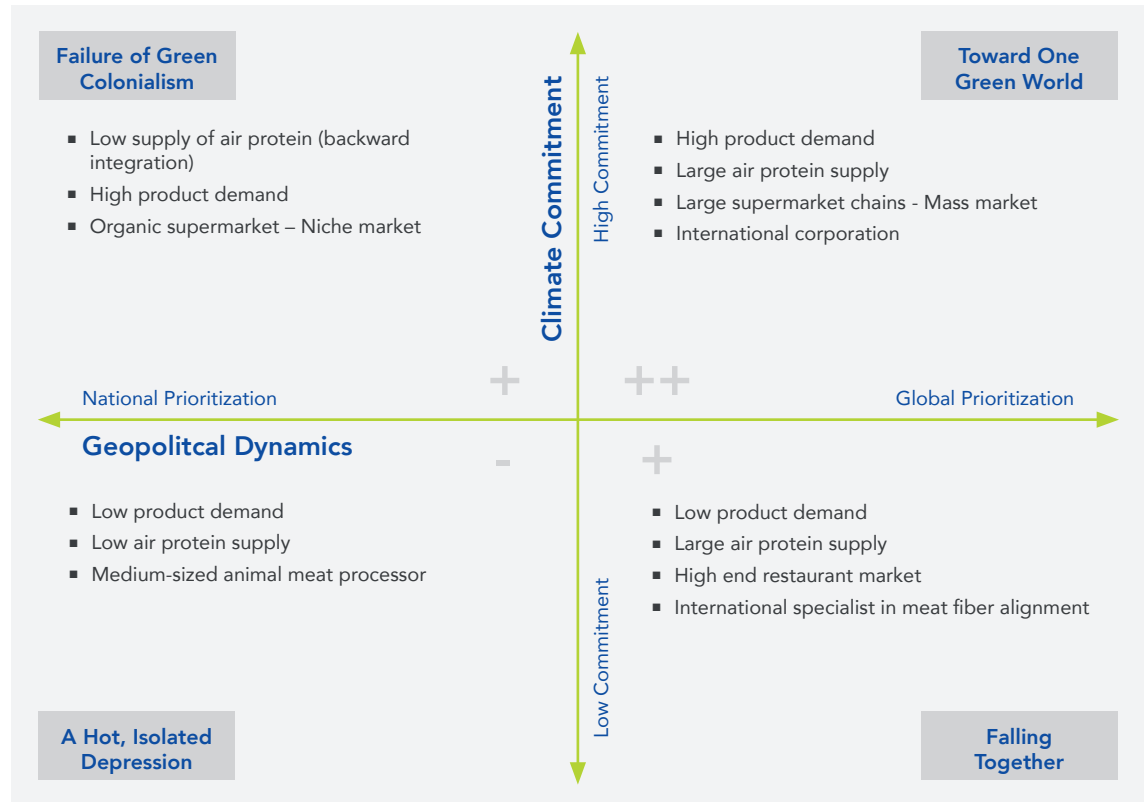
Toward a Green World: With an ever-increasing climate commitment in Germany and all over the world, the demand for meat alternatives would grow exponentially. Climate-aware consumers thereby particularly value Meat.AI's steaks for being based on air-based protein powder, which reduces the amount of CO₂ in the air. Also, due to increasing globalization, the supply of air-based protein powder from international companies should be cost efficient. Having optimized the meat-producing technology, Meat.AI would be able to offer its beef steaks for a lower price than real

Meat.AI

meat. With this cost advantage, they establish themselves as a brand in large supermarket chains in Germany. Building on the huge success in Germany and low export tariffs, they would expand globally to the US, China, and India within a few years. Thereby, they further refine the production technology and logistics to become carbon negative, which would make them even more competitive due to large CO2 offsetting prices.

Falling Together: In this scenario, low individual commitment to climate action could significantly lower the importance of sustainability in Meat.AI's products. There would be no general demand for meat substitutes out of environmental concerns. However, Meat.AI's production process would still thrive within a niche market of deluxe products. The innovative approach, together with the option of personalizing the meat texture and form to the consumer's preferences would make it a great addition to the menu of luxurious restaurants that offer a food experience. In a globalized world, this market would still have a considerable size, turning Meat.AI into a company specialized on the high-end food supply market. Global trade, scientific and technological exchange lower the price of the air-based protein, so Meat.AI could fully concentrate on improving its meat texturizing processes and succeed in its niche market.

A Hot, Isolated Depression: When climate commitment in Germany is low, the demand for meat alternatives would decrease, and real meat from farming factories is preferred. Also, the general population and the government are not interested in binding CO2 from the air but rather react to catastrophes caused by climate change. Moreover, due to huge import tariffs, air-based protein powder could not be procured from suppliers like AirProtein, which is located in the US. Reacting to these conditions, Meat.AI establishes with its experts in biochemistry and computer science a high-tech meat processing company. After buying local meat from farming factories, they process it into different kinds of processed meat like sausages. Due to its unique taste and the large product portfolio, Meat.AI could grow steadily into being a medium-sized company.



Challenges

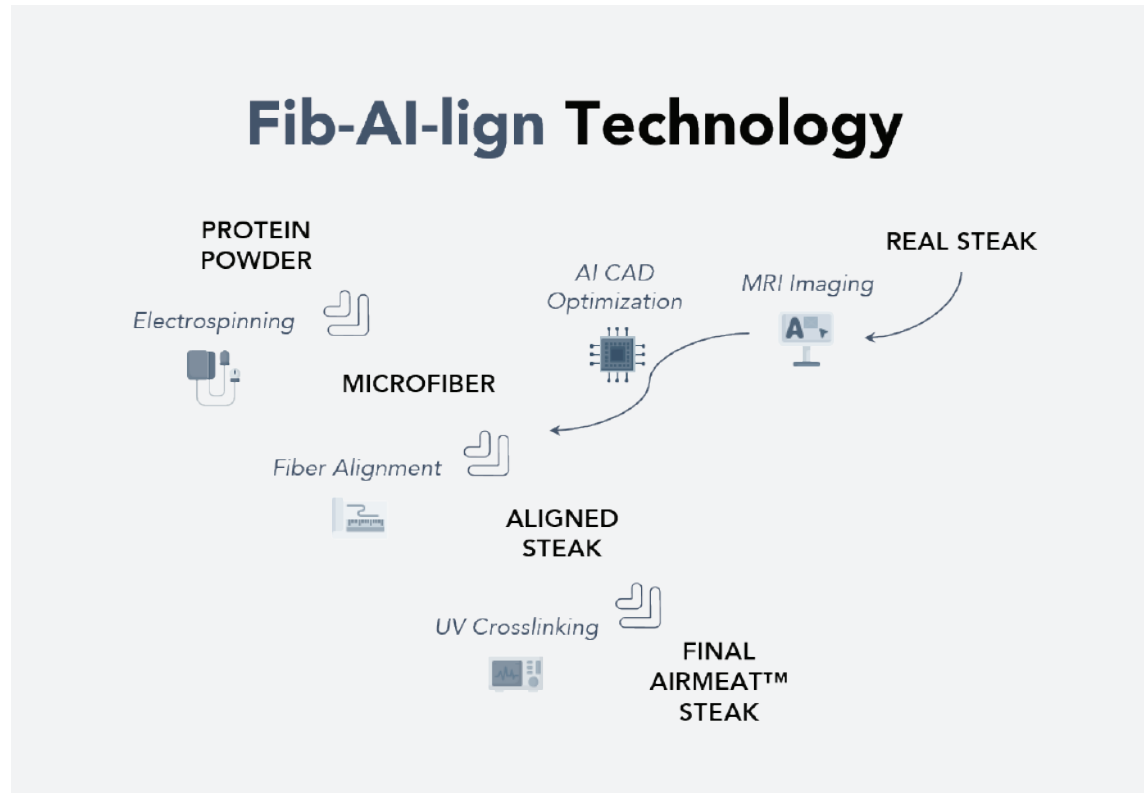
- High barriers to enter the market due to large investments in R&D (e.g., MRI technology and the Fib-AI-line technology) are needed.
- To ensure carbon negativity, Meat.AI's production processes must be optimized for low emissions. They depend on sustainable energy suppliers and green logistic companies.
- Air-based protein powder suppliers could credibly pose the threat of forward integration and produce meat alternatives themselves.

- Governmental subsidies for real meat and a maximum tax rate for meat alternatives can make meat substitutes more expensive than real meat.
- Decreasing demand for meat alternatives due to a missing shift in the consumer behavior toward sustainable alternatives.
- Technological failure to create a texture and taste similar to real beef could impact overall demand.
- Scalability of the production technology to supply organic supermarkets all over Germany might be challenging.
- Increasing technological advances in the agriculture of soy could make plant-based alternatives more sustainable.

Outlook

In the future, Meat.AI plans on expanding in two directions: First, enriching its product portfolio and second, expanding its addressable market. By further implementing customer feedback and collaboration with research institutes at TUM and LMU, they want to optimize the texture and taste of air-based protein meat to also produce different kinds such as pork, chicken, and fish. As they profit from a half-year durability, Meat.AI bets on additional meat substitutes becoming a strategic advantage.

Having supermarkets and online buyers as their main customers, Meat.AI would expand and sell products to large supermarket chains in the low-to-medium price range. Also, Meat.AI will try to gain healthy and organic restaurant chains or university canteens as customers make meat alternatives more widely available and steadily increase their customer base. In a later stage, they plan to expand geographically in neighboring countries of Germany, such as Austria or Switzerland. For this geographic expansion, joint ventures with other food processing firms are under discussion to increase the overall sustainable impact of Meat.AI. In the long-term, Meat.AI plans to establish itself as an international meat producer with its headquarters in Germany.



SAVEVA

Revolutionizing Office Energy Systems

The energy sector is the highest GHG producer worldwide, emitting around 73% of all emissions. This amounts to more than 15bn tons of GHG per year due to inefficient resource usage that contributes to the global resource scarcity landscape. One of the main factors is energy use in commercial real estate, accounting for 6.6% of global GHG emissions. To tackle this massive emission and resource misuse problem, not only is increased public awareness needed, but also smart solutions that tackle the issue effectively. In the general case, companies do not want to waste human capital in monitoring and regulating energy systems. That is why SAVEVA makes use of the increasing automation trend and provides an AI-based software solution that works as an add-on to existing energy consumption products. The platform will start tackling the heating industry by enhancing smart thermostats via software-only tracking and regulation functionalities. This will result in both lower emissions and lower costs for the

customers. Once these heating issues are solved, SAVEVA will develop into an integrated energy solution, expanding to the electricity and water industry as an overarching facility management tool.

The product-market fit of the product resides on two arguments: On one hand, this software differentiates in comparison to all possible competitors because of its generalization across devices and industries. No other company on the market currently tackles the combined topic of energy optimization, which includes water, electricity, and heating at once. On the other hand, it is fully personalized. It perfectly matches the energy systems in usage, leveraging over the current fragmented industry solutions by synchronizing the many uncorrelated and varying IoT devices. SAVEVA's synchronized solution provides up to 30% of the yearly consumption reduction by regulating energy according to time preferences,

workloads, and locations. The collected data is then used to improve the software, integrating it with weather forecasts and calendar occupations to perfectly adjust the needed energy. The software serves as an interface to smart homes and company settings, making B2B partnerships the key focus of the business model, as it can meet the energy challenges of industrial buildings, offices, and retail spaces alike.



Business Model



Value Proposition

For Office Users: This group defines the institutions or companies that either already acquired smart thermostats or buy and install them via one of SAVEVA's partnerships. By adding SAVEVA's software, customers can save up to 30% of their energy costs, pursuing not only temperature adjustments of smart heating and AC systems but also efficient monitoring and control of electricity and water expenditures. This significant reduction leads to lower GHG emissions and supports companies to become carbon neutral and reduce their environmental footprint. Moreover, the integrated ESG reporting feature further facilitates companies' climate actions. As SAVEVA connects a broad variety of smart energy systems, it reduces the operational overhead of interacting with different tools and providers. SAVEVA provides its customers with one central platform that connects all smart energy systems. With a comprehensive overview of the energy consumption, it allows for leveraging the optimization potential of individual systems by integrating the collected data into a single AI-based optimization model.



Energy Hardware Providers: Energy hardware providers include companies like thermostat suppliers or smart lighting companies. Not only does SAVEVA promote smart thermostats, but it furthermore enables a re-selling channel for those, making it particularly attractive for suppliers to partner with SAVEVA. Moreover, the top layer software solution provides additional value to the products, leveraging their selling proposition toward the end customers.

Energy and Heating Suppliers: Energy and heating suppliers also profit from SAVEVA's solution. Via partnerships, these companies not only benefit from better and more accurate consumption tracking but can use the platform as an additional distribution channel to contact end customers. Furthermore, the energy accounting and reporting system provides these suppliers with more transparency and higher data quality regarding the energy use of their customers.

Customer Segments

SAVEVA has three main customer segments: users that rent office space, office owners, and governments. There are three main incentives to use the product: climate awareness, cost savings, and interconnectivity of energy systems. They want to reduce their utility bill and their footprint alike.

Companies Renting Offices: For many companies, offices are an essential part of their operations. They are inclined to make the office climate comfortable for their employees. Firms can reduce their office area and use space more efficiently with SAVEVA. The solutions help them to understand how their office resources are being used by integration into existing infrastructure. SAVEVA enables them to reduce their footprint and increase their green public appearance. This segment is reached via distribution partners and online marketing, and they typically start with a basic package.

Property Management Companies with Multiple Properties: SAVEVA helps this segment to understand how different buildings behave and how their customers use office space differently. Objects may have a variety of smart devices, connected to various features of the software that are not interchangeable. The administration is easier because less time is spent scheduling heating and energy provider appointments. Project developers use SAVEVA's solution to renovate old buildings that use resources more sustainably. They are targeted through distribution providers and typically, they are interested in a premium or Climate Hero package.

Governments: Public buildings are often not used efficiently, both when it comes to heating and the use of space in general. With sustainability also being a rising factor in the public sector, SAVEVA helps tackle these two challenges. For governmental customers, it is usually harder to implement change, but their level of impact is also bigger. These customers are reached via providers and benefit the most from the premium or Climate Hero package.

SAVEVA



Customer Relationships

Unsupervised Installation: The customer does not need personal help from SAVEVA to start using the core product. Automatic installation and the simple onboarding process allow an easy transition to the digital overview.

Personal Contact for any Issues: If any issues occur during the installation or operation, trained professionals can assist SAVEVA's customers in all situations, answering questions, and resolving problems. As the first step of help, extensive guidelines and Frequently Asked Questions (FAQs) exist. This targets a high level of customer satisfaction and a high net promoter score.

Over-the-air Updates: To receive security updates, bug fixes, and a steady stream of new features, there is no need for customers to do anything as the updates are automatically installed. Specifically, the monthly subscription fee includes access to all new features without additional cost. This allows SAVEVA's product to be future-proof and increasingly interoperable between brands, working also with very new technology while simultaneously guaranteeing a high level of safety from software errors and hackers.

Customer Self-service Tools: An interactive dashboard allows the customer to view available information at all times. In the dashboard, all settings can be adjusted by the customer clearly and simply. This allows for a smooth customer experience and low support cost for SAVEVA.

Anonymized Feedback Through Telemetry Data: SAVEVA can analyze anonymized customer data to improve its services. For example, algorithms for the control of thermostats can be tweaked based on accurate usage data. Therefore, the customer also adds value to the product.



Channels

SAVEVA is a top layer software solution for existing energy hardware solutions, hence the company targets two channels. First, our company focuses on businesses that already have smart energy systems and sells SAVEVA's solution as a top layer software. Because of the potential savings, there is a clear incentive to switch to SAVEVA. The second channel is directed toward the acquisition of new customers within the target area through the marketing of a joint hardware and

software solution. Customers can then buy the hardware from SAVEVA's partners and the software from SAVEVA directly.

Distribution Partners: SAVEVA uses its network of existing hardware partners for distribution, including specialist dealers and wholesale in the heating installations sector, smart thermostat producers, as well as energy and heating providers. Sales partners profit from selling the company's solution through sales commissions. Smart device producers are incentivized to recommend SAVEVA's AI solution to add more features to their products and have a competitive advantage. Energy and heating providers are inclined to recommend the solution to their customers because it automates the usage collection process for them. Carbon accounting providers promote SAVEVA's solution as a use case for their software.

Marketing: SAVEVA uses typical online platforms used by the target customer segments for online ads. The company focuses on placing ads in all major expert forums, real estate platforms, and comparison portals. Additionally, SEO keywords help prospective customers to find SAVEVA's solutions. A structured sales approach increases the conversion rate within the sales funnel. Ads on comparison portals aim at customers that want to reduce their utility costs; ads on real estate platforms target companies looking for office buildings and are thus interested in reducing their monthly utility expenses.



Key Activities

SAVEVA enables its customers and their smart energy infrastructure to be fully hardware vendor-independent, allowing for maximum efficiency and longevity of use. Additionally, the top layer software integrates various data sources for optimal energy management. SAVEVA's prediction model helps its customers understand how resources are being used within their buildings. SAVEVA's solution includes innovative visualizations while guaranteeing a high level of security and privacy for such critical infrastructure.

Integration of Different Data Sources (e.g., Sensors, Occupation, and Calendar): Many external and internal factors influence the efficiency of electricity use and heating inside office buildings. In traditional solutions, most of these factors are not considered. SAVEVA combines data from calendars, weather forecasts, seasonal effects, geography, alignment, layout of the building, and the occupancy of different rooms. Top Layer Software Development for Existing Hardware Components: The market for smart energy devices consists of heterogeneous products featuring either proprietary or Do-It-Yourself (DIY) software. SAVEVA offers a simple, unified platform for all energy-related IoT devices.





AI Prediction Model for Utilization of Heatmaps in Offices: Once enough data is available, SAVEVA's AI prediction model can forecast future occupancy in different rooms and adapt heating and electricity accordingly. This information is then used for more efficient planning and office space utilization, further driving down costs for SAVEVA's customers.

Front-end Visualization via Dashboards: The platform includes visualization of the office's energy usage and occupation data. SAVEVA will extend this functionality gradually to become the one-stop shop for all information on building-related resources. This digital twin approach helps customers to understand how exactly their buildings use resources and how their employees use the facilities.

Guaranteeing Data Privacy and Security: To minimize any potential attack vectors when integrating into crucial infrastructure, SAVEVA is certified in all relevant security and data privacy certifications.



Key Resources

As SAVEVA is a typical software business, the key resource is having the best engineers in their respective fields. On the hardware side, including different existing smart energy and heating systems is essential. On the software side, SAVEVA needs high-quality data as well as custom algorithms. Finally, trustworthy brand perception is necessary to strive in the rather traditional real estate industry.

Software Developers: As SAVEVA represents a business with high impact on a societal relevant topic combined with challenging problems, it will probably attract talented people. However, the fierce competition in the high professional engineering labor market makes human capital a very costly resource.

Smart Energy Devices: SAVEVA replaces existing traditional hardware like thermostats, power outlets, and other power systems with smart ones from their partners and integrates a majority of existing smart thermostats and IoT devices. SAVEVA connects all these devices on the core platform and uses the data to add value. Therefore, these devices are crucial for SAVEVA's software layer.

Trustworthiness Brand Perception: Both the energy and heating systems, as well as the real estate sector, are very traditional industries subject to operating on a foundation

of trust between participants. SAVEVA is establishing itself by transparently delivering results. SAVEVA has proven to save energy costs through detailed monitoring and understandable dashboards.

High Quality of Data and Algorithms: Most of SAVEVA's value stems from both the existence of labeled data and its intellectual property regarding advanced AI algorithms. This is mainly because every thousandth in efficiency saving is a comparative advantage for SAVEVA, free money for SAVEVA's customers, and fewer emissions.



Key Partners

Smart Energy System Producers: To make SAVEVA's product also viable for customers that do not have existing smart thermostats, smart electricity meters, or other energy-related IoT devices, SAVEVA needs partners that provide these products. SAVEVA offers customers to purchase IoT devices through SAVEVA's website. When a customer signs up for a subscription and buys hardware devices for it, partners pay a commission fee to SAVEVA for each sold unit. To underline the platform independence of the energy optimization software, SAVEVA will not only cooperate with one or two selected companies, but establish multiple partnerships with smart energy system producers. These partnerships are also necessary in order to enable SAVEVA's software to fully control a manufacturer's device. The collaboration benefit for the producer of the smart device is that its customers receive a broader array of features with the same hardware.

Energy Providers: A pain point and cost issue for energy providers, including electricity, water, gas, and long-distance heating, is the manual collection of meter readings in fixed periods. SAVEVA simplifies the process for these providers enormously, allowing simple, tamper-proof digital reporting of the amount of energy used. In exchange, SAVEVA benefits from using the providers as a sales channel, creating an incentive for them to convince their existing customers to switch to SAVEVA's product.

Reporting Partners for Carbon Certification: SAVEVA offers automatic ESG reporting of the impact of office heating and electricity usage on the environment. To offer this reporting in a scientifically sound and credibly certified way, SAVEVA needs a recognized ESG reporting partner. This collaboration also adds credibility to SAVEVA as an environmentally friendly company in general.

Revenue Streams

Revenue is generated through software subscription fees and commissions for selling smart energy devices.

Software Subscription Fees: Businesses choose one of three subscription packages (Basic, Premium, Climate Hero) and pay a monthly fee to use the SAVEVA software. The specific price depends on the customer's office space as well as the selected package. In addition, a discount will be granted if customers choose the annual payment plan. The Basic package includes the automatic adjustment of all office energy systems like electricity and heating. Furthermore, it includes heat maps to track the overall office occupation as well as an accounting integration to directly report the energy consumption to the respective energy providers. The Premium package contains all Basic features and additionally offers integrations for calendars and weather data to further improve temperature adjustments and energy usage. Finally, the Climate Hero package extends the Basic and Premium features with a professional ESG reporting integration as well as a smart room booking tool. Based on SAVEVA's calculations, the subscription fees of all packages are covered by 20-30% of the cost savings of the customers, which creates a financial incentive to use SAVEVA's service.

Commissions From the Sale of Smart Energy Devices: SAVEVA works with existing smart energy systems. However, if customers are not using such systems yet, SAVEVA offers a network of partners to which these customers can be referred. SAVEVA receives a commission fee for each device sold via the SAVEVA website. To underline the platform independence of its main product, SAVEVA will always work with multiple partners and not only recommend one single brand. As the market for smart energy systems gets increasingly saturated, producers of reliable and high-quality devices should be willing to pay the commission fee to draw more attention to their products and increase their market share.

Cost Structure

Initial Investments: Before SAVEVA can start its operations, it needs a basic version of the software, including interoperability with the most common brands of smart heating systems, the features for energy saving through adaptive heating, and the occupational heatmap. This first version of

the software should be already developed in-house to allow the easy development of new features in the future. Therefore, wages for developers are a cost point. In addition, the usual founding cost will accrue, like setting up the business plan, registering the company, research expenses, and the cost of technical equipment.

Fixed Cost: To operate, SAVEVA needs office space and employees. Therefore, the rent and employee wages form the main part of the expenses. In-house software developers are adding new features to SAVEVA's core product, adding interoperability with more and more brands of smart heating systems. The development team needs to also fix any issues continually and react to security threats to guarantee a secure and future-proof product. Besides software developers, SAVEVA also needs salespeople to win businesses as customers and energy providers as partners. To allow operations, administrative and executive staff is also needed. SAVEVA's IT infrastructure is rather lightweight: while a website is necessary, additional server infrastructure is not required as the data is being processed at the customer's company. Lastly, a marketing budget is necessary to gain traction in the market.

Variable Cost: Each additional customer comes with initial acquisition and software installation costs. Besides that, there are fees for external payment processors and an outsourced hotline. To remain attractive and get a high net promoter score, it is very important that SAVEVA also invests in highly skilled personnel for maintenance coordination.

Eco-Social Costs

Electronic Waste From Smart Devices: SAVEVA relies on smart energy systems by third-party manufacturers. While these electronic devices can be more convenient, more flexible, and more environmentally friendly than classical thermostats, AC, and electricity systems, they also require additional resources for their production, such as copper, gold, and rare earths. This increases their CO2 footprint, but also makes recycling more difficult compared to non-smart devices. Therefore, even if the positive impact on the climate compensates for the higher initial emissions during the device lifetime, the problem of electronic waste should not be neglected.

Job Losses Through Automation: SAVEVA's product intends to radically simplify the process of collecting meter readings for energy provider companies. By transmitting the amount

of primary energy used for electricity and heating digitally to the provider company, no manual readings are necessary anymore. This could lead to a loss of jobs if the energy provider does not retrain its employees.

Security Risks of Smart Devices: Due to their internet connection, smart devices may become potential targets of hacking attacks, thus increasing the security risks of companies using such devices. In the worst-case scenario, heating and electricity systems might fail, or might even be locked, leading to limited usability of the office until the problem is fixed. However, hacking attacks also bear a systemic risk for electricity and gas networks, because many single IoT devices can be forced to strike in a concerted attack of amplified power. Therefore, security must be considered in all steps of designing hardware and software of internet-connected devices. After deploying the systems, regular security updates must be provided.

Eco-Social Benefits

Decreased GHG Emissions: The core purpose of SAVEVA is well aligned with efforts to reduce the usage of primary energy to decrease GHG emissions. SAVEVA's product will allow the customer to save energy costs by smartly heating or cooling rooms only as much as needed and reducing electricity usage of (unused) devices. Energy use in commercial buildings makes up 6.6% of global CO2 emissions [440], a large share of which is created by heating. Electricity is a driver of GHG emissions, too, as in an overwhelming majority of countries a large part of electricity is still produced in unsustainable ways. Therefore, SAVEVA has a huge potential impact on the fight against climate change.

Optimized Office Space Usage: Through SAVEVA's dashboard with utilization heatmaps, businesses have a comprehensive overview of how they do - and especially do not - use their available office space. For example, a customer might find out that some parts of their office space are mostly unused. In that case, the company can choose to move to a smaller office or rent out the unused space to other parties. This will, again, ultimately lead to decreasing resource usage and GHG emissions.

Creation of Pleasant Work Climate: SAVEVA helps companies to keep their office at the perfect temperature while not wasting any money on additional heating. This creates a pro-

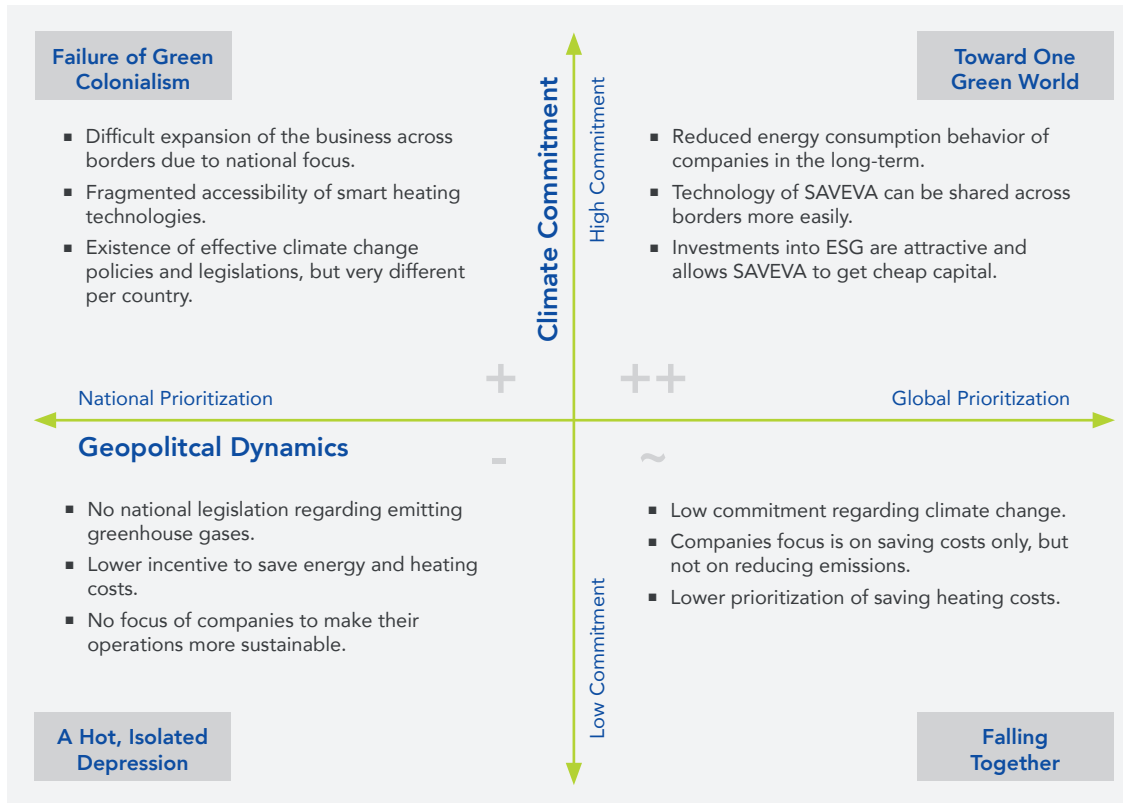
ductive and enjoyable atmosphere in the office, decreasing stress levels, and increasing employee satisfaction. Especially lighting and temperature are work environment factors that are often overlooked but can have a subtle but significant impact on collaboration and individual productivity.

Scenario Fit

Toward One Green World: In this utopian scenario, both individual climate commitment and global prioritization are high. This situation results in a systematic global approach to solving the climate crisis. For SAVEVA's business model this is the best case for several reasons. Companies and individuals adhere to standardized GHG budgets and use SAVEVA's solution to do so. SAVEVA's products are very attractive as even with the use of fully renewable resources, using less is a competitive advantage for customers. The seamless integration into mandatory carbon accounting and reporting solutions allows businesses to boost their brand value. Global governmental policies and shared technical standards make expanding the business across borders very easy. The overall green awareness among investors and their willingness to invest in sustainable companies results in highly available capital for SAVEVA.

The Failure of Green Colonialism: In a world with high individual commitment but national prioritization, SAVEVA's business would still thrive. However, some challenges are more difficult to deal with in this scenario. Companies in different countries have different priorities due to the lack of effective supranational regulations, e.g., regarding carbon prices, or carbon accounting subsidies. Additionally, heterogeneous technological standards lead to a higher effort regarding integrating different devices. However, with rising resource prices, companies still use SAVEVA's solution to save money by using resources smarter. To deal with that, SAVEVA puts more effort into adapting to local markets regarding regulation. The engineering focus lies on integrating different local technologies into the platform. SAVEVA utilizes the individual commitment of consumers by helping building owners improve their green branding through the provably increasing sustainable resource use.

Falling Together: In a scenario with low individual commitment and high global prioritization, companies and individuals focus on their well-being and saving money, but most do not care about sustainable behavior. SAVEVA's



business model is still viable in this scenario. However, it is hard to scale the business. This is because of the imminent lack of commitment to buy products because of their sustainability aspects. The business model can be adapted to better fit this scenario by shifting the focus to the cost-saving benefits of SAVEVA's solution. This selling proposition and the ease of doing business globally allows to target this market easily.

A Hot, Isolated Depression: In a future with low commitment and national prioritization, SAVEVA has difficulty surviving as a business. In this world, neither governments nor companies nor individuals focus on sustainable technologies

and consumption. This implies that all of SAVEVA's environmental benefits do not yield any utility for customers. In this scenario's society, there simply is no incentive to act sustainably. The lack of national legislation makes it even harder for SAVEVA as a sustainability tech provider. However, there might still be an uncertain potential to make a profit in that case. The focus would have to shift toward saving energy costs. However, this highly depends on overall resource prices. This implies that SAVEVA's best bet is on resources to be as scarce as possible before running out of funding.

Challenges

- Proving that SAVEVA can achieve significant energy savings for commercial buildings.
- Capturing the targeted market share and convincing customers of making the additional investment.
- Developing new functionalities to that perceived partners implement competing software solutions.

Outlook

As SAVEVA is still in the pre-seed investment phase, the focus lies on developing a proof of concept that shows an initial 10% efficiency increase over existing heating solutions. This is supposed to be tackled in the upcoming quarter of this year. Subsequently, as an expansion strategy, new partnerships with smart thermostat producers and energy providers will be established. Once the contracts are processed, SAVEVA will enter the seed investment phase. The software service will mature over the first quarter of next year, impacting the market by being one of the leading smart facility management tools. After that, SAVEVA will technologically expand its product by adding electric energy-saving software. Adjusting lights and electrical consumption of devices is supposed to additionally reduce emissions by up to 20%. Finally, a water optimization and monitoring software will be included in the product suite. Even though the extensions for electricity and water will require further partnerships, the increasing energy database of SAVEVA will eventually make it easier to win new clients and form new partnerships.



VERDEO

Leveraging AI for More Reliable, Green Microgrids

The growing number of natural disasters, but also the limited availability of fossil fuels and currently Germany's dependence on Russian gas, are forcing us to act. The Paris Agreement aims to limit the temperature increase between 1850 and 2100 to a maximum of 1.5°C and to achieve a global reduction in CO2 emissions [441]. Energy generation is responsible for two thirds of global emissions and has been increasing in recent years [442]. Microgrids are a promising solution that have emerged as one of the most reliable sources of power generation for future electricity systems [443]. The concept of decentralizing energy infrastructure using microgrids equipped with renewable energy and energy storage is becoming more viable as costs continue to fall and integration problems are solved [444]. Microgrids are characterized by increased grid reliability, higher efficiency, and easier circular economy integrations.

Verdeo is a full-service microgrid and software provider. Verdeo offers a user-friendly plug-and-play platform, enabling a seamless integration of the desired hardware modules and Verdeo's control software. The microgrid can be updated with state-of-the-art green technology, such as solar panels or battery energy storage systems. Customers benefit from a flexible solution tailored to their needs. The core of a Verdeo microgrid is formed by the AI-powered optimization engine. It ensures optimal operation and considers real-time electricity prices, the state of charge of the energy storage, weather forecasts, and consumer behavior. This data is then used to create an exact digital copy of the real-life microgrid, used to simulate changes, make performance predictions, and optimize the dispatch schedule. Furthermore, the maintenance status can be checked in real-time with Verdeo's digital twin. This allows system failures to be prevented at an early stage and extends the service life of microgrid components.

VERDEO

Verdeo provides higher resilience to extreme weather events and cyber attacks, improves the local management of power supply and demand, and guarantees zero-emission electricity. Further, any surplus energy can be fed into the grid and shared with other members of the Verdeo community. The conscious use of energy is financially rewarded and can result in 0 USD electricity costs for the customer.

 **Key Partners**
Electricity Infrastructure

- Grid providers
- Hardware providers

Software Infrastructure

- Cloud providers hosting the critical infrastructure
- Data providers for creating the initial model

Regulatory Stakeholders

- State and municipalities provide regulatory guidance and subsidies

 **Key Activities**

- Developing and maintaining software
- Sourcing state-of-the-art hardware components
- Consulting customers
- Dispatching installation teams to new sites

 **Key Resources**

- Data from all connected components and external factors
- Human capital
- Initial capital to buy or lease grid components

 **Value Proposition**

- Easy access to sustainable technology
- Higher convenience
- Reduced operating and maintenance costs
- Robust, reliable, and independent electricity supply

 **Customer Relationships**
Onboarding

- Personal assistance during setup
- Self-service for basic day-to-day requests

Crisis Management

- Dedicated emergency customer support

 **Channels**

- Directly owned channels
- Positioning toward end customers
- Partner indirect via hardware suppliers

 **Customer Segments**
Residential Buildings

- Real estate developers

Commercial Buildings

- Shopping malls
- Hospitals
- Universities
- Companies

Remote Locations

- Remote villages

 **Cost Structure**
Initial Investments

- Software and website development
- Data acquisition
- First set-up for testing

Fixed Costs

- Office rent, loans, utilities, insurances
- Development and maintenance of battery storage

Variable Costs

- Salaries
- Marketing, sales, customer acquisition
- Cloud computing and storage
- Hardware

 **Revenue Streams**

- One-time set-up fee
- Leasing
- Financing
- Per-user licensing

 **Eco-Social Costs**

- Privacy concerns due to sensitive data handling
- Additional stress on scarce materials
- Government regulations and subsidies

 **Eco-Social Benefits**

- Decarbonizing up to 70% of CO2 emissions
- Contributing toward a zero-emission
- Stronger state independency of foreign energy sources
- Preventing power isolation

Value Proposition

Easy Access to Sustainable Technology: Verdeo's plug-and-play microgrid solution allows customers to access precisely the technology their project requires. Regardless of the size or state of the property, Verdeo offers a variety of microgrid extensions in both hardware and software to fulfill the customer's needs. This process involves little to no effort for the customer, as experts will analyze the project and create possible setups.

Higher Convenience: Setting up a Verdeo microgrid is extremely easy, from start to finish. First, there is no large upfront investment for the project owner, given the leasing revenue model. Second, once the microgrid is set up, everything around Verdeo's product is automated. The microgrid administrator does not need to keep track of the performance, analyze the sensor data to schedule a repair, or perform any other tedious task. The Verdeo engine understands what is best for the customer and automates everything that is needed to achieve it.

Reduced Operating and Maintenance Costs: Using predictive model control, the AI-powered engine optimizes for best consumption patterns, ensures the health of all components, and sends alerts to the maintenance controller. This way, Verdeo can boost the grid's efficiency by up to 14% compared to logic-based controllers [445]. Additionally, with real-time tracking features, anomalies are detected before the grid components are damaged. This results in lower maintenance and operation costs and thus increased consumer satisfaction.

Robust, Reliable, and Independent Electricity Supply: Verdeo's microgrid solutions can store energy and ensure electricity supply even when the main grid is down, e.g., during a blackout caused by a climate disaster. On the one side, the island mode ensures independence from the main grid. On the other side, the AI-powered controller plans power distribution in advance taking into account consumers' behavior and individual configuration.

Customer Segments

Residential Buildings in Grid-Connected Locations: The biggest potential customer segment of Verdeo are real estate developers planning new large-scale residential projects. By including a microgrid solution already in the planning process, the need for refitting existing infrastructure diminishes.

The microgrid and its components can be placed and connected as part of the building process. Real estate companies would buy Verdeo's solution and could use the smart microgrid to market their houses and flats as truly green and self-sustaining living spaces. Apart from new residential areas, Verdeo can be marketed to existing communities that are currently still relying on the main grid. Interested communities can get their electricity infrastructure refitted and converted to a smart microgrid with Verdeo. The plug-and-play solution allows customers to tailor Verdeo to their specific community needs.

Commercial Buildings and Public Institutions: Larger building complexes, such as universities, hospitals, and shopping malls, offer great potential for smart microgrid solutions for several reasons. They usually provide a large area where renewable energy plants could be installed (e.g., parking lots or flat rooftops) and have a stable electricity requirement. Many of these institutions have diesel-fueled backup generators, creating significant emissions upon usage. A microgrid offers the opportunity to use green energy stored in batteries. In light of the increasing energy prices, Verdeo would offer them a long-term solution to source cheaper energy and accelerate their way to a green transition.

Remote Locations: The remote locations that are not connected to the main grid and currently rely on diesel generators to supply their electricity represent the last customer segment. By targeting this segment, Verdeo could reduce the GHG emissions stemming from the traditional fossil fuel based solution.

Customer Relationships

Verdeo pursues a close relationship with its customers since Verdeo operates in a market that requires a high trust level. Energy is a necessity, and blackouts or energy leakages can be catastrophic. Therefore, from the first interaction with potential customers, the brand must convey professionalism, trust, and quality. This must be accompanied by excellent, personal customer support so that in case something does go wrong, customers directly feel comforted, and their issues are solved as soon as possible.

Onboarding: The customer relationship starts after reaching them through dedicated marketing and sales channels. In case of interest, they will receive a personal consultation to find the product constellation that perfectly fits their energy needs and financial capabilities. During the software

onboarding process, the customers receive access to the product, which includes an easily usable software tutorial that guides them through the operating suite.

Crisis Management: When customers run into issues, Verdeo provides them with a phone number reaching a Verdeo agent who solves their problem. Infrastructure services rely on strong upfront trust with their clients, especially in crises. Therefore, it is crucial to have excellent customer service. For issues that are not time-sensitive or energy-critical, a detailed FAQ section answering most questions is provided, allowing customers to easily access the required information.



Channels

Directly Owned Channels: Verdeo reaches customers along multiple streams. The company website includes information about microgrids, their benefits to access green energy, as well as the comprehensive offering of Verdeo. The website is often the first touchpoint the customer has with Verdeo. Therefore, it must include Verdeo's key selling points and pricing model while establishing trust through clean design and professional appearance. The website also includes a direct connection to sales agents, who personally answer the questions potential customers might have. This ensures a personal relationship from the beginning.

Positioning Toward End Customers: In addition to word of mouth, Verdeo intends to actively pull potential customers to the website through marketing campaigns. The focus here is on both companies and individuals. This way, Verdeo creates the demand either directly at the person responsible for setting up the energy supply or through a demand-pull from the electricity user. Marketing to both customer groups in parallel requires having multiple persona-fitting messages. The end-user is mainly exposed to the green movement behind smart microgrids and the comparison to conventional, non-green energy sources. In this comparison, Verdeo highlights the lower price originating from the self-supplying nature of their microgrids. In the case of an already energy responsible individual, they would rather be steered toward easy energy handling, 24/7 monitoring, and crisis avoidance through predictive maintenance.

Partner Indirect via Hardware Suppliers: Further, Verdeo intends to establish close partnerships with module suppliers, who will ideally list Verdeo as their preferred integration platform for their products. Exclusive hardware licensing agreements will be set up, allowing customers to buy the latest innovation in renewables technology on the market at a lower price. The partner can focus on their core business, producing modules, while Verdeo and its installation teams handle the operation and setup of the grid itself.

Key Activities

Products and Services: In order to keep up with technological advances, the AI engine and Verdeo's digital platform, the software needs to be improved constantly. Furthermore, Verdeo aims to deliver a flexible product tailored to the customer's needs. This is especially relevant when it comes to the hardware components of a grid. That is why Verdeo sources state-of-the-art components from an extensive network of providers, enabling microgrid customers to always benefit from the latest technology.

Managing Customer Relationships: Microgrid projects are highly individualized. For this reason, most of Verdeo's activities revolve around the customer. Verdeo must understand their needs, wishes, and the project's circumstances to suggest a grid setup that best fits their case. After a successful acquisition, Verdeo dispatches an installation team of the appropriate size and skills for the given project. Once this process is finished, Verdeo continues working closely with the customer during the installation, the creation of the digital twin, and the setup of the grid administrator platform. While most of Verdeo's smart microgrid functions are automated, the project owner might have different requirements regarding what kind of data they prioritize.

Once a microgrid is successfully installed and running, Verdeo keeps track of the maintenance status of all components and whether any of them can be upgraded to newer technology. In that case, a maintenance team is sent automatically, to take care of the repair or the upgrade.

Key Resources

Data: With an AI engine at the core of Verdeo's product, data plays an essential role. On the one hand, Verdeo needs data on hardware wear-out signs, historical electricity prices, and battery life cycles to build and improve the engine. While some of this data is easy to gather, hardware wear-out signs used for predictive maintenance, for example, are often kept secret by the manufacturer. On the other hand, Verdeo needs a constant stream of data once the grid is operating to make simulations and optimizations. This data includes real-time performance data, metrics on the grid load, and general consumption behavior.



Verdeo

Human Resources: There are several areas where Verdeo relies on skilled employees. First, Verdeo requires microgrid experts that understand how the components integrate, perform and decay over time. These experts need to work closely together with the AI developers since all their grid knowledge must be reflected in the architecture of the models. Second, given that Verdeo works closely with the customers, large operations, sales, and customer success teams are essential. Lastly, Verdeo aims to build a vast network of maintenance and installation teams across the market. This is crucial to support customers quickly, as a failure in the electricity system can be disastrous. In the beginning, these teams could be provided by hardware partners directly.

Initial capital to buy or lease grid components: In order to offer state-of-the-art hardware components from the beginning, a significant initial investment is needed to either buy the components directly or lease them from the respective providers. Verdeo aims to find agreements with hardware providers to have Verdeo's customers lease the hardware directly from them. This would significantly reduce the initial capital needed.

Key Partners

Electricity Infrastructure: The local grid provider is an important partner for Verdeo since, in most cases, Verdeo's microgrid solution will still be connected to the main grid to supply energy for times when the microgrid cannot supply enough energy on its own to meet the total demand. Furthermore, surplus electricity can be fed into the main grid to stabilize it and generate additional revenues. Next, Verdeo's ability to source high-quality and low-cost components highly depends on its relationship with hardware manufacturers, such as solar panel or battery manufacturers. Their hardware will be integrated into the microgrid solution and require sensors compatible with Verdeo's system. Lastly, Verdeo needs to partner with local service providers, who install the microgrid components.

Software Infrastructure: Verdeo's software platform aggregates data from various parts of the grid and optimizes the model based on multiple microgrids. A cloud provider is needed to host the smart microgrid infrastructure. Given

that electricity is considered a highly critical resource, these providers need to be reliable and equipped with high-security standards to avoid cyber attacks. This is of great importance, otherwise, the product cannot be applied in hospitals or other critical institutions. Verdeo's initial model will be dependent on external data from existing grids and microgrids, resulting in a need for strong relationships with the data providers.

Regulatory Stakeholders: The expansion of renewables strongly depends on regulatory incentives to switch from fossil fuels to renewable energy solutions. Government subsidies, for example, make it more attractive for people to switch to microgrid solutions. Besides being potential customers, municipalities are key partners for the smart microgrid implementation since they provide building regulation and infrastructure for all buildings in their area.

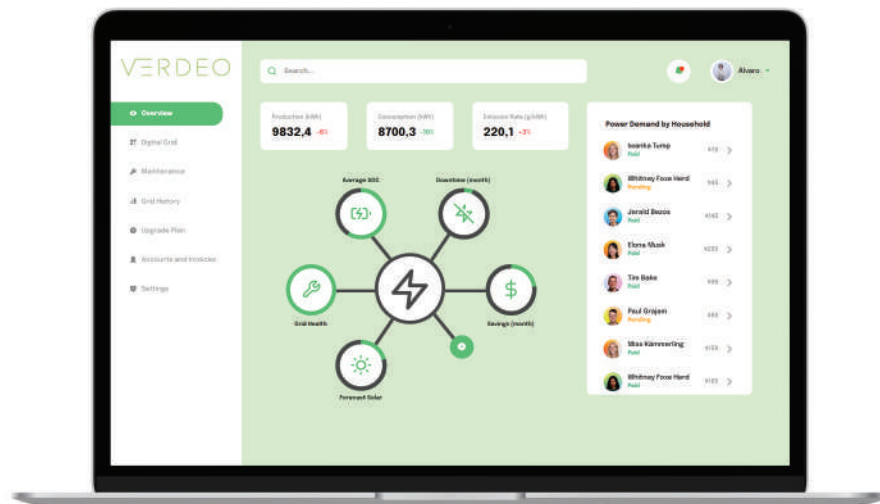
Revenue Streams

Verdeo's revenues are generated from both one-time setup fees per project and recurring revenues per customer. Two models with different options are proposed by which the product can be offered to a wide range of different customers. Either the software alone is being provided through licensing, or the customer can benefit from an integrated software-hardware solution.

One-Time Setup Fee: After subscribing to Verdeo, the customer must pay a one-time setup fee. This fee is calculated according to the type and number of devices installed and connected to the grid. It also includes the customer advisory and matching the software to the client's requirements.

Leasing: Verdeo charges a monthly fee dependent on the number and type of devices being installed as well as the duration of the leasing contract. Therefore, the hurdle to choose the product from Verdeo is lower, as no high investments are required.

Financing: To create an additional revenue stream, the customer can also choose a financing model. The monthly fee depends on the amount of the down payment. At the end of the financing, the customer has the option of keeping (e.g., solar panels) or re-selling the product.



Per-user licensing: Verdeo's core competence is software development. The customer can select from different software solutions. There is also the possibility to upgrade the software in an existing micro-grid to Verdeo's smart, AI-based solution instead of a logic-based solution. The customer can pay on a monthly basis per user. Since Verdeo's value increases with each acquired customer, user-based pricing was chosen.

Cost Structure

Initial Investments: Before the launch of Verdeo, several expenses are incurred for accounting, legal and administrative purposes. It is further necessary to cover the costs of product development. This includes data acquisition, training and testing of the model, and design and user testing of the platform. Verdeo's code is written in-house by software and AI engineers collaborating with data analysts. Investments in early marketing, SEO, and online advertising will be required to build strong brand awareness, making Verdeo visible to the customer. In addition to the costs for the platform and the foundation, the office's initial setup, including technical and office equipment for employees and further R&D, is an additional source of costs.

Fixed Costs: Significant fixed costs are personnel costs for customer support, marketing, software development, and administration staff. Since Verdeo's core competence lies in software development, acquisition of local service providers, e.g., for the installation of solar panels, energy storage systems, and the execution of maintenance work is needed. Additional costs are related to the operational activities of Verdeo. These include rent for the office, utilities, human resource (HR) management, legal, accounting expenses, insurance fees, and costs of IT maintenance and hosting.

Variable Costs: The most considerable variable costs occur due to hardware and maintenance services and increasing client support. These variable costs are also related to interactions with potential or existing customers. This includes customer acquisition and costs of tailoring Verdeo to the customer. Moreover, certain parts of the IT infrastructure which Verdeo outsources, such as data storage and data processing, are cloud-based and can therefore be scaled dynamically, depending on the current number of customers.

Eco-Social Costs

Data Handling: Building a digital twin, setting up interconnectivity of components and grids, and overall development of the plug-and-play system requires a lot of data about consumer consumption, grid parameters, and operation and fault behavior. Initially, Verdeo must rely on data provided by other players in the energy market or open-source data. After setting up the installations, Verdeo will record the consumption patterns to optimize the performance of its service and its own site user's data (e.g., consumers). In both phases, Verdeo must consider the social cost of interfering with customers' data privacy. Especially in cases where there are multiple data subjects involved, Verdeo must use high-security methods to prevent data misuse and work according to ethics and data protection laws.

Additional Stress on Scarce Materials: Despite sustainably generating electricity, the production and recycling of components built into the microgrids still requires fossil fuel-heavy resources. Expanding the global microgrid market increases the production of components such as solar panels and batteries. This, in turn, creates high emissions and exploits scarce natural resources, further accelerating climate change. Furthermore, when processing the non-recyclable waste produced during the installation or operation of the microgrids, Verdeo must not only act in accordance with local laws but also find a sustainable way to deal with such waste. Otherwise, Verdeo's attempt to make an impact and fight climate change would be neutralized.

Government Regulations and Subsidies: The current market of sustainable microgrid operators is not saturated. However, to accelerate the adoption of sustainable microgrid solutions, there must be more governmental action. This is expected to happen in the following years given the rising climate change awareness and growing urgency due to scarce natural resources. Nonetheless, in many countries, including Germany, lobbyists representing competitive market leaders in the energy sector influence the decision-making or even slow down the regulations and subsidies for solutions that advocate energy grid decentralization.

Eco-Social Benefits

Decarbonization of 70% CO2 emissions: Pollution caused by energy production accounts for about 70% of global emissions [446], with more than 50% coming from burning fossil fuels [447]. In Germany, traditional grid and energy sources make up 60% of the gross energy consumption. With Verdeo, meeting net-zero energy goals becomes possible. Installing Verdeo's microgrid solutions contributes to lowering carbon emissions by removing the less efficient and high-emitting traditional grid from the consumer's chain.

Contributing toward a zero-emission world: Easy access to reliable and environmentally friendly energy sources would empower more people to switch from traditional, environmentally unfriendly energy sources to sustainable microgrids. Verdeo contributes to higher social acceptance by being a one-stop shop for state-of-the-art microgrid systems, thus offering a convenient and affordable way to contribute to a sustainable future. In addition, user consumption optimization and covered maintenance boost the social acceptance of sustainable alternatives.

Stronger state independency: Germany is highly dependent on foreign energy imports and thus suffers from price fluctuations caused by, e.g., political tensions [448]. By switching to sustainable energy sources, Germany can actually gain autonomy in the process [449]. Even on a more local level, by



Verdeo

installing affordable, highly efficient microgrid solutions from Verdeo, communities can become independent of political ties and price fluctuations and contribute toward decarbonization.

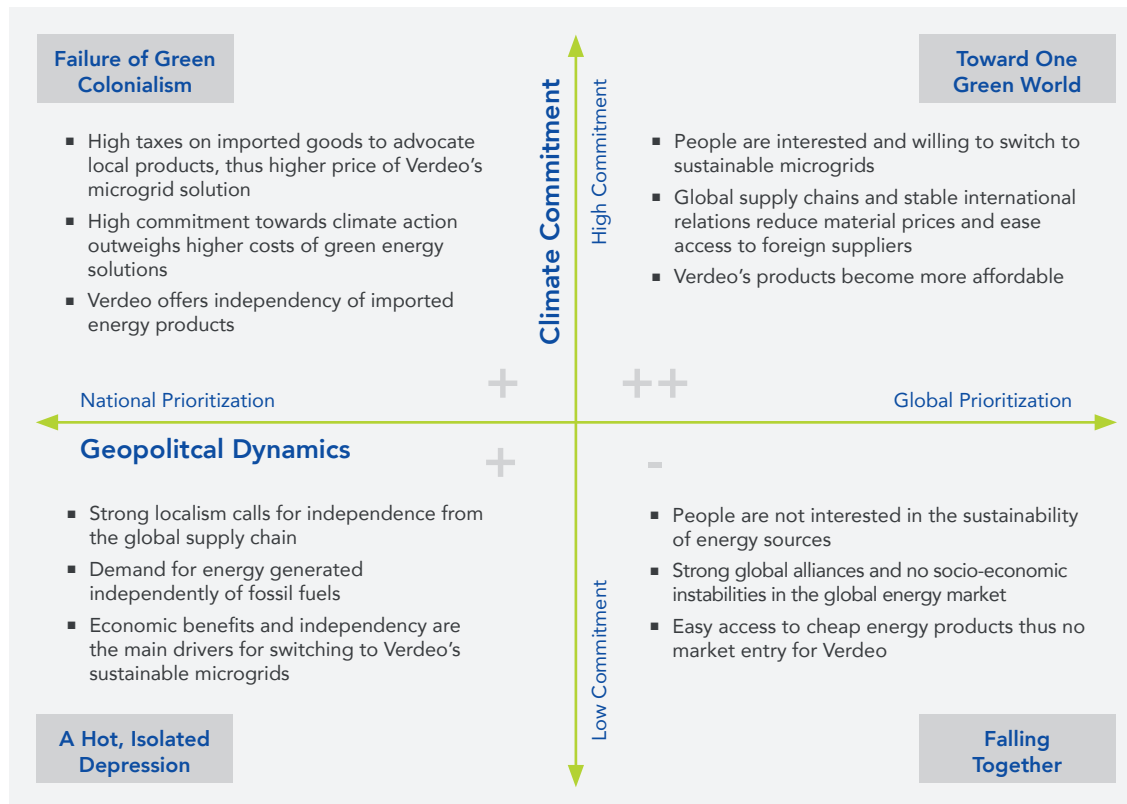
Preventing power isolation: As climate destruction progresses, natural disasters and other extreme events become even less predictable. Furthermore, political tensions in Europe could provoke significant power blackouts in Germany and across the continent. Being able to operate completely disconnected from the main grid, Verdeo's microgrids remain operational even when the main grid is down.

Scenario Fit

Toward One Green World: Verdeo's microgrid solution would be a perfect match in a world united to fight climate change. In this scenario, people are highly committed to sustainability. They would be willing to invest more in zero-emission energy since fossil fuels in energy generations account for almost 70% of global emissions. Furthermore, well-established, and stable global supply chains would allow for lower prices of materials and easier access to foreign suppliers. This would help Verdeo appear even more attractive on the market by widening its product portfolio and being more affordable. With the pressure of society and higher demand for sustainable energy, new residential areas would be built to be sustainable. Having expertise in setting up microgrids with predictive control and high efficiency, Verdeo could enter this market early and be involved in the early stages of construction planning.

Failure of Green Colonialism: In a scenario of high climate commitment and strong local prioritization, society strives for independence and a sustainable future. To limit the dependency on foreign partners, countries would look for alternatives to imported oil and other fossil fuels. Strong local prioritization would also mean higher taxes on imported goods and thus raise the cost of Verdeo's energy solutions. However, people are committed to fighting climate change and would be willing to sacrifice for the benefit of their local environment. In such a setting, Verdeo could offer an ideal solution for providing a robust, independent, and emission-free energy source. Installing Verdeo's microgrid systems would contribute to higher autonomy and benefit the local environment.

A Hot, Isolated Depression: Strong local prioritization requires independence from the outside world. Countries would be reluctant to participate in the global trade system and look for alternatives to all imported goods, especially



those that may endanger national autonomy, such as oil and other fossil fuels. Despite low climate commitment, there would be a market for solutions that ensure reliable and independent energy supply. Verdeo could further expand its services and offer to operate the network of green microgrids. However, as there is no climate awareness, the economic benefits and affordability would dictate the adoption of the new technology and Verdeo's product. If Verdeo could manage to offer an affordable solution, despite potentially higher costs of some components, microgrids could be an attractive option for independent energy supply. Otherwise, the low climate commitment hinders the establishment of a sustainable business model.

Falling Together: A society with low climate commitment in which communities rely on a global supply chain would not prioritize green energy. In such a scenario, international relations and global trade would be flourishing. There would be no disruptions in global supply chains. Importing fossil fuels and other unsustainable goods would be increasingly adopted, disorienting people from pivoting to microgrids. Furthermore, global alliances create security funds and would be willing to share natural resources, avoiding socioeconomic inequalities in the energy market. On a societal level, there would be no common understanding of the problem caused by emissions of generating electricity. In such a world, there would be no market share for sustainable and decentralized solutions.

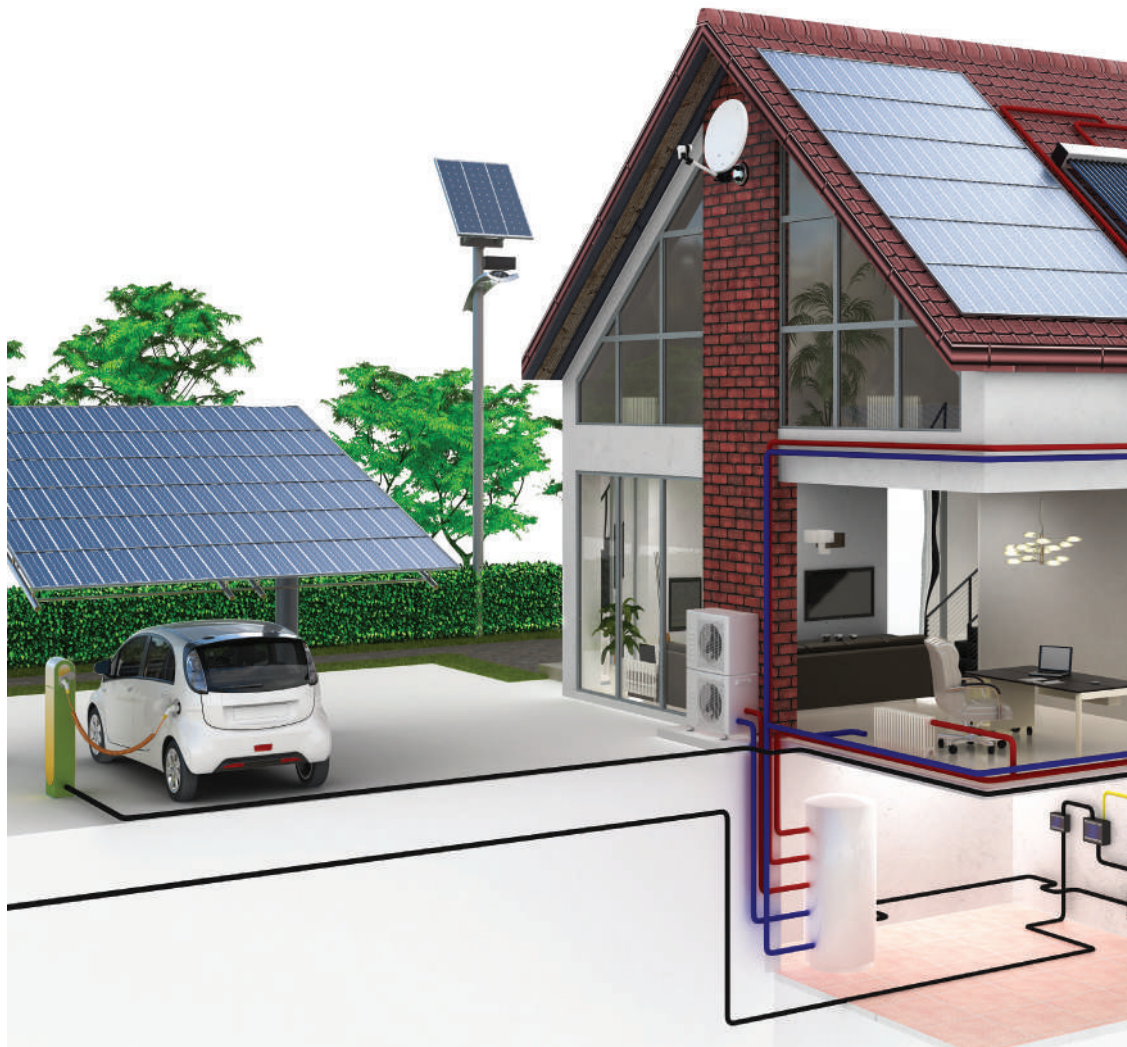
Challenges

- Clean and well-structured data is of high importance for Verdeo. The heterogeneity of the initial data could pose technical problems for the controller and predictive maintenance model development.
- Microgrid applications in critical infrastructure (e.g, hospitals) require very high model accuracy.
- To provide affordable plug-and-play solutions, Verdeo needs tight relationships with a lot of suppliers. This will take time to establish.
- A shortage of skilled workers setting up the microgrid would make a fast implementation and scale-up difficult.
- Convincing people living in an area with a stable main grid of the need for a microgrid can be challenging.
- The greenflation phenomenon poses a risk to the affordability of microgrid components. As a result, fossil fuel energy from the main grid might be a cheaper option.

Outlook

Verdeo envisions itself to become the leading provider of reliable, green microgrids for communities and businesses. This would ensure the required resilience of the energy system that is needed to serve the future demand reliably.

The importance of green energy is significantly growing due to high fossil fuel prices and further accelerated by emission reduction targets. Because of the government support, Verdeo plans to launch first in Germany and then scale up to Europe and the world. Germany plans to phase out coal energy and has just announced the target of having net-zero energy by 2035. Currently, renewables make up only 40% of the energy mix. Verdeo tries to bridge the gap to 100% renewables by leveraging AI to control the grid and solve the problem of intermittent energy source control. Furthermore, the growing number of microgrids allows Verdeo to capture economies of scale, and the respective data points offer the potential to improve Verdeo's controller module and the predictive maintenance solution. Based on these insights and considering recent events, Verdeo's market potential and relevance will be increasing in the years to come.



REDROP

Shower Differently

Freshwater scarcity is increasing worldwide and conflicts about water sources will emerge, making water-saving increasingly important. The most significant part (approx. 36%) of freshwater in German households is used for showering or bathing, which makes it particularly interesting as a savings potential. The used shower water is considered greywater requiring a less intense cleaning and purification process, but this advantage is lost once it is contaminated with blackwater, e.g. from toilet flushes. Additionally, warming the shower water costs a lot of energy which is lost once it goes down the drain. To make showering economically and environmentally more sustainable, the greywater should be reused and the warmth conserved.

A handful of companies already offer solutions that work through pumping up the water from the drain, cleaning and filtering it, and reintroducing it into the showerhead.

This way, around 80% of water can be saved and less energy is needed for warming it. However, current solutions are expensive with a price of about 5000EUR and thus not widely adopted yet. Redrop's mission is to make this sustainable technology accessible to everyone by transforming the existing business model into a service-based offer.

Households get to know the Redrop system through advertising campaigns, their local plumber, or furnishing houses. After the initial ordering, the shower system will be delivered and installed by one of its partnering sanitary installation companies. The customer does not need to pay anything up to this point and can start showering immediately. The shower tracks how much water is purified and therefore saved. Redrop then sends the customer a utility bill for the amount of purified water, charging a rate below the local utility providers'. This way, less freshwater is used overall, the customer



saves on water and energy, and Redrop pays off the upfront investment costs. The customer will conduct regular occurring maintenance tasks like filter exchanges. To ensure availability and cut shower downtime, AI is leveraged for predictive maintenance. Further, the gathered data will be used for fraud detection preventing intentional misuse.

 **Key Partners**

- Component and infrastructure suppliers
- Real estate builders
- Global advertising platforms
- Local sanitary installation companies
- Global shipment providers
- Financial institutions

 **Key Activities**

- Product development
- Marketing and partner management
- Predictive maintenance
- Assembly and installation
- Financing

 **Key Resources**

- Durable hardware components and data capital
- Human resources: engineers, AI and software developers
- Loans from financial institutions

 **Value Proposition**

- Scarce resources saved (energy and water)
- Money saved
- Transparency on resource consumption

 **Customer Relationships**

Customer-facing app offering:

- Data confidentiality
- Direct feedback loop
- Transparent impact
- Centralized service offering

 **Channels**

- Online marketing via social media, paid advertising and SEO
- Offline marketing via TV and radio advertising, furnishing fairs and print media

 **Customer Segments**

- Households with 2+ people (low to middle income)
- Single households focused on sustainability (middle to high income)
- Secondary focus on B2B (fitness studios, hotel chains, swimming pool operators)

 **Cost Structure**

Initial Investments

- In-house development costs on system design
- Engineering team salaries
- Investments in equipment

Fixed Costs

- Research and development
- Human resources (e.g., experienced engineers)

- Assembly and storage facilities
- Interest rates on loans

Variable Costs

- Hardware supply
- Delivery & installation
- Spare parts & maintenance
- Marketing

 **Revenue Streams**

- Yearly utility bills for saved energy and purified water
- Yearly base rate
- Advertisement revenue and data monetization

 **Eco-Social Costs**

- Low utilization of water network
- Collection of private data
- Increased logistics efforts
- Hindering mindset change

 **Eco-Social Benefits**

- Reduction of water and energy consumption
- Awareness about resource consumption
- Stress reduction on local infrastructure
- Accessibility to a sustainable life



Value Proposition

Redrop's value proposition to customers is based on three pillars: saving costs, saving energy and water, and gaining transparency on their resource consumption.

Saving Costs: Redrop's technological solution allows users to save around 25% of their energy and water bills related to showering (depending on the length and temperature of each shower). Due to the dynamic pricing model based on local utility prices, these savings can be generated independently of the customer's location. Assuming regular shower usage, there is no green premium needed to act sustainably.

Saving Energy and Water: Using Redrop's product, water consumption in the shower is reduced by roughly 80% and the energy consumption is reduced by approximately 70%. These savings directly positively impact the scarcity of water and emissions caused by the underlying energy sources. Thus, Redrop provides customers with an easy way to cut down their ecological footprint without actually having to change their lifestyle. This factor also makes the product attractive for single households or people who seldomly shower but want to act sustainable and are thus willing to pay a green premium.

Transparency: Through the Redrop app, the impact of showering behavior on the environment is made transparent to the user. This allows users to get a better understanding of their footprint. The transparency incentivizes sustainable behavior like buying water-efficient showerheads.



Customer Segments

Redrop's general focus lies on customers living in metropolitan areas, where utility costs for water and energy are usually higher. Thus, the financial incentive for using the Redrop shower system is higher. Besides the monetary incentive, metropolitan areas also simplify the establishment of a broad partner network with plumbers, real estate developers, and furnishing houses.

B2C as Main Target Group: Within the metropolitan areas, Redrop's main customer segment is individuals (B2C). Cost-wise, the usage of the Redrop system makes sense for

households with one shower and two or more people that regularly use it. Thus, one segment of the B2C space contains multi-person households such as families or shared flats. Unlike its competitors, Redrop does not require any high upfront acquisition and installation costs and is thus especially interesting for the lower to middle-class income group. However, the incentive to contribute to saving the environment by conserving water and energy is also relevant for single households. This is reflected in Redrop's second segment of the B2C space, namely the "single or two-person households with a strong sustainability focus". This group consists of high-income singles or couples committed to acting sustainably. They are willing to install the filter system despite the fact that they might have to pay a 'green premium' because their money savings are below Redrop's yearly base rate.

B2B as Secondary Target Group: Redrop's pricing structure is particularly interesting for individual customers. But the filter system could also be of great value for businesses or public organizations such as fitness studios, hotel chains, or swimming pool operators, as the showers in their facilities are used very frequently.



Customer Relationships

After targeting and convincing customers via both offline and online sales channels, Redrop's main channel to maintain the relationship with its customers is the app. All core functionalities that serve the customer are built-in.

Data Confidentiality: Since the collected data on the personal shower behavior is very private, it is only transparently shown within the app. Furthermore, the app shows how the data is being used.

Direct Feedback Loop: The app offers a direct feedback opportunity, meaning that customers can directly impact product development. This increases customer stickiness and gives Redrop insights into how customers perceive the product.

Transparent Impact: Customers using Redrop's product can be motivated by two reasons: financial attractiveness and reduction of resource consumption. The impact on savings of both money and resources is transparently shown within the app. Tracking one's impact is fostering climate and finance

awareness while at the same time continuously reinforcing their motivation of using Redrop.

Centralized Service Offering: Monthly utility bills are digitally managed via the app by allowing the user to store financial information and directly contact Redrop's customer support if inconveniences occur. Furthermore, maintenance tasks can be seen and communicated via the app. A continuous overview of the lifetime of all product components enables users to plan maintenance tasks well in advance. Via the app, customers will also be updated about new product developments.

Having such a close relationship with the customers via the app is one of Redrop's main competitive advantages over other market players having only one touchpoint with the customer at the point of sales.



Channels

Online Channels: Redrop uses a variety of online marketing strategies. As a company focusing mainly on B2B customers, the online activities are targeted toward two main segments: Social media advertising as well as SEO and Google Ads. Environmentally-focused influencers will cooperate with Redrop to present the shower filter system to their broad audience, specifically emphasizing the absence of any high upfront costs for the installation. Paid ads on YouTube will be shown primarily on climate change documentaries and furnishing-related content videos. High-quality website content such as knowledge blog posts around the topics of affordable, sustainable living will help Redrop to push the search engine ranking organically. In addition, Redrop uses specifically targeted keywords such as "water recycling", "shower filter systems", and "water consumption" to target potential first-mover customers.

Offline Channels: As not all potential customer segments can be reached via online media, Redrop uses offline channels to target an even broader, not as digital-native, audience. A huge part is focused on TV advertisements as well as podcast and radio spots. 15 to 20 second spots during prime-time on private channels such as ProSieben and short advertisements on local radio channels play an important role in reaching the low- to middle-income class across age groups in the short term. Traditional channels like furnishing fairs and print

Redrop

media (flyers and posters in public bathrooms, advertising pillars, and bus stations) enrich the offline channel targeting. After the market launch, a specific focus will lie on equipping existing customers with additional print media, accelerating the word of mouth advertising. Finally, plumbers, real estate builders, and furnishing houses can be used to reach customers across the first four of the five channel phases (awareness, evaluation, purchase, delivery, after-sales). By leveraging the partnerships with these players, potential Redrop customers do not only gain awareness but are properly supported in the complete evaluation, purchase, and delivery process.

Key Activities

Product Development: To build a customer-centric product, continuously challenging the product design and gathering user feedback is at the core of Redrop. Since Redrop delivers a hardware product installed at its customers' homes where it cannot be maintained, before the launch it needs to be sure that the core elements of the product are defined and developed. The main challenges during the product development will be to efficiently manage the complexity of a multi-part hardware system and create a state-of-the-art sensor system efficiently handling the blending of our purified water with freshwater, achieving the right temperature and pressure. After launching the product, it is planned to further enhance the offering through customer feedback. These enhancements will mostly focus on the software side of the product.

Marketing and Partner Management: Moving into the consumer market, creating awareness for the product and the brand is essential to achieve critical market penetration. Both large-scale marketing campaigns and valuable partnerships with real estate builders are needed to gain visibility within the core customer segment. Only playing both channels will allow Redrop to scale quickly, become profitable, and achieve massive reductions in energy and water consumption.

Predictive Maintenance: By offering a subscription model that covers all costs for the end customer, keeping the maintenance efforts low is fundamental for profitability. Low maintenance efforts are achieved by analyzing the sensor data gathered in the showers with machine learning algorithms predicting the lifetime of all product components. This prediction allows for efficient spare part management, ultimately cutting downtime of the shower systems and increasing comfort for the users.

Assembly and Installation: Managing the hardware value chain efficiently will cut costs and keep the promise of excellent product quality. Critical steps are assembling the product components and installing them at the customer site. As Redrop expands to more locations, coordinating the installation partners will quickly become very complex and time-intensive.

Financing: Offering a subscription model will demand high upfront investment. To ensure financial liquidity during the scale-up phase of Redrop, several financing streams are needed. Only with such, many European cities can be reached during the expansion.

Key Resources

The critical resources for Redrop's success span along the different dimensions of its value chain: production, installation, maintenance, and billing, complemented by financing as a supporting element.

Hardware and Data Capital: Reliable and monitorable hardware components build the foundation of Redrop's shower systems. First, it reduces expensive repairs and maintenance. Second, it is the primary source for gathering data regarding usage but also the state of the shower system. The data lies at the core of enabling AI-based approaches in Redrop's predictive maintenance and fraud detection strategy. The predictive maintenance allows the state tracking of the showers hardware components and possible malfunctions. Furthermore, it will be combined with usage-related data to detect possible fraud from users by changing the system after installation.

Human Capital: Redrop needs to hire skilled engineers, AI specialists, and software developers to build the product. The network of trustful local sanitary installation companies enables Redrop to physically bring the product to Redrops customers and create brand awareness.

Financial Capital: The as-a-service business model is very capital-intensive, so Redrop needs to take on a lot of debt. This will be especially important during the ramp-up phase when entering the market. Good standing with banks is crucial for Redrop and governmental funds focusing on the support of green technologies can potentially further facilitate the credit approval process.





Key Partners

Establishing Redrop in every household requires an entire value chain from product manufacturing over installation to maintenance. Partnering with other companies along the product life cycle is crucial to reduce the complexity and let Redrop focus on its core activities.

Component and Infrastructure Suppliers: Redrop's shower system combines several standard components such as sensors, filters, UV-radiation units, and valves. Most of the components are supplied by specialized hardware partners to reap the benefits of economies of scale. Redrop's business model is built around a durable shower solution, long-lasting components are the foundation requiring a deep and trustful relationship with suppliers.

Real Estate Builders and Global Advertising Platforms: The current unawareness and misconceptions around sustainable showering require a strong marketing campaign. Redrop initiates two distinct partnerships accounting for the differences in customer situations of having new and old bathrooms. Real estate builders promote the shower system as a configuration option to directly include them for new houses. Global advertising platforms offer access to Redrops customers across segments, create awareness, and finally, momentum.

Local Sanitary Installation Companies: To install the showers in the customer's bathroom and incorporate local differences across regions, close collaboration with local sanitary installation companies are key. Special care is given to these relationships as the installation process constitutes the first personal touchpoint and accurate execution influences the later working of the shower.

Global Shipment Providers: Due to the regular exchange of the shower's filter system over time, their distribution and shipment is an important part of the post-installation product phase. Global shipment providers are especially valuable to take advantage of their distribution networks enabling us to keep a few central storage locations while keeping shipment times low.

Financial Institutions: The nature of Redrop's business model requires a high upfront investment with R&D, installation, and production costs. Debt and investment will be crucial to run the business. Therefore, financial institutions are a key

partner for sustaining the ramp-up phase until the incoming paybacks are established.



Revenue Streams

As Redrop offers the distribution and installation of the water purification system free of charge, the main revenue stream is based on billing the customer for every cubic meter of purified water used and kilowatt-hour of electricity saved. A yearly deductible base rate ensures the economic viability of the installation. Additional smart shower functionalities like personalized shower profiles, water usage, and saving statistics can be accessed through an app that is monetized through ads.

Yearly Utility Bills for Saved Energy and Purified Water: Redrop's main revenue is generated by charging its customers for the energy they save and the amount of purified water they use. The water usage as well as the exact temperature of the water are tracked by sensors and directly reported to Redrop through the smart connectivity capabilities of the shower. The water temperature is then used to estimate the amount of saved energy. Redrop bills the customer dynamically for the saved electricity and water at 60% of the local utility provider rates.

Yearly Base Rate: Redrop charges a yearly base rate that is fully deductible from the saved energy and purified water utility bills a city sends out. This makes Redrops revenue streams more predictable and ensures costs are covered. It also sets an incentive to only install the shower in bathrooms where at least two people shower regularly.

Advertisement Revenue and Data Monetization: The app gives the customers access to additional functionality. In-app advertisements serve as an additional revenue stream and are sold to energy providers, toiletries manufacturers, and companies offering other water-saving solutions. As the shower collects detailed information on the individuals' resource consumption behavior, anonymized data can be collected over time and then sold to interested parties such as local water suppliers or shampoo providers. This, however, has to be closely aligned with Redrop's privacy goals.

The cost structure will change as Redrop shifts its focus from growing the business to day-to-day operational activities. Initially, most of the expenses will be related to developing the product. Later, resources will be focused on running the assembly lines, distributing, and maintaining the product.

Initial Investment Costs: Initially, a lot of resources will be spent on designing the system, as Redrop aims to develop the shower solution in-house. At the beginning of the development process, the most significant costs will be the salaries for experienced engineering staff and the necessary technical equipment. Later, investments into machinery for scaling the production and initial marketing expenditures become necessary.

Fixed Costs: For the product assembly line and storage facilities, multiple buildings need to be rented. As Redrop's business model is very hardware-intensive, interest rates on loans to finance the shower systems are a major fixed cost. Highly qualified civic and environmental engineers are needed to develop and improve the product, making personnel expenses another important, regular cost. Besides direct marketing campaigns, other fixed costs include subscriptions to office software, communication platforms, project management tools, and website hosting.

Variable Costs: Most of the variable costs are product-related. Redrop buys the parts from different suppliers and assembles them in its facilities. Launching offline marketing campaigns will be a major variable cost as Redrop scales its business operations. When a customer orders the shower system via one of Redrop's sales channels like plumbers, online advertisements, or furniture houses, the partner generating the sale receives a commission. Then, another partner is paid by Redrop to deliver and install the system. Once installed, the system needs regular maintenance, which generates additional costs for spare parts.

Utilization of Water Network: In areas without water scarcity, water supply networks are often not designed to perform with little water throughput. Some utility providers flush additional water through water pipes to ensure the functionality and cleanliness of the pipes. The solution provided by Redrop could intensify this problem by massively reducing the water used for showering. This problem, however, should remain relatively local to a few cities since water scarcity is a much larger problem.

Collection of Private Data: Collecting data on shower behavior is strongly personal. Handling this data trustfully is essential to ensure a long-term relationship with the customers. The collection of this private data poses a potential risk to Redrop that could become a cost if data security measures are not put in place. Potential outcomes could be hackers getting access to the data analyzing the behavior of the household or data leaks that lead to social media shaming.

Logistics: Redrop's shower system has more exchangeable parts than a standard shower, mostly due to the filter components. To reduce the maintenance-related costs, the product is designed to allow for the exchange of spare parts by the customer. Providing the customer with the right spare part at the right time leads to increased use of resources and logistics overhead from delivery and packaging.

Hindering Mindset Change: While Redrop's product reduces water and energy consumption, it might also hinder the mindset change toward greener behavior. Showering long and hot will become more sustainable, which might be perceived by customers as a proof point that their individual behavior does not need to change. Such a barrier could reduce the adoption rate of other behavioral changes needed to tackle climate change, like changes in diet or flight habits.



 Eco-Social Benefits

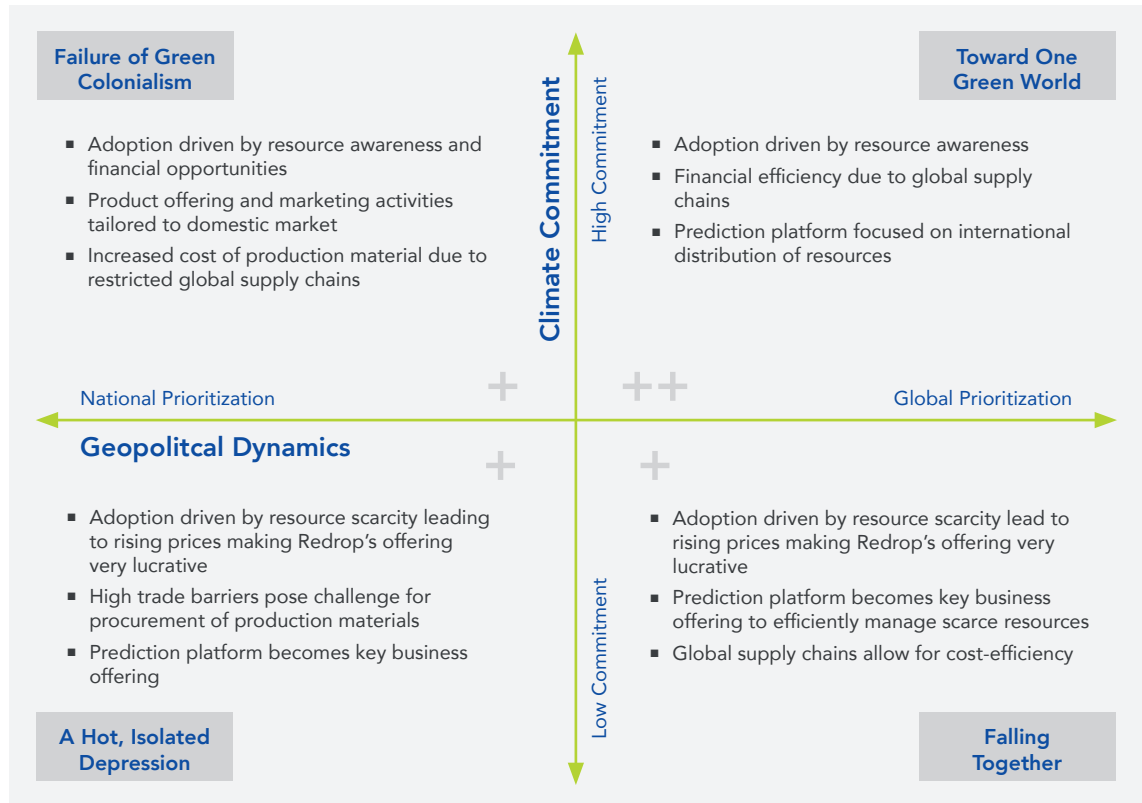
The showering system saves energy, freshwater, and reduces wastewater. Therefore, it also takes pressure off the local infrastructure. It is very affordable and enables everyone to act sustainably.

Resource Conservation: The showering system purifies and reuses the water reducing the water consumption by 80%, which decreases the stress on the local freshwater reserves, especially in regions where water is scarce. As less water needs to be heated, roughly 70% of energy is saved. For one shower at 39°C and a showering length of appr. 8 minutes this would result in 4.93kWh. This decreases the carbon footprint of each shower, as the heating usually consumes a lot of energy. As of now, shower heating is mostly not sourced from renewable energy systems.

Increasing Awareness about Resource Consumption: The app accompanying the shower shows the users how much water and electricity they use for showering. This way, the customer becomes increasingly aware of their resource usage. Seeing how much resources can be saved using Redrop, people will start looking for similar potentials in other aspects of their daily lives.

Enabling Urbanization: Redrop's system takes the pressure off the local water and electricity infrastructure, which decreases some of the downsides of extensive urbanization. This makes cities more liveable and enables them to cater to the needs of more inhabitants.

Increasing Accessibility to a Sustainable Lifestyle: The Redrop solution is not only accessible, but even comes with a financial benefit for the customers, as long as they live in a 2 or 3 person household. For example, low-income families sharing one bathroom can decrease their spending on utilities and make life more sustainable as a side effect. If the shower is deployed at a larger scale, it decreases the pressure on the local infrastructure and utility prices. This keeps utilities affordable, even to people that do not use the Redrop shower system.



Scenario Fit

Toward One Green World: In this scenario, Redrop would thrive. Interest in Redrop's product would be created by the strong commitment of individuals toward sustainable living, the increased energy prices, and global water scarcity. Under the assumption that more people would live in shared apartments in cities, Redrop's product would offer a value add to many people's daily life. In a globalized world, Redrop would benefit from efficient supply chains and shared resources. This would make procurement of the hardware materials cheaper and more sustainable due to access to the most efficient and long-lasting materials. Marketing activities

could be further streamlined and bundled in one country, due to equal global interests. The AI-driven predictive maintenance platform would offer even greater value as the clients can analyze global consumer data.

Failure of Green Colonialism: Redrop would benefit from society's high commitment to act sustainably. In this scenario, water would not be scarce in Germany yet. In other parts of Europe and the world it would be already scarce and therefore more expensive. Due to this, an opportunity to save both water and money would be attractive. Especially Redrop's lower-income target customers, e.g., young people living in shared flats or young families, would

Redrop

be interested in easy and economically viable ways to save the planet. Overall, Redrop would be in an ideal position to gain market share and grow. Due to localization, marketing activities would be aligned to each entered market. This would increase the costs for such campaigns. The predictive maintenance platform, a later addition to Redrop's offerings, would also have to be adopted in domestic markets. Restricted global supply chains could impose challenges on sourcing sustainable production materials or increase their cost.

A Hot, Isolated Depression: Despite the population having no interest in committing to climate change, Redrop would find customers in this scenario. The key selling points are built around saving money and resources, which would both be scarce in this world. Due to continued irresponsible consumption, inefficient global supply chains, and high trade barriers, water would be scarce and therefore expensive. Likewise, electricity would be very expensive due to the unsustainable consumption behavior of the broad society resulting in less spending budget for the customers. Hence, offering a product that saves water and electricity would be attractive to society. On the other side, high prices would impose challenges on the procurement of production materials as well as the production itself. As many firms would struggle with this, Redrop's consumer behavior and predictions platform could be a valuable tool for utility providers to plan energy demand and avoid blackouts.

Falling Together: In a globalized world with lacking climate commitment, Redrop would still gain ground and offer value to its clients. Although the sustainability aspect would not necessarily attract consumers, saving on water and electricity costs would. It can be expected that energy prices would skyrocket due to an unconscious increase in consumption worldwide. Simultaneously, resource prices would rise and water would be increasingly scarce. With a decline in global GDP, Redrop could expect people to be interested in an efficient, inexpensive solution like Redrop. Furthermore, due to globalization, inexpensive global material markets would make it possible to operate cost competitively. Lastly, the predictive maintenance platform could be of value to support balancing the energy grid and water infrastructure maintenance.

Challenges

- The development of the product itself involves considerable R&D. As there are already some organizations out there that offer similar products with existing or pending patents, Redrop needs to ensure that there is only small overlap with competing products.
- To differentiate from competitors and make the product available to everyone, Redrop will offer its solution as a "plug-on", requiring no major bathroom renovations. However, this might come with challenges as the product needs to be easily adaptable to different existing shower systems and bathroom designs.
- No acquisition and installment costs for customers result in high up-front costs for Redrop. Securing the funding for a hardware-as-a-service model will be one of the first major challenges to tackle.

Outlook

Showering has a significant environmental impact. In a time where resource scarcity is becoming increasingly severe, Redrop is on a mission to help individuals and businesses save valuable resources by implementing a new showering system making behavioral changes redundant.

The plug-on system will make it possible for everyone, from low-income to middle and high-income households, to leverage the sustainable benefits of a water purification filter system. By establishing a large network of partners across metropolitan areas within Europe, Redrop will be able to become the leading sustainability solution for showering. After addressing the B2C segment, introducing "Redrop for Businesses" will make it possible for organizations with exceptionally high water consumption – such as hotels and fitness centers – to save resources in their daily operations.

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TACKLING CLIMATE CHANGE IN THE AI ERA

Climate Change is one of the biggest challenges of our time, confronting us with cascading effects if no action is taken now. Global frameworks such as the Paris Agreement illustrate the way towards a carbon-neutral future. Now is the time to deliver on climate commitments and actions. The difficult task, however, is reaching this ambitious goal.

One promising solution is using AI and its applications. For example, Robotics and IoT, to push forward data-driven processes, which can be used to better understand past and present events in order to tackle climate change. AI has already disrupted many industries. Using AI in

sectors such as agriculture, energy and transportation can lead to economic benefits while reducing greenhouse gas emissions.

How can we tackle Climate Change with the support of AI solutions? How can this technology be leveraged to create tangible impact and pursue a transformation that creates opportunities for all? How to develop ethical and trustworthy AI systems without a large carbon footprint?

This report looks into these questions and provides an understanding of the potential of AI for tackling climate change in the next 20 years. It describes trends (political and

legal, economic, social and environmental, technological, business models) that explain the current and upcoming challenges passed by climate change. Further, it identifies potential future scenarios, and innovates new business models, ensuring a balance between sustainability, technology, and future prosperity. The generated business concepts include an urban planning and monitoring simulator, a smart control system for office energy usage, a carbon-negative beef alternative from ambient CO₂, AI-powered green microgrids, and an innovative resource-efficient shower system.



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