THE FUTURE OF UTILITIES IN THE ERA OF AI

TREND REPORT SPRING 2024

CDTM
CENTER FOR DIGITAL TECHNOLOGY AND MANAGEMENT

The Future Utilities in the Era of AI

ISBN: 978-3-9826340-0-5

Kindly supported by Stadtwerke München

Stadtwerke München (SWM) is a communal company that offers public services to the city and the region of Munich. SWM is wholly owned by the city of Munich. This means that SWM belongs to the citizens of Munich and is therefore an essential part of municipal services of general interest. It takes responsibility for people, resources, and the environment. The company is also committed to education and social issues and is one of Munich's largest employers, with a workforce of more than 11,000 people. SWM supplies the city of Munich with electricity, natural gas, district heating, district cooling, and fresh drinking water from the foothills of the Bavarian Alps. Its services include grid management for the energy and water networks, distribution, and sales.

The mobility subsidiary MVG is responsible for the subway, bus, streetcar, and MVG Rad under the umbrella of the SWM. With the expansion of fiber optics and other communication networks, SWM is laying the foundations for the networked and liveable city of the future. SWM is Europe's largest municipal utility company and ranks among Germany's principal energy providers. Expanding use of renewable energy has been a central element in the company's strategy since 2008. With its services, SWM is an important part of municipal services of general interest and makes a major contribution to the economic strength and quality of life in Munich and the region.

Visit www.swm.de for more information.

A Project of the Center for Digital Technology and Management

The Center for Digital Technology and Management (CDTM) is a joint, interdisciplinary institution for education, research, and entrepreneurship of the Ludwig Maximilians-University (LMU) and the Technical University of Munich (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.

TABLE OF CONTENTS

PREFACE OF THE PROJECT PARTNER

SWM is a forward-thinking municipal company owned by the city of Munich, delivering various public services to the city and the wider Munich region. Amongst others, our services are fundamental to energy and heating supplies in Munich and serve as the backbone of the city's mobility transition. We bear this responsibility as a dependable partner in line with the EU climate targets.

To successfully navigate related challenges of the energy and mobility transitions, SWM strongly engages in leveraging new technologies and finding ways to increase efficiency. AI plays a significant role for utility companies as one core technology, applicable from both market and operations perspectives. From a market standpoint, the intricacy of modern power grids demands advanced digital tools for enhanced predictions and increased automation. Operationally, it is essential that the SWM workforce is equipped for the AI revolution. In response, the SWM AI Initiative has been established, with a dedicated team of experts evaluating the impact of AI on SWM's environment to derive strategic action and foster an AI-ready workplace environment.

Innovation is the key to progress, and even though we have already introduced numerous AI use cases at SWM over the past few years, we recognize that shaping the future of utility services requires a broader examination of potential impacts and opportunities. To get a state-of-the-art external perspective on what the future might hold for companies like SWM with the continued advancement of AI technologies, partnering with the CDTM was an ideal choice.

We were thrilled about the chance to collaborate with 25 interdisciplinary innovators from the CDTM on a trend seminar dedicated to *The Future of Utilities in the Era of AI*. This seminar aimed to envision the evolution of utilities over the coming years until 2040 and to discover how AI could address challenges and unveil new opportunities in the utility sector.

Guided by a well-established framework provided by the CDTM, the students were encouraged to examine various trends in areas such as societal and environmental shifts, political and legal frameworks, economic fluctuations, and emerging business models that could redefine the utilities landscape. What made this seminar exceptionally challenging was its broad scope. The Centerlings, as the students of the CDTM are called, delved into an industry encompassing energy, water, telecommunications, and – though not typically included within utilities – mobility services. Focusing on AI technologies amidst these traditionally rather less digital-native sectors added another layer of complexity. Nonetheless, the students mastered this difficult task in an excellent manner and our SWM team was fascinated by the enlightening discussions and insights from the seminar.

We would like to give special thanks to the students who have been nothing short of impressive. The students' blend of dedication, enthusiasm, and professionalism stands out as truly remarkable. We encourage them to maintain this infectious energy and to continue pushing boundaries as the innovators who will revolutionize tomorrow's industries.

Additionally, our special thanks go out to the supervisors, Vera Eger and Felix Dörpmund, whose leadership of the students, as well as their professional partnership management with the SWM throughout this seminar, were of stellar quality.

Thank you all for 7 intense weeks, 25 trends, 5 areas of opportunity, and 5 business models!

Sonja Reppenhagen – Head of Innovation
Dr. Maximilian Pohl – Technology Innovation and Cloud AI
Dr. Denis Bytschkow – IoT and DataLab
Nils Punke – Inhouse Consulting
Kilian Egger – Corporate Strategy
Anita Subotic - SWM
Christian Hickisch - SWM
David Baum - SWM
Marianne Matthiesen - SWM
Nils Meinken - SWM
Sophia Bildstein - SWM

Vera Eger 

Felix Dörpmund 

PREFACE OF THE EDITORS

> **Everybody can learn from the past. Today it is important to learn from the future!**
>
> Herman Kahn

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 CDTM aims to connect, educate, and empower the innovators of tomorrow. It is our mission to equip our students with the tools and knowledge they 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. 25 selected students of various disciplines, such as Business Administration, Psychology, Medicine, Computer Science, Electrical Engineering 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 SWM for supporting this Trend Seminar. Particularly, we want to thank Sonja Reppenhagen and Kilian Egger as well as their colleagues for their collaboration, valuable insights, and feedback throughout the project. We hope our findings support you in driving innovation in the context of *The Future of Utilities in the Era of AI*!

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

Alena Strittmatter - CDTM
Aaron Defort (BCG)
Alex Worbs (Picus Capital)
Bastian Küppers (Stadler)
Bastian van der Put (b2venture)
Bernd Rüger (SWM)
Denis Bytschkow (SWM)
Dr. Gesa Biermann (Pina Earth)
Julia Balowski (CDTM)
Julian Herzog (SWM)
Kai Riemenschneider (econvio)
Kilian Egger (SWM)
Laura Stotko (CDTM)
Lorenz Haubner (Ponte Energy)
Markus Drews (SWM)
Martin Wessel (CDTM)
Matthias Möller (CDTM, Buildery)
Matthias Poeverlein (SWM)
Max Deichmann (Langfuse)
Maximilian Pohl (SWM)
Maximilian Rogg (IICM)
Moritz von Klot (Earlybird)
Nadine Schmidt (Professional Coach / Alumna)
Nils Punke (SWM)
Pietro Belligoli (CDTM)
Robert Richarz (CDTM)
Sophia Escheu (Speedinvest)
Steffen Schülzchen (Entrix)
Susanna Heidbrink (CDTM)
Tom Schelo (CDTM)
Florian Keller (SWM)
Florian Wiethof (CDTM)
Jeremiah Hendren (Hendren Writing)
Johan Börje (Stockholm Exergi)
Jose Vega (CDTM)
Dr. Oliver Schoppe (UVC)

Last but not least, we would like to thank the CDTM students of the class of Spring 2024. They put great energy and enthusiasm into this project, which made it a pleasure for us to supervise the course and coach the individual teams. Special thanks to the heads of the editing-, layouting-, and QA-team (Valentin Gölz, Niko Pallas, and Elisabeth Goebel) for finalizing the report.

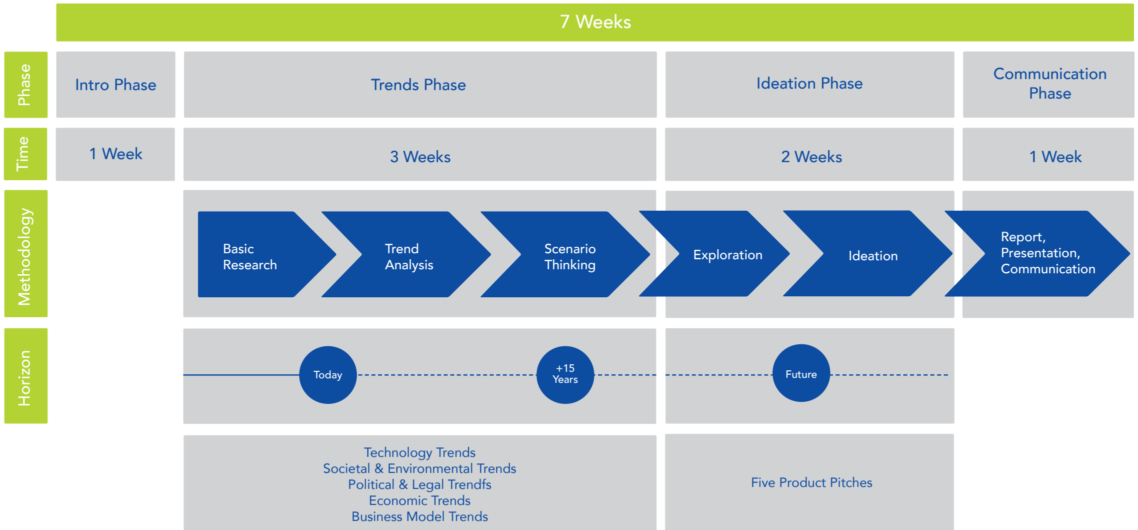
Vera Eger and Felix Dörpmund

Center for Digital Technology and Management (CDTM)

METHODOLOGY

The objective of the Trend Seminar is to provide a methodological approach for diving into a specific subject or industry sector and contemplating its future trajectory. The seminar guides its participants through three phases of trend research: trend, exploration, and ideation. Following this approach, the seminar first analyzes current trends and developments using in-depth desk research, site visits, and interviews with leading experts to establish a shared industry understanding. Next, participants identify areas within the sector where problems and opportunities will likely arise. In the final seminar phase, the students generate future-proof business ideas for products and services, addressing the identified problems and opportunities.

Up to twenty-six students, supervised by two doctoral candidates, pursue the Trend Seminar for seven weeks full-time during their semester break. The sector and framing for the seminar is provided by project partners from within the industry, who share their expertise and feedback, acting as sparring partners to the participants. In each phase, interdisciplinary subteams are formed with students from business, technology, and other disciplines. This interdisciplinarity allows for novel ways of thinking and the development of non-obvious ideas as well as leverages the students' professional and personal growth throughout the course.



During the introduction week, the participants are prepared for the intense trend research ahead. First and foremost, the students are introduced to the specific industry the seminar is diving into. Project partners and industry experts present past and current industry developments from their individual stakeholder perspectives, engaging in open discussions with the students. Additionally, interactive sessions teach trend research methodologies and refine the participants' communication and teamwork skills.

Following the introduction, the **trends phase** of the seminar covers desk research, expert interviews, and expert lectures, enabling the participants to dive deep into the topic at hand. During the expert interviews, students are empowered to pose specific questions to challenge their initial assumptions on how the industry will develop. Beyond that, site visits at the project partners' facilities complement the students' body of research and allow for further verification of their hypotheses. The derived trends are extrapolated 15 years into the future, providing a long-term perspective.

The first half of the **ideation phase** is about **exploring**, future opportunities and problems are clustered into specific spaces based on the research done in the preceding phase. The students are reshuffled into new teams and explore these spaces by looking into existing start-ups and projects. Through interviews and discussions with industry experts, the teams validate their hypotheses to identify unmet needs and existing gaps in the industry landscape.

During the second half of the **ideation phase**, students brainstorm **business solutions** addressing the previously identified gaps. To facilitate the ideation process, structured and unstructured ideation methods are introduced to the students. This allows them to generate many ideas before consolidating them and building comprehensive business models. Finally, the research results and the business ideas are pitched to the project partners, industry stakeholders, and the general public.

LIST OF ABBREVIATIONS

3D
3-Dimensional

5G
5th Generation (of Mobile Communications)

ADMS
Advanced Distribution Management Systems

API
Application Programming Interface

AR
Augmented Reality

ARR
Annual Recurring Revenue

B2B
Business-to-Business

BCG
Boston Consulting Group

BEHG
Brennstoffemissions-handelsgesetz

C&I
Commercial and Industrial

CAGR
Compound Annual Growth Rate

CBAM
Carbon Border Adjustment Mechanism

CISA
Cybersecurity and Infrastructure Security Agency

CSRD
Corporate Sustainability Reporting Directive

CX
Customer Experience

DER
Distributed Energy Resources

DRL
Deep Reinforcement Learning

DT
Digital Twin

EC
Edge Computing

ECB
European Central Bank

EEG
Erneuerbare-Energien-Gesetz

EGDIP
European Green Deal Investment Plan

EPC
Energy Performance Contract

ERP
Enterprise Resource Planning

ETS
Emission Trading System

EU
European Union

EV
Electric Vehicle

GDEW
Gesetz zur Digitalisierung der Energiewende

GDPR/DSGVO
General Data Protection Regulation/Datenschutz-Grundverordnung

GenAI
Generative Artificial Intelligence

GHG
Greenhouse Gas

GW
Gigawatt

HEMS
Heating Energy Management Systems

HRES
High-Resolution Forecast System

ICT
Information and Communications Technology

IEA
International Energy Agency

IoT
Internet of Things

IRA
Inflation Reduction Act

ISSB
International Sustainability Standards Board

kWh
Kilowatt-Hour

LLM
Large Language Model

ML
Machine Learning

MsbG
Messstellenbetriebsgesetz

NDT
Network Digital Twin

P2P
Peer-to-Peer

PLC
Power-line Communication and Programmable Logic Controller

PPA
Power Purchase Agreement

PPP
Public-private Partnership

PV
Photovoltaic

SaaS
Software as a Service

SAIDI
System Average Interruption Duration Index

SAIFI
System Average Interruption Frequency Index

SAM
Serviceable Addressable Market

SCADA
Supervisory Control and Data Acquisition

SME
Small and Medium-sized Enterprises

SOM
Serviceable Obtainable Market

TAM
Total Adressable Market

TCFD
Task Force on Climate-related Financial Disclosures

TNFD
Task Force on Nature-Related Financial Disclosures

ToU
Time of Use

US
United States

USD
United States Dollar

V2G
Vehicle-to-Grid

VC
Venture Capital

VPP
Virtual Power Plant

VR
Virtual Reality

WEF
World Economic Forum

YoY
Year over Year

TRENDS

The following chapter lists current trends that have a strong influence on the development and long-term strategic orientation of *The Future of Utilities in the Era of AI*. In accordance with the Trends Phase methodology, trends and related driving forces are structured into five areas: technology trends, societal and environmental trends, legal and political trends, economic trends, and business model trends.

TECHNOLOGY TRENDS

INFLUENCING THE FUTURE OF UTILITIES IN THE ERA OF AI

Digital Twins: Spotting Disasters

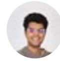
Smart Network Optimizations

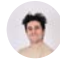
Safety for the Grids of Tomorrow

Emission and Energy Prediction

Future Energy Sources

Elisabeth Goebel

Het Dave

Jan Jakob

Ruslan Mammadov

Thomas Kaar


TECHNOLOGY TRENDS

Technological Advancements Transform the Utility Sector

The utility industry is one of the most critical industries for people and the integration of AI is a pivotal force shaping its trajectory. From Digital Twins (DTs) to decarbonization, AI-driven innovations are revolutionizing how utility companies manage grids, optimize networks, and tackle cybersecurity.

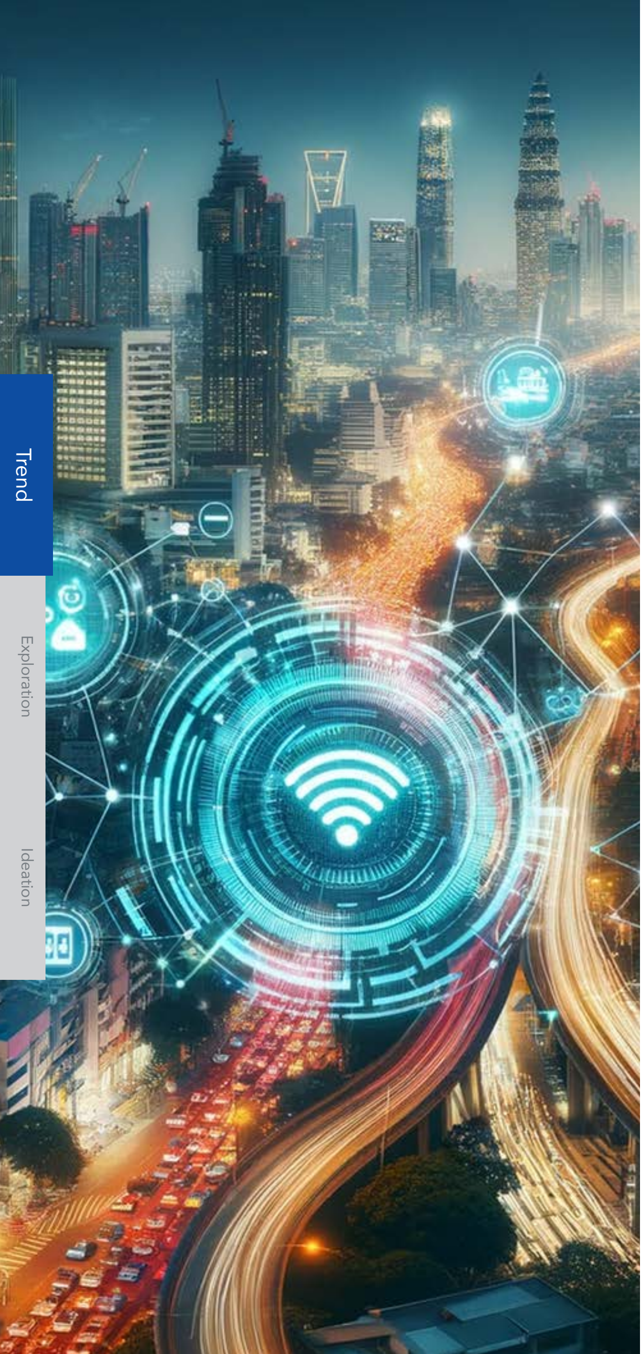
With the help of technological advancements such as AI, quantum computing, computer vision, and big data, the utility sector can proactively focus on optimizing challenges such as grid utilization, network outages, cybersecurity, and other use cases. The biggest problems of the next two decades in the utility sector could be solved by leveraging the technological trends mentioned in this report.

Identifying the right technological trends in this space is particularly challenging due to the sheer breadth and importance of the utility sector. It requires a deep understanding of the industry's current and future challenges and a balanced approach. This approach must not only consider the positive impacts but also the associated risks of implementing these technologies. For instance, while computer vision, Virtual Reality (VR)/Augmented Reality (AR), and quantum machine learning can all significantly impact business operations, a conservative risk assessment must also be completed when crafting implementation strategies, as the utility sector includes critical infrastructure.

In the subsequent sections, this section delves into the trends that have the unparalleled potential to reshape the utility industry. It explores the future of energy sources, envisioning a transition from fossil fuels to sustainable alternatives such as hydrogen and nuclear fusion [1, 2, 3]. This transition aligns with climate goals and underscores technology's significance in mitigating carbon emissions over the next two decades. In addition, it evaluates DTs and Internet of Things (IoT) sensors as a means to spot disasters and lower maintenance costs [4]. AI allows us to better predict future scenarios using past data, which is especially important for utility companies.

The gradual decentralization of energy production infrastructure is particularly interesting as more and more consumers start turning into prosumers and generating their electricity. This consequently also leads to more grid destabilization [5]. Concurrently, the imperative of cybersecurity looms large as threat actors leverage advanced AI and intricate hardware to exploit vulnerabilities within utility architectures. Cybersecurity, however, goes hand in hand with modern network optimization techniques, and the future of edge computing needs a secure and stable infrastructure. Thus, a comprehensive examination of these trends, encompassing factors, key drivers, and challenges, is essential to fortify the industry's resilience.

In conclusion, as utilities embrace AI, they embark on a journey toward innovation, sustainability, and resilience in a rapidly evolving landscape. The utility industry can optimize operations, enhance customer experiences, and navigate the complexities of a rapidly changing energy ecosystem by harnessing the transformative power of AI technologies.



DIGITAL TWINS: SPOTTING DISASTERS

Building Infrastructure Resilience: How Digital Twins Safeguard Against Disasters

DTs are transforming disaster and leakage detection processes. They facilitate precise predictions and swift responses to potential threats by utilizing real-time data with detailed virtual models [6]. Regarding pipeline networks moving water specifically, DTs are especially impactful, offering solutions for detecting and resolving leakages [4]. This innovation leads to significant reductions in economic losses and waste of resources. DTs can dynamically map data bidirectionally between the physical system and its digital equivalent [7]. This mapping improves operational safety and efficiency.

Moreover, DTs support decision-making processes by simulating various scenarios and outcomes, enabling preemptive actions against potential disasters. DTs' predictive maintenance capabilities are crucial for critical infrastructure management, ensuring long-term sustainability and reliability [8]. As DTs evolve, they are to become indispensable tools in mitigating risks and enhancing the resilience of essential services and infrastructures.

Facts

- The innovative project "Smart System for Leak Detection for Water Supply Network of Aigio" in Greece utilizes sensors and Supervisory Control and Data Acquisition (SCADA) systems with Programmable Logic Controllers (PLCs) to monitor water supply pressure and quality, aiming to reduce water leakage by about 48% of the town's total water supply, thereby saving approximately 600,000 m^3 of water annually [9].
- The study found that implementing a Network Digital Twin (NDT) in electrical distribution systems leads to more efficient anomaly detection, with 25% of anomalies identified through thermal visualization. Additionally, 3-Dimensional (3D) grid modeling is estimated to reduce the system average interruption duration index (SAIDI) by 0.9% and the System Average Interruption Frequency Index (SAIFI) by 0.47%, enhancing service quality and reliability [10].
- DT technology can also manage underground gas storage wells, focusing on leak detection and integrity. This technology simulates internal conditions to identify leaks and assess risks, leading to informed decisions about maintenance. In particular, the DT was instrumental in two cases, including one where its use led to a 60% reduction in failure consequences, proving its effectiveness in enhancing safety and reducing costs [11].

Key Drivers

- With climate change and urbanization increasing the risk of infrastructure failures, there is an increased demand for systems like DTs to aid disaster preparedness and mitigation [12].
- Modern pipeline and water distribution networks are becoming increasingly complex. DTs offer a sophisticated way to manage this complexity through simulation, analysis, and optimization [13].
- The exponential growth in computing power and advances in data analytics have made it feasible to process the vast amounts of data required for effective DT operation [14].

Challenges

- High initial setup cost and complexity in integrating DT systems with existing infrastructure pose a significant challenge [15].
- Navigating the regulatory landscape and ensuring compliance with various standards and laws can be challenging, especially in different geographical regions with varying regulations [16].

Impact on the Future of Utilities in the Era of AI

Adopting DT technology in pipeline and water system management significantly enhances operational efficiency and safety. By enabling real-time monitoring and predictive analysis, DTs can reduce the risk of leaks and failures, leading to cost savings, improved resource management, and enhanced disaster preparedness. This proactive approach transforms traditional reactive methods, positioning organizations to handle future pipeline and water system management challenges better.

SMART NETWORK OPTIMIZATIONS

Leveraging Edge Computing, AI, and IoT to Enhance Reliability and Sustainability

AI and IoT technologies are reshaping energy management by promoting renewable sources and Distributed Energy Resources (DERs) like solar panels and wind turbines, shifting away from centralized power generation. This approach leverages green energy while boosting power system flexibility and resilience [17]. Edge Computing (EC) enhances the capabilities of the IoT by enabling data processing on IoT devices closer to where the data is generated. This synergy streamlines the operation of smart devices and energy management systems. By processing data on the edge rather than sending it to centralized cloud servers, energy systems benefit from reduced bandwidth usage and faster responses, making real-time decision-making possible.

EC and AI revolutionize energy management by enabling real-time predictions of demand surges, optimizing supply adjustments, and reducing energy use [18]. These technologies significantly streamline data handling, thus lowering the energy needed for urban infrastructure operations. AI's ability to adapt and optimize energy use in real-time is transformative, markedly decreasing energy consumption in building management and mobile networks [19, 20]. This synergy not only enhances efficiency in waste management by cutting transportation time and costs but also leverages data analytics to make energy systems more responsive and sustainable [19].

Facts

- In a case study in Gustavsberg, Sweden, AI technology reduced energy consumption in buildings by 20%. It has been able to halve electricity usage for mobile networks by having adaptive AI algorithms to optimize energy where needed [19].
- Including smart devices with EC capabilities reduces latency and enables more compute-intensive use cases such as microgrids, energy trading to increase market efficiency, or additional grid capacity using Vehicle-2-Grid (V2G) technology [5].
- Cities consume a major part of global energy, partly driven by collecting, processing, and communicating data, which can be more energy efficient on the edge [18].

Key Drivers

- In 2021, 29% of European companies were using IoT [21], with a consistently rising trend for IoT usage in smart cities [22].
- Nokia conducted a study in collaboration with Telefónica revealing that the 5th Generation of Mobile Communications (5G) technology is up to 90% more energy-efficient per traffic unit than previous technologies [20], facilitating swift and energy-conscious data transmission for IoT devices [23].
- According to forecasts, there could be 8-15M electric cars in Germany by 2030 [24, 25]. Smart algorithms to decide when to charge the vehicles will be essential to prevent overloading the current power grid [26].

Challenges

- Infrastructure must be upgraded towards smart IoT and edge devices. Therefore, about 584B EUR in electricity infrastructure investments will be needed within this decade in Europe as stated by the EU commission [27].
- IoT and edge devices are becoming increasingly interesting targets for cyber attacks [28]. Having safe protocols and standards for communication between the devices to ensure high reliability for critical infrastructure will be highly important [29].

Impact on the Future of Utilities in the Era of AI

The rapid advancement of research in EC highlights the potential of data-driven applications that can revolutionize how utilities operate. However, the impact of these technological advancements heavily depends on establishing supportive policies. A notable example is the smart meter, where regulatory challenges hinder technological progress [30]. Furthermore, edge computing-powered AI technologies facilitate the decentralization of energy providers, enabling a more resilient and efficient energy grid by employing energy storage systems and driving the utility sector toward a more sustainable and consumer-friendly future.

SAFETY FOR THE GRIDS OF TOMORROW

Future-Proofing Utilities: The AI Approach to Cybersecurity

The development of AI influences cybersecurity in the utilities sector from multiple perspectives. Firstly, the interconnection of hardware sensors and software systems creates numerous vulnerable entry points for potential cyber-attacks, thereby expanding the attack surface for malicious actors. Additionally, AI-powered tools enable attackers to leverage sophisticated techniques for hacking and infiltrating utility systems, posing significant threats to critical infrastructure [31]. Recent advancements in Quantum Machine Learning (ML) could also prove to be a threat to current cryptographic systems [32]. The utility sector must navigate this evolving landscape, balancing the opportunities associated with AI-enhanced efficiencies against the heightened risks of sophisticated cyber-attacks, ensuring the resilience of critical infrastructure against emerging threats.

Facts

- The utility sector reportedly saw a 46% Year over Year (YoY) increase in cyberattacks in 2021, averaging 736 attacks per week, because of threats posed by the evolving growth of DERs [31].
- Decompilation, crucial for retrieving source code from binary executables, serves various purposes in cybersecurity. A new approach combining Large Language Models (LLMs) and program analysis significantly enhances variable name recovery, outperforming the state-of-the-art by around 15% precision and 20% recall [33].
- LLMs can analyze vast textual data to detect cyber threats from various sources, like news, research, and forums. They excel in spotting emerging threats and unusual patterns, surpassing traditional methods [34].

Key Drivers

- The increase of DERs in power systems and the recently increasing digitization and decentralization of the electric power grid expand the threat surface, making robust cybersecurity measures essential to safeguard grid operations against potential cyberattacks facilitated by AI-driven adversarial capabilities [35].
- Cyberspace is increasingly becoming a battleground for geopolitical conflicts, e.g., at the beginning of Russia's invasion of Ukraine, the outage at Viasat Inc., triggered by a cyber attack, disabled a significant number of modems across Europe just as Russian forces began entering Ukraine and firing missiles [36].
- With Shor's algorithm, attackers can break all modern cryptography, and it will become practically useful when general-purpose scalable quantum computers are available, estimated to be in the mid-2030s [32].

Challenges

- Often, cybersecurity does not receive the necessary strategic attention at board levels until an attack occurs [37]. Implementing cybersecurity standards and guidance is also uncertain, and compliance is challenging as technology keeps evolving at a higher pace [37].
- The performance of LLMs keeps increasing, which poses an increasingly larger threat to critical infrastructure as attacks become more robust and common [32]. This escalation in threat level would require a significant investment in security measures for utility companies.
- IoT devices connected to the grid pose a growing cyber risk, with an estimated 40B devices online by 2025 [37].

Impact on the Future of Utilities in the Era of AI

Cyberattacks on critical power infrastructure can lead to devastating consequences, potentially resulting in loss of life [38]. Hence, there's an urgent need for a more resilient architecture and enhanced technology to counter these attacks, especially as they exploit current AI advancements to disrupt increasingly decentralized and interconnected utility grids [38]. As cybersecurity is often a data problem, LLMs are pivotal due to their efficiency in analyzing vast textual data to spot threats and vulnerabilities. While the emergence of LLMs tremendously increases the possibilities for hackers, it also creates new opportunities for red and blue teams. In this light, Generative Artificial Intelligence (GenAI) provides a turning point for both sides.

EMISSION AND ENERGY PREDICTION

Leveraging AI to Enable Emission-Free Energy Production

Decarbonization involves shifting from fossil fuels to renewable energy sources like solar and wind power. However, this transition challenges energy grids due to their intermittent and variable nature. Balancing costs arise when there is a mismatch between energy supply and demand [39]. Grid operators must constantly adjust the supply to maintain grid stability, often relying on fast-responding but non-carbon-neutral fossil fuel plants when renewable sources fall short [39]. Effective forecasting minimizes these occurrences, reducing reliance on costly backup solutions and thus lowering balancing costs. It is instrumental in managing energy supply and operational costs, making the transition to renewable energy successful [40].

Facts

- In Germany, the costs of balancing the energy grid, specifically for congestion management, reached over 4B EUR annually in 2022 [41].
- By integrating data from diverse sources, including sky cameras and satellites, deep learning can enhance solar energy forecasting, effectively overcoming traditional forecasting method limitations [42].
- In 2023, DeepMind introduced GraphCast, an AI model exceeding the accuracy of the High-Resolution Forecast System (HRES) for global weather predictions up to 10 days ahead [43].
- Google claims that the ML model trained by DeepMind has enhanced the value of their wind energy by about 20% compared to a scenario without time-based commitments to the power grid [44].

Key Drivers

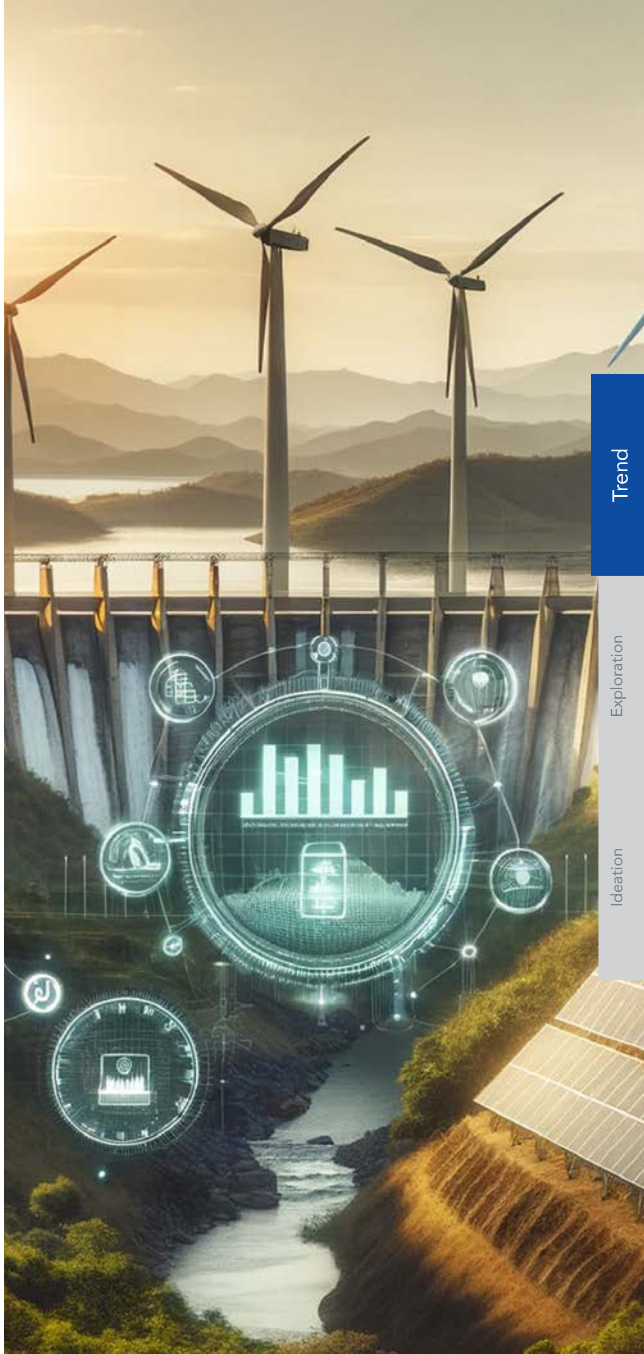
- Renewable sources like solar and wind are intermittent and variable. AI-driven forecasting can more accurately predict these energy sources' availability, helping to optimize their integration into the energy mix [40].
- Modern AI algorithms have shown remarkable improvements in forecasting accuracy. They can process vast datasets to predict energy supply and demand with high precision. This is essential for integrating renewable energy sources such as wind and solar, which are variable by nature's conditions [45].
- The shift to renewable energy sources challenges traditional grid operations due to the scale and uncertainty in energy supply and demand. AI can accelerate this transition because many grid decision-making processes align with complex ML tasks [40].

Challenges

- There is a significant challenge in integrating complex, new tools into existing operational workflows. This difficulty is compounded by the need to connect with necessary input data sources, such as real-time satellite image fluxes [42].
- Industries need more financial and technical resources to incorporate these innovations into their operational systems. This includes a need for more computing power to implement advanced methods, monitor forecasts, and assess their value [42].
- Climate change introduces greater variability and unpredictability of weather patterns, complicating energy forecasting [46]. This affects wind energy due to alterations in wind patterns and intensity [47, 48].

Impact on the Future of Utilities in the Era of AI

By leveraging AI-powered forecasting, utilities can efficiently integrate renewable energy sources like solar and wind, enhancing energy security and resilience while minimizing the need for costly fossil fuel backup plants and reducing balancing costs [40, 49]. A significant impact lies in empowering energy consumers; accurate forecasting allows utilities to provide consumers with real-time insights into energy availability and pricing, enabling them to make informed decisions about energy usage [45]. AI-enabled energy forecasting thus serves as a cornerstone for integrating renewables, securing the grid, and equipping consumers with actionable energy insights.



FUTURE ENERGY SOURCES

AI Accelerates Research, Adoption, and Deployment of Clean Energy Sources

In a world grappling with the urgency of increasingly devastating climate change effects, the need for sustainable energy sources has never been more critical. Despite growth in renewable energy generation capacity, over 60% of Europe's energy supply still comes from coal, oil, and natural gas [50]. To further reduce CO2 emissions, new energy sources like green hydrogen, nuclear fusion, and increased geothermal energy must be considered [1]. What if we can accelerate progress on nuclear fusion with instability detection [2]? What if we can improve the production processes of green hydrogen to fuel vehicles in the future [3]? What if we could significantly increase the share of clean heating energy with reduced cost of geothermal energy [51]? Advancements in clean energy technologies offer promising solutions to mitigate climate change and ensure sustainable energy production for the future. Leveraging AI presents an opportunity to address critical challenges across clean energy sectors. By harnessing the potential of AI, researchers aim to propel the transition towards renewable energy sources, driving down carbon intensity and fostering energy resilience.

Facts

- The German government invested over 1B EUR in fusion research between 2023 and 2028. "Fusion is a huge opportunity to solve all of our energy problems. ," according to German Research Minister Bettina Stark-Watzinger (Free Democratic Party) [52].
- The National Hydrogen Strategy targets achieving a capacity of 10 Gigawatts (GWs) for green hydrogen production via electrolyzers in Germany by 2030 [53].
- Germany aims to increase geothermal energy production from 1.2 TWh of climate-neutral heat to 100 TWh annually by 2050 [54].

Key Drivers

- Researchers used deep reinforcement learning to forecast and prevent potential instabilities during nuclear fusion in real-time, preventing disruptions - the biggest roadblocks to achieving a sustained fusion reaction [2].
- Integrating machine learning data with reservoir engineering knowledge rapidly identifies meaningful reservoir areas, reducing analysis time significantly [51].
- AI-enabled power and process simulation can accelerate the transition to green hydrogen [3]. AI models integrated with battery technology are crucial in material discovery and battery design, improving performance and life span [55].

Challenges

- Progress in fusion energy is very slow and expensive. Experts predict that fusion plants might be feeding power into the grid by around 2050 and can become a steady source of energy, especially post-2060 [56].
- Hydrothermal energy usually requires water-bearing layers, but alternatives like "enhanced geothermal systems" promise viable options, e.g., for granite rock layers and closed-loop systems such as the Eavor-Loop in Geretsried, Germany [57, 58].
- Without the necessary infrastructure for hydrogen energy, private mobility continuously relies on fossil fuels, which highly contribute to CO2 emissions [59].
- Explainable AI enhances green energy competitiveness by processing complex data for informed decisions, fostering stakeholder trust [60].

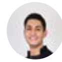
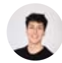
Impact on the Future of Utilities in the Era of AI

AI offers opportunities to expedite research in clean energy sources and enhance the cost-effectiveness of energy production. While achieving nearly limitless clean power through nuclear fusion within the next three decades remains uncertain, AI is expected to contribute to advancements in this area. In the meantime, optimizing geothermal drilling processes can improve efficiency and facilitate broader geothermal energy deployment. Similarly, AI-driven advancements in material discovery and durability in green hydrogen will impact the demand for essential infrastructure, potentially supporting wider adoption.

SOCIETY & ENVIRONMENT TRENDS

INFLUENCING THE FUTURE OF UTILITIES IN THE ERA OF AI

- Eco-Conscious Revolution
- Weather at the Breaking Point
- Looming Threat of Microcontaminants
- Confidence Dilemma - AI
- AI's Energy Consumption Surge

Ben Ta 
Hamze Al-Zamkan 
Johann Stürken 
Marcelo Rohn 
Niko Pallas 

SOCIETY & ENVIRONMENT TRENDS

Societal Change Forsters Technological Disruptions for Utilities

Utilities are inherently connected with society and the environment. They serve society, e.g., by providing electricity, water supply, and heat. Additionally, utilities are bound to operate based on external environmental conditions. With climate change becoming a reality, they must anticipate how their operations will be affected to ensure long-term success.

Society refers to the collective of individuals, communities, and consumers focusing on behavioral shifts. It includes the evolving dynamics of social responsibility, ethical consumption, and the drive towards more sustainable living practices. The environment is defined as the natural world and climate, encompassing ecosystems, biodiversity, and the physical conditions on earth. It considers efforts to preserve, protect, and restore the natural world for future generations, highlighting the interconnectedness of all living beings and their habitats.

People's environmental awareness and willingness to drive sustainable change are growing in an eco-conscious revolution [61, 62]. This is reflected in customers demanding greater transparency and in the shift in the utility landscape towards more decentralized, cost-effective, and green solutions, such as installing Photovoltaic (PV) panels on rooftops [63, 64, 65, 66, 67]. Weather changes at the tipping point demand an increase in awareness. Regular weather patterns are changing through more extreme summer heat waves, leading to the widespread installation of air conditioning in Central Europe [68]. In addition, one-off extreme weather events are occurring with higher frequency and intensity, requiring more resilient infrastructure [69]. AI could support efforts by providing novel forecasting methods [70, 71, 72]. In addition to weather challenges, trace-level chemicals, and tiny plastic particles accumulate in the ecosystems [73]. This poses significant threats to biodiversity, food chains, and human health [74]. AI systems could support waste and water management practices in preventing pollutant leakage into ecosystems and filtering out those already present [75].

While AI applications are experiencing exponential growth [76], society must be involved. Confidence in these AI applications is the most critical factor influencing the acceptance and implementation of AI applications. Failure to address this issue will likely hinder societal acceptance and realization of the benefits [77]. As we navigate the rise of AI, its hidden cost becomes evident through a surge in energy demand [78, 79]. This reality brings to light the delicate balance between embracing technological advancements and safeguarding our environment [80]. The utility sector must address this challenge, ensuring that progress in AI goes hand in hand with sustainable practices [80, 81].

The future direction remains uncertain. The utility sector must navigate the complexities of integrating AI technologies with an acute awareness of citizens' trust. Ensuring users are well-informed and educated about AI's capabilities and intentions becomes paramount. Utility companies must communicate transparently and demonstrate how AI can enhance efficiency, sustainability, and service quality. By addressing concerns and highlighting benefits, the sector can foster a supportive environment where AI is leveraged to its fullest potential.

ECO-CONSCIOUS REVOLUTION

Environmental Problems Drive Consumer Action and a Surge in Prosumerism

Awareness of imminent climate catastrophes has been rising for years, influenced by movements such as "Fridays For Future" [82]. However, a new development in this is the rising willingness of people to drive change and take matters into their own hands [61, 62]. This shift is especially evident in the stance of younger generations, who are also willing to invest in sustainable practices and products, reflecting a more profound commitment to ecological stewardship [83]. As customers increasingly demand transparency to optimize consumption [63], they drive the demand for options for greener energy consumption. This represents an opportunity for utility companies to become the tool through which customers take action against climate change.

On the other hand, the improving technological capabilities also lead to increasing prosumerism and decentralization in the utility sector [64, 83, 84, 85], as is evident by the increase in installations of personal solar panels on household rooftops [83]. Solar thermal panels, heat pumps, rainwater harvesting, and others demonstrate that this shift also goes beyond electricity [64, 65, 66, 67].

Facts

- 91% of Germans support the transition to a more sustainable economy, and 73% of consumers are changing their purchasing habits for environmental reasons [86].
- As of 2020, 60% to 70% of consumers would pay a premium on their purchases if they included sustainable packaging [87].
- Decentralized PV systems can already cover up to 80% of the energy needs of private households, and local energy storage systems can completely buffer the excess energy peaks generated during the day [88].

Key Drivers

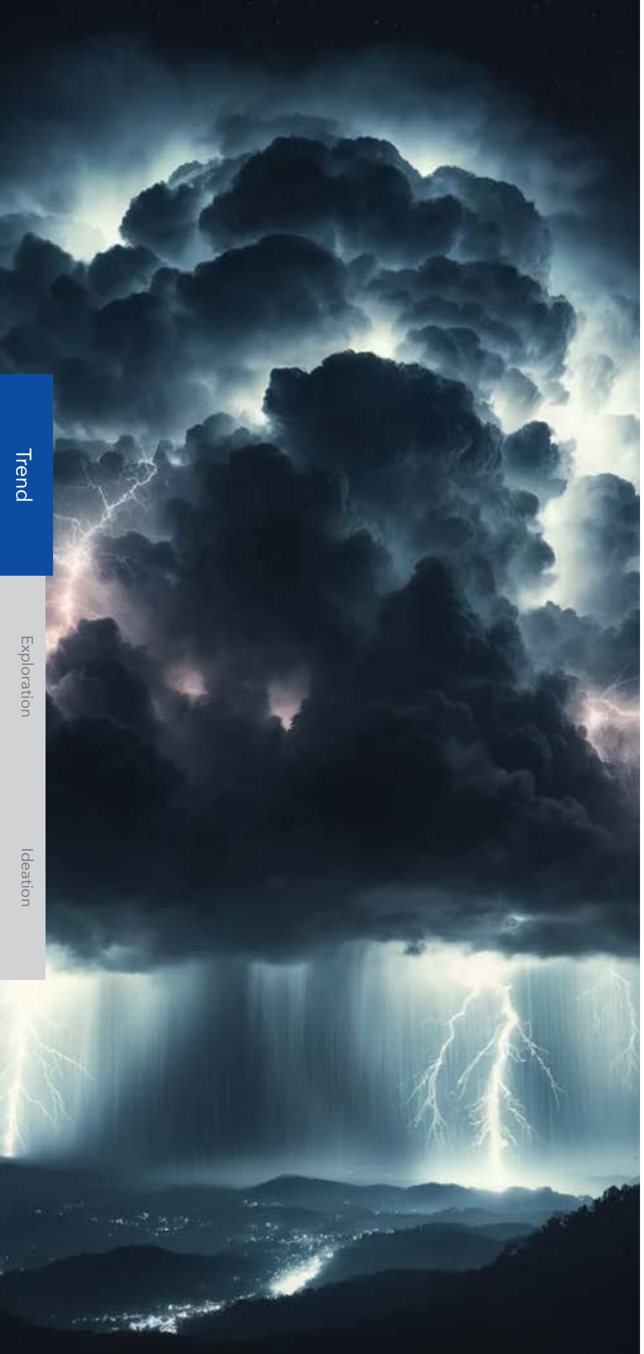
- The escalating impact of climate change on everyday life is a significant motivator for increased public engagement with environmental sustainability, driving demand for more responsible energy consumption and propelling the shift towards decentralized utility systems [89, 90].
- The intensifying regulatory pressure to curb carbon emissions and the possibility of combining it with sustainable and decentralized utility systems makes communities and industries consider these to an increasing extent [91].
- The German government aims to enhance the nation's energy self-sufficiency, reducing reliance on external sources and meeting climate goals [85,92].

Challenges

- The social acceptance of and trust in new technologies, such as smart meters for monitoring electricity usage, significantly impacts their adoption and could slow the implementation of new solutions [93].
- People living in cities do not usually own their homes but live in apartments. Investment coordination between stakeholders with different resources and interests complicates the advancement of prosumption [94].
- Balancing the need to expand and upgrade the utility infrastructure by integrating new technologies and an aging workforce poses the most significant challenges for utility providers [95].

Impact on the Future of Utilities in the Era of AI

The Eco-conscious revolution will force the utility sector to adapt its offering to shifting customer demands and the changing infrastructure landscape. AI can enable personalized services and pricing by optimizing energy use and storage and enhancing intelligent water management by forecasting demand and detecting leaks, thereby facilitating the transition towards a more eco-friendly offering. Overall, AI will help increase the utility industry's customization level, allowing for a more efficient distribution of its services and, thus, reducing environmentally damaging consumption [96].



WEATHER AT THE BREAKING POINT

Changes in Weather Accelerate and Impact Utility Consumption and Infrastructure Planning

Extreme weather patterns shape short-term utility consumption and long-term infrastructure planning through weather-induced one-off natural disasters. Fluctuations in weather patterns and seasonal changes directly influence consumption. While heating consumption drops during warmer periods, reliance on cooling systems to combat rising temperatures is heightened, increasing electricity consumption [97, 98]. Similarly, rain and sunshine influence people's utility consumption [99]. Forecasts indicate that the frequency of extreme temperatures and precipitations will keep rising [100], increasing the described effects for utilities.

Additionally, the number and severity of one-off natural disasters are rising [69], with the Ahrtal catastrophe showing a significant gap in natural disaster preparedness in Germany [101]. Utilities are affected by natural disasters as they are both active players in and impacted by them. They have an active role in reducing disasters, such as building water reservoirs and designing more resilient infrastructure [102]. After natural disasters, utilities must restore services as soon as possible to prevent cascading negative impacts due to bad sanitation or support recovery efforts through mobile data services [103, 104].

Facts

- The average annual temperature has risen by over 1.6°C (compared to 1881) [105], with Europe experiencing the fastest rise in temperatures [68].
- The days with temperatures exceeding 30 degrees have tripled since 1950 [106].
- The winter of 2023/24 witnessed the highest levels of rainfall since 1881 and the third-warmest since recordings began [107].
- Weather- and climate-related disasters in Central Europe have risen by 211% from 1981-1990 to 2011-20 [108], with winter days with torrential rain increasing by 25% between 1951 and 2006 [106].

Key Drivers

- Increases in global surface temperatures through increased Greenhouse gas (GHG) emissions and natural variability lead to climate change [109, 110].
- Available climate data is rising exponentially in the new space economy [111]. Amongst others, ML allows understanding of previously hidden patterns, while Deep Reinforcement Learning (DRL) can be employed to analyze satellite data [112].
- AI is set to revolutionize weather forecasting, crucial for utility planning, by overcoming the current limitations of time-consuming analyses on supercomputers, significantly extending forecast lead times, and improving accuracy [70, 72, 113].

Challenges

- Variations in weather conditions affect the output of renewable energy sources such as solar and wind power, influencing the composition of the energy mix.
- As AI is being relied upon for life-critical tasks, human interaction, and manual verification could be required in critical tasks [114].
- Data availability is a limiting factor, especially for rare, difficult to automatically detect events like earthquakes [115].
- Additionally, it can lead to adverse effects if the AI advises building a new seawall, which leads to unintended consequences for the marine ecosystem [112].

Impact on the Future of Utilities in the Era of AI

Utilities must prepare for further climate change, leading to more cascading effects with ever-changing scenarios in either new consumption patterns like the roll-out of air conditioning in Central Europe or an increased number of more severe natural disasters. Based on those changing external conditions, utilities should understand the application potential of AI to address such situations and how it can be embedded with traditional technologies. In doing so, the highest safety, both in terms of supply security and health and safety, can be ensured [116].

LOOMING THREAT OF MICROCON-TAMINANTS

Waste and Water Management Facilities Face the Rising Challenge of Trace Contaminants

Micropollutants constitute trace-level chemicals, such as residues of pharmaceuticals or personal care products [117]. Microplastics are plastic particles with a diameter of less than 5mm that originate from sources such as the breakdown of more considerable plastic waste [118, 119]. Both contaminants result from waste created in industrial processes and individual daily activities [120]. They accumulate in the environment to an ever-increasing extent [121]. Due to their potential toxicity for different organisms [122, 123], and their resistance to degradation [124], they negatively impact ecological systems [120].

Both types of pollutants are projected to increase due to the rapid advancement in industrial activities, consumerism, and the global population's growth [121, 125, 126]. This development showcases that the boundaries between water and waste management are increasingly blurred. Standing at the forefront of this challenge, the utility industry is uniquely positioned to drive innovations and integrated approaches in combating micro pollution. The advent of AI enhances the ability to detect, analyze, and remove these environmental pollutants, thereby playing a crucial role in developing more efficient and effective waste and water treatment processes [127].

Facts

- As of 2022, Germany's per capita municipal waste production was 593 kg, significantly above the European Union (EU) average of 513 kg [128].
- In 2024, the amount of microplastics in the surface ocean is estimated to be 0.7M tonnes. By 2050, this amount is estimated to be between 1.5M and 2.7M tonnes [129].
- The average person ingests around five grams of plastic per week [130], and people who eat shellfish consume approx. 11,000 pieces of microplastic annually [131].
- Marine pollution is the top environmental concern that Germans are worried about [132].
- Some microplastics need at least 400 years to degrade in nature [126].

Key Drivers

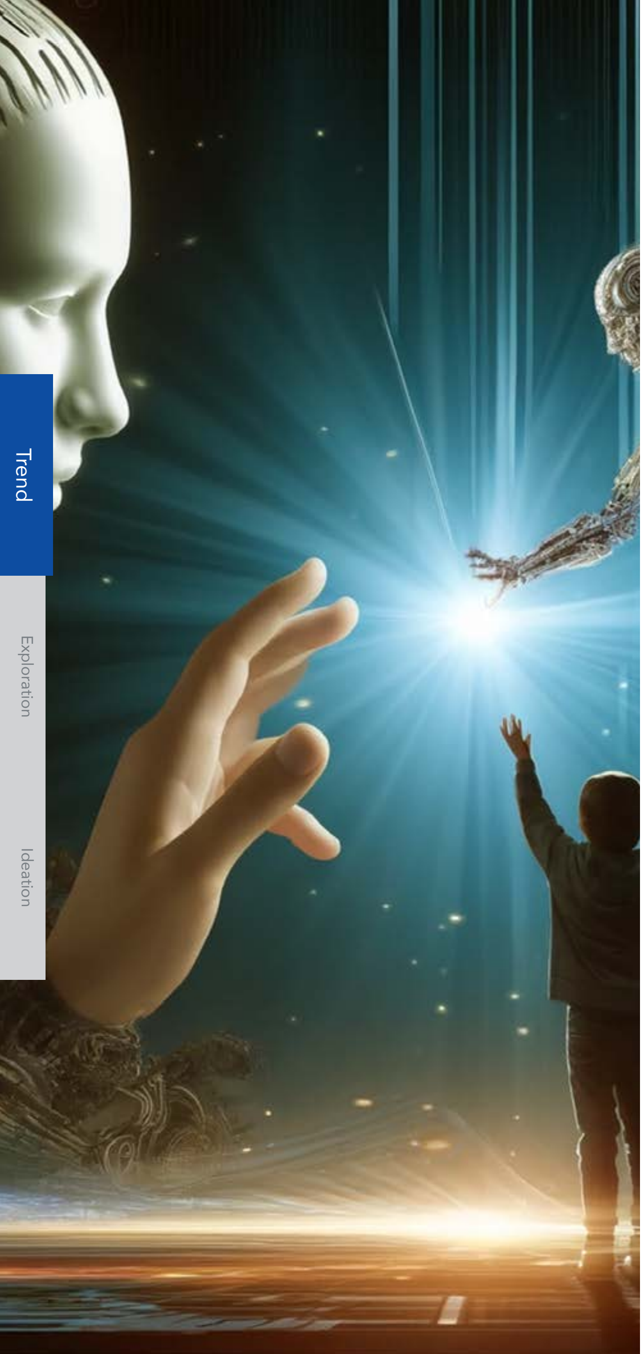
- The primary sources of microplastics are the laundering of clothes made from synthetic materials and the abrasion of vehicle tires [119].
- The global production of plastics has risen from around 2M tonnes in 1950 to 460M tonnes in 2019 [133].
- While micropollutants originate from several sources, such as using personal care products [117], most micropollutants accumulating in surface water resources pass through wastewater treatment plants but can not be entirely removed [124, 134].
- European wastewater utilities have few economic incentives to invest in improved micropollutant removal facilities [135].

Challenges

- Currently used technologies and processes cannot remove all trace-level chemicals from wastewater [136, 137].
- The environmental impact of the different types of pollutants has yet to be fully understood [136, 138].
- Sustainable solutions must be coordinated between different stakeholders across the globe [120, 139, 140].
- Many pollutants are unknown because they are either ill-defined or undisclosed for confidentiality reasons [139].

Impact on the Future of Utilities in the Era of AI

As the volume and complexity of pollutants increase, traditional waste and water management practices are stretched to their limits. AI poses immense advancement opportunities in preventing further pollution and aiding in removing existing pollutants. AI-facilitated decentralized treatment solutions, such as smart filters, can help reduce the amount in landfills or water bodies. AI-enabled sensors could monitor water quality, identifying a broader range of contaminants at lower concentrations than ever, thereby facilitating tailored removal technologies [141].



CONFIDENCE DILEMMA OF AI

Surge in AI Adoption Clashes With Low Public Trust

Similar to past technological advances, the adoption of AI services faces the question of integration, especially in sensitive areas like utilities. The trajectory of AI innovation and application diverges from societal trust and acceptance [142, 76]. In 2023, several prominent AI researchers published an open letter urging AI labs worldwide to halt the development of large-scale AI systems to "give society a chance to adapt" [143, 144]. On the other hand, in just five years (2017-2022), the adoption of AI has skyrocketed from 20% to 50%. This exponential growth heralds a new era of possibilities [76].

However, amidst this enthusiastic embrace of technological advancement, a palpable tension emerges - rooted in the delicate balance between innovation and societal trust [142]. While industry leaders consider AI a catalyst for transformative change [145], the broader public remains cautious, especially in Germany [142]. Yet, trust is the most relevant factor for acceptance, particularly for critical infrastructure [146]. To successfully implement AI, addressing concerns such as explainability and reliability is essential, improving general knowledge and fostering social acceptance [147, 148].

Facts

- Perceived risks in decision-making are lower when a human is in control [149].
- 72% of leaders in the energy sector think of AI as a chance for the upcoming transformation. From those, 88% could imagine implementing AI in energy management [150].
- The public's trust in AI systems is generally low; 39% of the population in Germany is unwilling to trust an AI system. Failure to address this issue will likely hinder societal uptake and realization of the benefits [142].
- In Germany, half of the population states they do not understand AI [142].

Key Drivers

- AI literacy refers to those who understand how and when AI is used. They are more likely to trust and accept AI systems [142, 148].
- Reliability is key in AI applications as it drives trust. If an AI system malfunctions, trust will decrease significantly [147]. Citizens expect high standards from AI systems regarding performance, data privacy, security, transparency, accountability, and human oversight [142].
- Believing that current regulations and laws are sufficient to ensure the safety of AI use and accountability is a strong driver of trust. However, many people perceive the current regulatory and legal framework as inadequate for ensuring the safety of AI [142].

Challenges

- In general society, there is a lack of expertise in AI. 87% of leaders in the German energy sector see missing knowledge as the main obstacle to new AI applications [150].
- The lack of transparent decision-making processes can reinforce social inequality and lead to dissatisfaction, making it essential to foster confidence in AI systems through explainability [147, 151].
- High trust in incapable technology can lead to over-reliance and misuse, potentially resulting in safety breaches and other undesirable outcomes [77].

Impact on the Future of Utilities in the Era of AI

The utility industry faces both opportunities and challenges in the era of AI. While industry leaders praise AI's potential for the desperately needed transformation [150], public skepticism remains, particularly in Germany and North America. As utilities are integral to daily life, trust is of utmost importance. To overcome this skepticism, focusing on a better understanding of AI, transparency in decision-making, and implementing robust regulatory measures is essential [142]. These steps are crucial to ensure the safety and effectiveness of AI, bridging the gap between technological advancement and societal acceptance.

AI'S ENERGY CONSUMPTION SURGE

The Hidden Environmental Cost of AI Progress

In the era of rapid technological advancement, AI is transforming industries and daily life through innovation, yet it has high environmental costs [152, 153]. AI's progress, spanning healthcare to autonomous driving, significantly increases energy consumption [154, 155]. The complexity and size of AI models escalate computational demands [155]. This rise, driven by extensive data and complex algorithms, boosts greenhouse gas emissions, electronic waste, and waste management challenges [156]. These developments prompt critical questions about sustainability in the digital age [153]. The complexity and size of AI models result from pursuing advanced, human-like AI capabilities [155], requiring vast data and computational resources. This progress, while promising, often comes at sustainability's expense [155]. At the intersection of technological progress and environmental stewardship, the focus shifts towards balancing AI's potential with planetary health [153]. Furthermore, AI's growing energy needs pose challenges for utilities, requiring infrastructure upgrades and a reevaluation of energy sources to sustainably support AI's growth [157, 158].

Facts

- By 2040, Information and Communications Technology's (ICT) emissions could reach 14% of global totals, primarily from data centers [157].
- Microsoft is exploring nuclear power to meet AI's growing energy needs, indicating a shift towards alternative energy sources [155].
- The World Economic Forum projects that by 2050 AI-related e-waste will exceed 120M metric tonnes, necessitating robust recycling efforts [156].
- Experts concur that the drive for bigger AI models contributes to rising power requirements despite the potential for efficiency [155].

Key Drivers

- There is relentless growth in AI technology adoption across various sectors [154].
- The industry emphasizes developing more powerful AI models, increasing energy consumption [155].
- The technological progression towards more extensive, complex AI models necessitates greater energy consumption for training and inference phases despite efficiency gains in hardware [157].
- The geographic location of servers and the associated cooling energy requirements substantially affect overall AI energy consumption, emphasizing the importance of server placement and data center efficiency [157].

Challenges

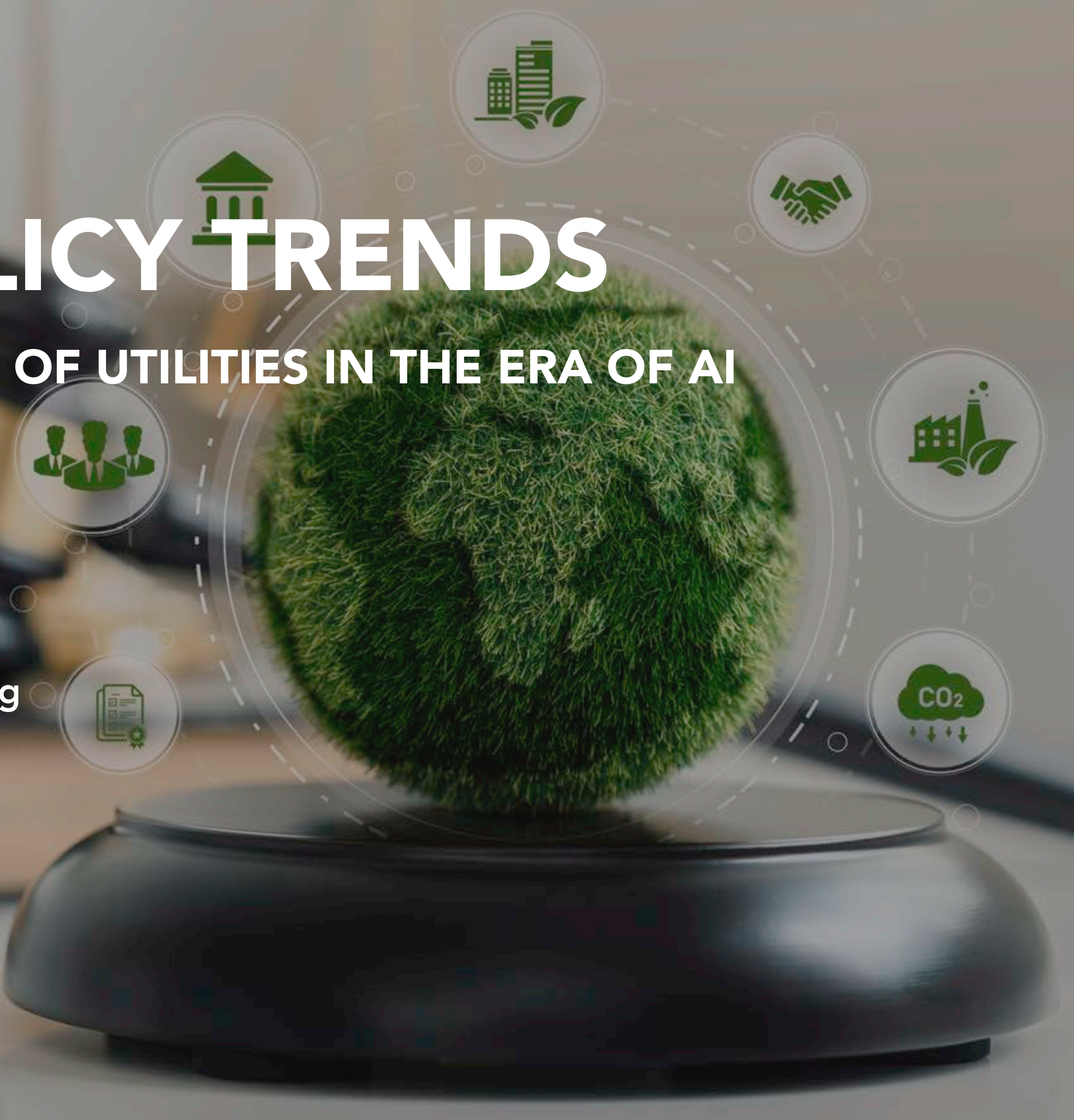
- Balancing AI's technological advancements with its environmental impact remains a pressing challenge [153].
- With their alternative energy solutions, tech firms challenge traditional energy dynamics [158].
- Overcoming the lack of transparency in AI's environmental impact, fostering responsible development and use [159].
- Navigating the transition to more sustainable energy sources to support the growing power demands of AI amidst concerns over the pace at which efficiency innovations can mitigate increased consumption [153].
- Economic and supply chain constraints significantly hinder the sustainable expansion of AI amidst growing concerns over its escalating energy demands [153].

Impact on the Future of Utilities in the Era of AI

As energy demand surges, the utility industry encounters challenges and opportunities with AI's growth. This necessitates a shift towards sustainable energy sources and innovative infrastructures to meet AI's computational demands while preserving environmental integrity. Utility companies are crucial in managing rising energy consumption and e-waste, necessitating improved recycling and waste management strategies. Moreover, the industry must balance technological advancements against their ecological impacts. As AI models increase in complexity, utilities must harmonize technological progress with environmental stewardship.

LEGAL & POLICY TRENDS

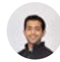
INFLUENCING THE FUTURE OF UTILITIES IN THE ERA OF AI



- Carbon Pricing
- Growing Need for In-Depth Reporting
- Green Investment Programs
- Smart Meter Rollout
- AI and Cybersecurity

Anna Rode

Finn Kosina

Muneeb Ahmed

Shouvik Ghosh

Zaid Efraij


LEGAL & POLICY TRENDS

Legislative Efforts Boost Green Evolution in the Utility Sector

Regulatory measures significantly impact the utility industry, as its role as a crucial component of critical infrastructure necessitates that its security and service quality meet societal needs. Therefore, the legislation affecting the sector is complex but also very dynamic, often aimed at steering the development of the whole industry. The drive for sustainable transition while competing with other countries through digitalization and new technologies shapes the current legal and policy trends.

At the forefront of this change is the expansion of emission pricing, specifically through the Emission Trading System (ETS) established by the EU in 2005. With the fundamental transition required to achieve sustainability goals, the number of affected industries and the price for emissions themselves will continue to increase. This trend will be a primary driver in reducing emissions and pushing utility companies to pursue more sustainable strategies [160].

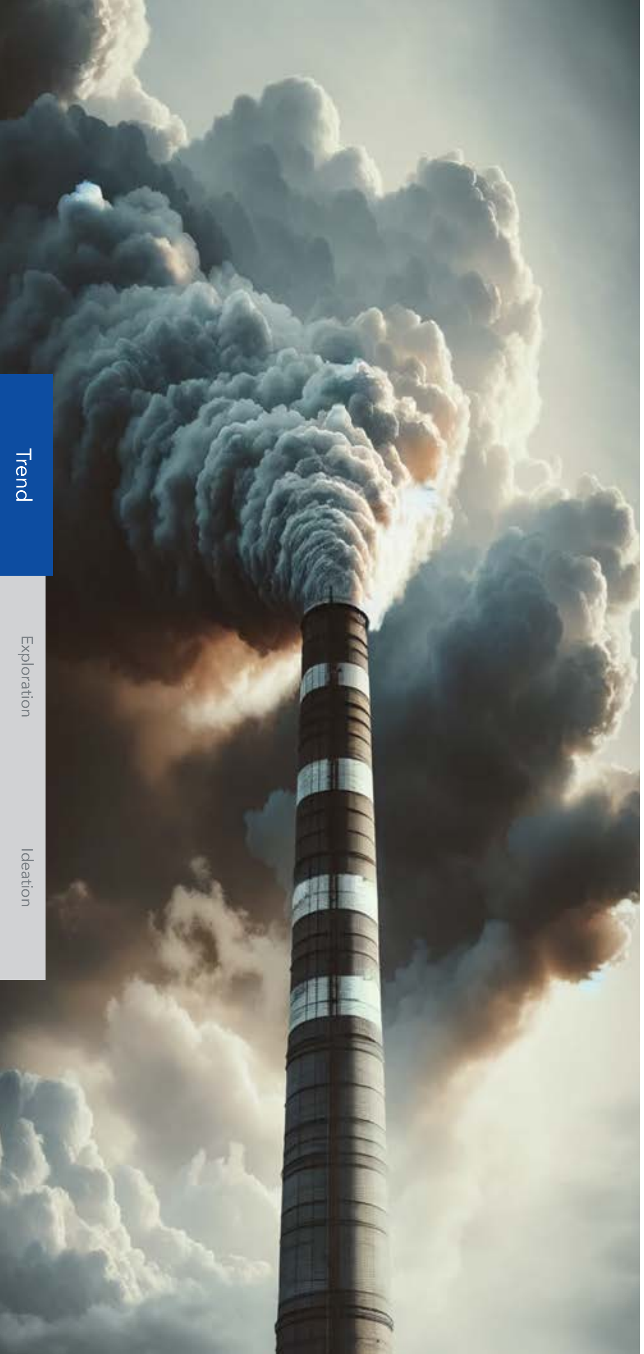
Additionally, the utility sector is witnessing a surge in the demand for comprehensive reporting and transparency regarding sustainability actions. Multiple reporting directives at national and international levels are being adopted to highlight organizations' efforts beyond mere financial performance. For example, the introduction of frameworks like the European Corporate Sustainability Reporting Directive (CSRD) emphasizes the double materiality of reporting, covering both societal and environmental impacts [161].

In parallel, the European Green Deal Investment Plan (EGDIP) and similar global initiatives underscore the state's role in mitigating climate change by fostering green investments [162]. These programs aim to propel investments in climate-friendly infrastructure and technologies by providing incentives such as grants or guaranteed loans. However, the complexity of subsidy systems and the prioritization of projects remain significant challenges, necessitating careful design to align with broader environmental and economic objectives.

Moreover, the shift towards smart grids and agile pricing models, supported by the Metering Point Operation Act, which mandates intelligent meter rollouts in Germany starting in 2025, represents an upcoming pivotal change in the utility sector [163]. AI and digital technologies enhance this transition towards real-time pricing, facilitating a more adaptable, responsive, and balanced system. While it offers potential cost savings for customers and improved grid stability, it raises essential concerns regarding public trust, data privacy, and integrating new technologies within existing infrastructure.

Cybersecurity in utilities is increasingly vital with advancing digitization and AI adoption. The industry faces heightened risks from cyber threats, necessitating stronger cybersecurity standards. The EU AI Act classifies AI applications in utilities as high-risk, mandating human oversight, risk management, and reporting obligations. Regulatory emphasis underscores utility companies' importance in keeping ahead of compliance requirements, balancing innovation with security and privacy concerns [164].

These trends underscore significant change in the utility sector, driven by regulatory changes, technological advancements, and increasing environmental awareness. As the industry navigates these developments, the convergence of legal, policy, and technological forces will shape the future of utilities in the upcoming years, demanding a holistic and forward-looking approach to unite sustainability, innovation, and security.



CARBON PRICING

Emission Trading Systems Driving the Regulatory and Market Dynamics

The EU set the foundation for greenhouse gas emission pricing by introducing the ETS in 2005. The expansion of included industries in the Act and rapid price increases of certificates can become a main driver for sustainable transformation within the utility industry as increasing costs for non-renewable energy and industry production will incentivize companies to adapt their strategies accordingly [165]. Existing policies have proven to have a positive effect on emissions reduction but have also created challenges through uncertain policymaking and regulatory complexities [166]. Nonetheless, carbon pricing mechanisms worldwide will be a major force shaping the development of the utility industry in the upcoming years through increasing speed and requirements.

Facts

- Frameworks like the ETS offer limited emission certificates for specific industries like the energy market and aviation. The system has been in place since 2005 and prices CO2 emissions at 55 EUR per ton at the beginning of 2024 [167].
- The EU ETS 2 will start including house heating and municipal waste incinerators, further affecting the utility industry from 2027 [160].
- Within the EU, national regulations account for gaps in the ETS by pricing individual industries not covered by the EU scheme. For example, Germany's Brennstoffemissionshandelsgesetz (BEHG) defines a CO2 price for industries such as mobility and agriculture [168].
- Similar concepts have been introduced in other parts of the world, including Korea's emission trading system and the cap-and-trade system in California and Canada [169]. In total, 61 comparable systems are operational worldwide [170].

Key Drivers

- Measures are taken worldwide to reach ambitious targets in reducing CO2 emissions, and emission pricing is one of the critical components of these strategies. The EU forecasts a reduction of 55% of net emissions through the ETS by 2030 [170].
- With the introduction of compensation mechanisms to account for differences in emission prices between countries, e.g., the EU Carbon Border Adjustment Mechanism (CBAM), it will become more attractive to keep emission-heavy industries within the EU and not evade the ETS by moving operations into less regulated locations [171].

Challenges

- Geopolitical instability may prompt policymakers to soften emission trading measures to reduce citizens' cost pressure [172]. This could cause uncertainty in realizing the "Fit for 55" EU initiative for the energy transformation, impacting utility companies' planning safety [173].
- Regulatory complexity may lead to contradictions with legislative goals. For instance, including waste incineration in the ETS by 2027 may financially favor landfilling despite the EU Landfill Directive aiming for only a 10% share of landfilling in 2035 [174].
- With the shift towards an auctioning system for ETS certificates in 2027, a price increase of 500% could be possible without a steady increase beforehand [175].

Impact on the Future of Utilities in the Era of AI

The impact of evolving emission trading on utilities will be profound. As CO2 costs rise, utility providers must pivot towards renewable energies, innovate, and diversify their production to mitigate financial risks. The expansion of emission trading to heating and waste management further incentivizes this shift, while potential price surges in certificates necessitate proactive adaptation strategies. Overall, emission pricing acts as a catalyst for the utility sector's transformation towards sustainability. Utility companies can utilize advanced AI-powered scenario planning tools to simulate various emission pricing scenarios, enabling advanced risk assessment and identifying new opportunities.

GROWING NEED FOR IN-DEPTH REPORTING

Ensuring Transparency Across Organizations' Sustainability Efforts

To enhance the visibility and impact of organizational sustainability initiatives, a variety of reporting directives have been introduced both nationally and internationally [176]. Initially centered solely on the financial risks associated with climate change, known as single materiality disclosures, the scope has expanded to include companies' societal and environmental impacts, defined as double materiality [161]. Moving beyond individual processes, these disclosures now encompass entire supply chains. Yet, it remains a challenge to harmonize the national and international standards, gather relevant data, and compare the information between companies.

Facts

- Sustainability reporting was primarily focused on the financial impact of sustainability activities, exemplified by the Task Force on Climate-related Financial Disclosures (TCFD), enabling disclosure of climate change-related financial risks in G20 countries [177].
- In September 2023, the Taskforce on Nature-Related Financial Disclosures (TNFD) expanded upon the TCFD, considering organizations' dependencies and impacts on nature in general [178].
- The CSRD, adopted by the EU in January 2023, introduced the concept of double materiality, requiring companies to report on financial and societal/environmental impacts [161].
- Germany's supply chain act enforces transparency across entire value chains, requiring impacted companies to comply starting January 1, 2023 [176].

Key Drivers

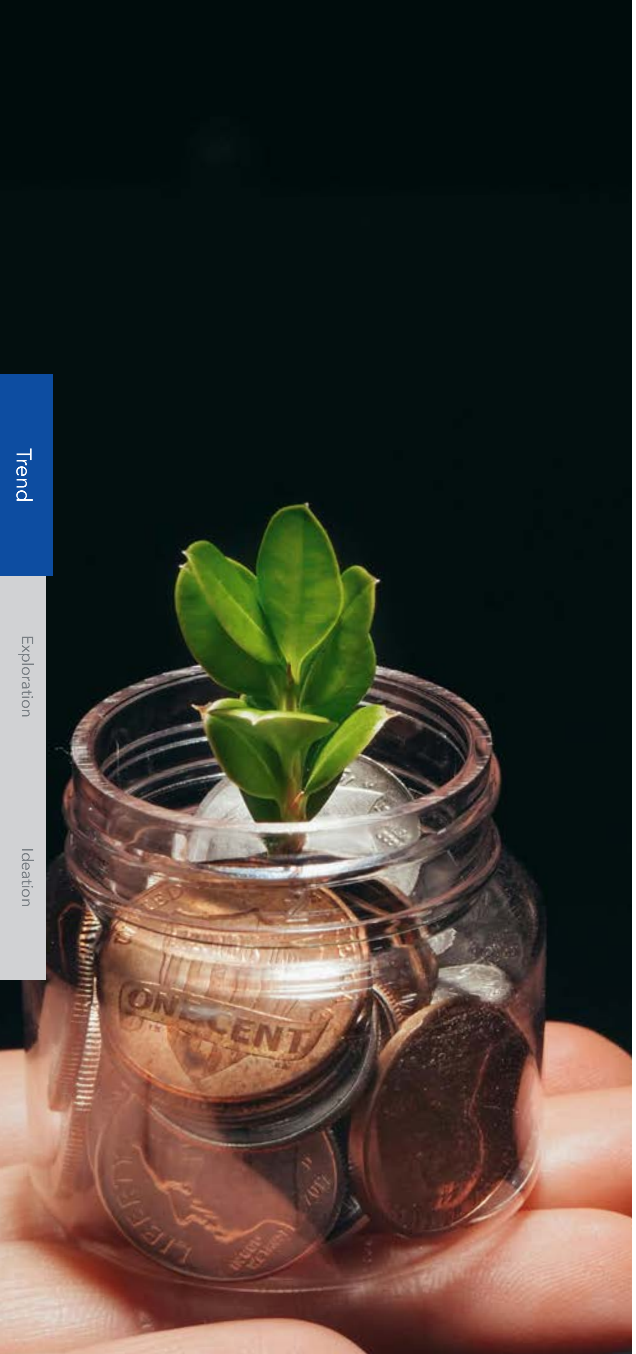
- As investors increasingly integrate environmental and social factors into their investment strategies, companies voluntarily embrace transparent reporting practices to align with these expectations and strengthen their sustainability profiles [179].
- Organizations are adopting climate disclosures to meet stakeholder demands for transparency and sustainability as customers, employees, communities, and NGOs increasingly focus on companies' environmental practices and their contributions to climate change [180, 181].
- Competitive pressure drives companies to disclose carbon emissions, making low carbon footprints a new market diferentiator [182].

Challenges

- Efforts to enhance the credibility of sustainability-themed financial products and to mitigate greenwashing require increased focus of policy-makers on enforcing the implementation of disclosure requirements at the product level [183].
- Lack of harmonization between international standards, e.g., set by the International Sustainability Standards Board (ISSB) and EU standards, leads to double reporting, reducing informative value and comparability of the data.
- Criteria for disclosing qualitative information, e.g., description of the processes, procedures, strategies, and mechanisms of actions, often remain vague, which makes it challenging to compare the information between reporting companies. Moreover, there continues to be difficulty in collecting the quantitative data points [184].

Impact on the Future of Utilities in the Era of AI

Carbon disclosures, propelled by regulations such as the EU's CSRD, are gaining traction globally as governments escalate their efforts to address climate change. Investors are increasingly scrutinizing the environmental impact of their investments. Yet, there remains a deficiency in the measurement granularity and a lack of standardization in disclosing company activities. AI can revolutionize data collection and compliance monitoring by automating these processes. It helps extract and organize corporate sustainability data, ensure product-level adherence to disclosure requirements, and enhance clarity and comparability among reporting companies.



GREEN INVESTMENT PROGRAMS

States Accelerating Investments in Net-Zero Transition

The world is racing against time to transition to a net-zero economy. The largest economies in the world - from the United States to China and the European Union - have all started to invest massively in green innovation. States lower the risk for utility transformation projects by creating incentive programs such as grants or guaranteed loans. However, complex subsidy systems also bring challenges. They require a careful design to align incentives with carbon pricing and other objectives. Moreover, they present a challenge regarding the prioritization of the projects, given the competition for funding among various industries and fragmented institutional frameworks [185, 186].

Facts

- In 2020, the EU Commission adopted the EGDIP, mobilizing public and private funds to support 1T EUR in green investment over the next decade [162].
- The Inflation Reduction Act (IRA) signed into law in August 2022 in the US, allocates 369B United States Dollar (USD) in federal funding to support clean energy initiatives, mainly focusing on clean electricity and transmission. Funds are provided through a combination of tax incentives, grants, and loan guarantees. The IRA advocates for the growth of renewable energies by providing corporate and budgetary support [187].
- In February 2023, the EU followed the United States (US) by presenting the Green Deal Industri al Plan for the Net-Zero Age as an addition to the EGDIP, including faster access to funding and aiming to create a favorable regulatory environment to foster a green transition [188].

Key Drivers

- Economies strive to remain competitive in a future net-zero industry. The IRA pursues objectives emerging from climate and industrial policies, including ensuring the USA's long-term supremacy as the largest energy producer and decreasing dependence on China and Russia, particularly regarding raw material supply [186].
- Governments aim to reduce reliance on fossil fuels and to increase domestic clean energy production, e.g., with the EU raising its goal for the renewables share in overall energy consumption to 42.5% by 2030 [189].
- A surge in private investment is needed to propel the green transition forward. Implementing IRA accelerates US Venture Capital (VC) investments in Climate Tech [190].

Challenges

- Currently, complex incentive systems are in place, which include many conditionalities, compliance requirements, and reporting rules, making them challenging to navigate [191].
- Projects compete to get funding, and questions arise on prioritizing projects based on their potential benefits to society [192].
- Implementing the subsidies alongside efforts towards reducing energy costs requires improving permitting processes to accelerate the energy transition [193].

Impact on the Future of Utilities in the Era of AI

There is a significant shift towards implementing policies and incentive programs that minimize the risk for businesses investing in climate infrastructure deployment. AI can help improve incentive program monitoring and evaluation by analyzing large datasets to assess impact and effectiveness. Moreover, it could be leveraged during the prioritization of the projects, e.g., ensuring that CO2 storage is made available to hard-to-abate sectors that require it most for decarbonization efforts [194].

SMART METER ROLLOUT

Revolutionizing Renewable Energy Consumption With Real-time Pricing

A smart meter is an electronic device that measures and records consumption data in real-time and communicates it to the utility provider. Therefore, smart meters are pivotal in transitioning towards pricing models, where electricity costs are adjusted dynamically based on demand patterns and the fluctuating availability of renewable sources. This evolution signifies a considerable shift from traditional, static energy systems to more adaptable, responsive frameworks [195]. Enhanced by AI, the grid is evolving beyond mere automation; it anticipates demand fluctuations and optimizes energy distribution accordingly. This integration has two benefits: First, it empowers consumers to adjust their energy consumption in response to price signals, potentially leading to significant cost savings. Secondly, it also promotes environmental sustainability by aligning energy usage with periods of high renewable availability [196].

Facts

- As projected by the European Commission, investments of 584B EUR by 2030 in the EU's electricity grids emphasize the regulatory prioritization of modern infrastructure, including smart grids, to support the energy transition [197].
- Germany's metering law requires 20% smart meter penetration by end 2025 and 50% by end 2028. Smart meters in German households should be "largely standard" by 2032 [163].
- Germany's Erneuerbare-Energien-Gesetz (EEG) (amended 2021) incentivizes flexible electricity consumption to balance renewable supply variability, setting the stage for dynamic pricing [198].

Key Drivers

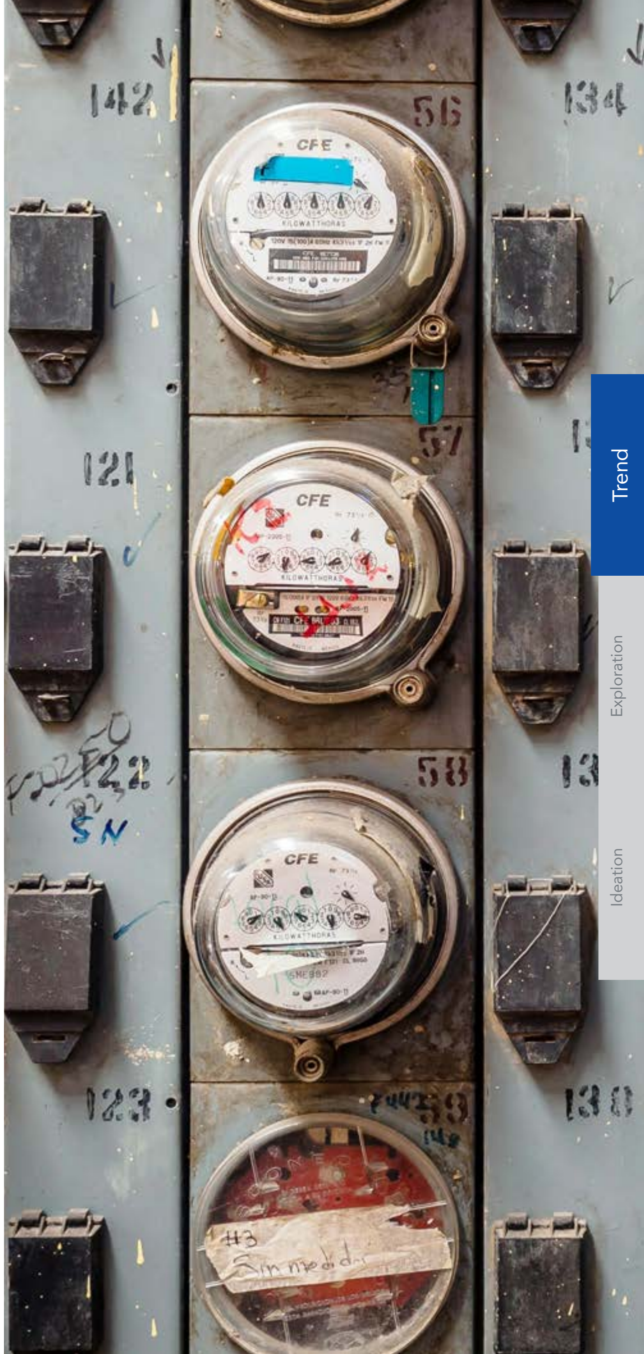
- The unbundling of the energy market in Europe facilitated a more flexible and accessible grid, laying the groundwork for the widespread adoption of smart meters [199].
- Due to the intermittent nature of renewable energy generation, matching generation patterns directly to consumption patterns is challenging. A robust smart grid capable of managing these fluctuations in power generation at scale is crucial [200].
- Dynamic pricing, facilitated by smart meters and AI, promotes energy consumption aligned with real-time demand and supply, especially from renewables. It enhances grid efficiency and sustainability by incentivizing off-peak usage, while AI algorithms optimize energy distribution and integration of variable renewable sources, driving economic and environmental benefits [196].

Challenges

- Building public trust and understanding is essential for the acceptance of smart meters. Clear communication on their benefits is critical. At the same time, updating laws to protect data privacy and security is critical to ensure that personal energy usage information is kept safe [201].
- The technological integration of smart meters with existing infrastructure poses significant financial and logistical challenges. The large-scale deployment across the energy infrastructure will require substantial capital investment and meticulous coordination to ensure seamless integration with legacy systems, all while minimizing potential service disruptions [202].

Impact on the Future of Utilities in the Era of AI

Utility providers must invest in AI and data analytics to leverage smart grid benefits. Integrating smart meters and AI enhances energy demand prediction, renewable energy management, and customer-centric pricing. This transition improves operational efficiencies, reduces costs, and promotes sustainable energy consumption. Yet, utilities must navigate the complexities of data management, privacy, regulatory compliance, and customer engagement to fully realize digital transformation benefits.



AI AND CYBER-SECURITY

Navigating the Regulatory Landscape for a Tech-driven Utility Sector

Digitization of the utility sector has become necessary, and as a result, it has become more efficient. The shift towards a digitized network of devices, the use of AI, and the related exponential growth of the IT infrastructure have made cyber-security increasingly crucial. Cyber attackers keep outpacing the development of stronger cybersecurity standards [203]. However, there is an increased fragmentation of standards worldwide, intensifying the burden on global companies by forcing them to comply with different legislation in different markets. Moreover, AI's potential in the utility sector is significant, with applications like power generation, demand forecasting, grid operation, and optimization [164]. The adoption of AI in this sector must balance innovation with regulatory compliance, data privacy, and security concerns.

Facts

- The US Critical Infrastructure Act of 2022 enforces infrastructure providers, including utilities, to report substantial cyber incidents that are likely national threats to the Cybersecurity and Infrastructure Security Agency (CISA) [204].
- According to the EU AI Act, AI applications in utilities, such as the management of power lines, are considered high-risk due to their significant impact on human life [164]. These systems are subject to the most stringent requirements, including human oversight, transparency, risk management, monitoring, and reporting requirements [205, 206].

Key Drivers

- According to the International Energy Agency (IEA), cyberattacks on critical infrastructure for the utility sector have more than doubled from 2020 to 2022, reaching 1,100 average weekly cyberattacks in 2022 [203].
- Cyber resilience tools are tailored to specific user needs and policies. Australia's framework uses ES-C2M2 and NIST CSF, with versions for varying criticality, and the EU uses CRA and Cybersecurity Incident Response Capabilities for the Electricity Sector, leading to fragmentation in standards [204].
- The EU AI Act mandates pre-market compliance for high-risk AI systems, supported by evolving harmonized standards to ensure AI cybersecurity aligns with technological advancements [207].

Challenges

- Institutions and businesses are concerned that the risk assessment standards are inflexible and cannot adapt to emerging technologies, especially in AI [208].
- The reliance on outdated systems in the energy sector can pose severe cyberattack threats. Microsoft has identified unpatched, high-severity vulnerabilities in 75% of the most common industrial controllers [209].
- The 2023 World Economic Forum (WEF) report highlights a significant 25% shortfall in the utility sector's workforce in cybersecurity skills [210].

Impact on the Future of Utilities in the Era of AI

Utilities must navigate complex, ever-changing policies addressing transparency, privacy, and cybersecurity to ensure responsible AI deployment and safe critical infrastructure. Legal frameworks underscore the importance of robust risk management strategies and ethical AI principles [205]. With regulatory frameworks imposing extensive regulations on high-risk applications in critical infrastructure, utility-related applications will face increased compliance burdens and scaling challenges. These regulations demand transparency, robustness, and accuracy, particularly in AI systems in critical infrastructure, due to their potential impact on human life [206].

ECONOMY TRENDS

INFLUENCING THE FUTURE OF UTILITIES IN THE ERA OF AI

Roles of AI in Skilled Labor Shortage

Carbon Leakage

High Interest Rates

Energy Price Development

Green Hydrogen Investments

Annemarie Schimkat 
Christina Hudgens 
Ju-Shan Chao 
Khola Raja 
Valentin Gölz 

ECONOMY TRENDS

Revolutionizing Utilities While Navigating AI and Economic Resilience

Traditionally known for its stability, the utility sector is experiencing a profound transformation driven by AI and technological advancements, as well as economic challenges. This shift is redefining the operations and strategies of energy, water, and waste management companies, pushing them towards a more digital and eco-friendly approach.
AI plays a dual role in addressing the skilled labor shortage by automating routine tasks while demanding new, tech-centric skills, thus necessitating workforce upskilling. AI's integration enhances operational efficiency, using advanced data analytics and machine learning to optimize resources, improve decision-making, and enable predictive maintenance. This leads to cost savings and contributes to the sector's sustainability and resilience [211, 212].

The challenge of carbon leakage represents another trend where production shifts to areas with laxer environmental regulations, impacting local climate goals and economic stability. Addressing this requires innovative policies like carbon border adjustments and international cooperation to balance economic competitiveness with environmental efforts [213].

Another critical trend influenced by the global push for sustainability is the challenge of carbon leakage, particularly in industrial powerhouses like Germany. The movement of carbon-intensive production to regions with less stringent environmental regulations undermines local climate goals and poses economic risks. This complex issue calls for innovative policy measures including carbon border adjustments and international collaboration, to ensure that environmental efforts do not inadvertently compromise economic competitiveness [214].

The macro economy, marked by fluctuating interest rates aimed at curbing inflation, also significantly impacts the utility sector. High interest rates can deter investment in essential infrastructure, particularly in capital-intensive industries like utilities, where the transition to green energy requires substantial upfront costs. This economic dynamic necessitates a careful balance between inflation control and the facilitation of critical investments in sustainable infrastructure [215].
Energy price volatility remains a pivotal economic trend, influenced by geopolitical tensions, the fluctuating supply and demand dynamics of fossil fuels, and the rapid expansion of renewable energy sources. The transition towards renewables, driven by their decreasing costs and lower environmental impact, reshapes energy markets and pricing structures [216].

Lastly, the surge in investments targeting green hydrogen highlights the sector's role in pioneering clean energy solutions. With its vast potential to decarbonize challenging sectors to electrify, green hydrogen represents a frontier for sustainable innovation. Despite the hurdles of production costs and infrastructure development, the burgeoning interest in green hydrogen signals a significant shift towards cleaner, more versatile energy carriers, offering both environmental and economic benefits [217].

These trends show the utilities sector's journey in the AI revolution era, underscoring the interplay between innovation, sustainability, and economic resilience. The sector's ability to navigate these trends will be crucial in shaping a sustainable, efficient, and equitable energy future.

ROLES OF AI IN SKILLED LABOR SHORTAGE

AI Helps to Tackle and Improve Operational Efficiencies

Exacerbated by an aging workforce and a shift towards AI, the skilled labor shortage is marked by a persistent surplus of vacancies over 'normal' turnover levels, driven by the industry's evolving skill requirements amidst green and digital transitions [218]. AI plays a complex role, deepening the skill gap by demanding new, technology-centric competencies and offering a remedy by automating routine tasks.

AI's impact enhances process efficiency and decision-making in the utility industry [219]. Moreover, AI-driven scheduling optimization alleviates staffing challenges by maximizing workforce utilization and reducing downtime. Additionally, AI algorithms are crucial in analyzing sensor data and customer interactions, offering energy optimization and cost reduction insights, such as peak capturing, heat trend prediction, and recycling classification [211, 212]. However, integrating these poses challenges due to legacy systems and decentralized structures [219]. This transition underscores the need for a balanced approach to addressing the labor shortage while embracing technological advancements for a sustainable and efficient future [220, 221].

Facts

- By 2030, 20% of the existing workforce in the EU energy sector will retire. On the contrary, it is estimated that 30% of jobs in that sector could be automated [222, 223, 224].
- The renewable sector needs 2.8M new workers. Regions like Germany face a significant worker shortage, with vacancies significantly outnumbering unemployed energy technicians by a factor of 1.7 [225].
- 74% of utility companies are adopting AI to boost productivity and optimize consumption, showcasing AI's importance [219, 226, 227].

Key Drivers

- The skilled labor shortage is due to an aging workforce, geographic imbalances, and rapidly evolving technology that outstrips current workers' skills [228].
- Mismatches between educational programs, industry needs, and slow hiring processes worsen this issue [228].
- AI is transforming the industry by improving efficiency, lowering costs, and fostering sustainability of energy production and customer service [220].
- The move towards a decentralized and digital energy system, coupled with the need for enhanced customer interaction and operational effectiveness, is driving the rapid adoption of AI [229].

Challenges

- Labor shortages raise costs and cause inefficiencies, including extended downtimes and lower productivity [230].
- Aggravated by the inexperience of available workers, the shortages result in poor service quality and project delays, thus delaying economic benefits and necessitating substantial training investments [230].
- The legacy systems and decentralized structures limit AI's full potential [227].
- The lack of in-house AI experts increases long-term costs and impedes innovation, as acquiring AI without requisite expertise can lead to underutilization and failure [220].

Impact on the Future of Utilities in the Era of AI

Utilities undergo transformative impacts that significantly enhance operational efficiency and sustainability. AI-driven solutions address the challenge by automating routine tasks, enabling workforce upskilling, and optimizing energy production and distribution processes. Advanced analytics and AI algorithms offer critical insights for energy optimization, reducing costs, and improving service quality. Despite challenges such as legacy systems and the need for AI expertise, adopting AI in utilities is driving a shift towards a more efficient, sustainable, and resilient energy sector, ultimately reshaping the utility landscape in the face of demographic and technological changes.

CARBON LEAKAGE

Germany has to Navigate Between Climate Policy and Competitiveness

Carbon leakage - meaning businesses relocate carbon-intensive operations to countries with looser climate policies - presents a significant challenge to Germany's climate goals, economy, and jobs [213]. Factors driving carbon leakage include the global competitive landscape, environmental standards disparity, and industries' need to stay profitable under strict regulations. To counter this, German policymakers are exploring measures like carbon border adjustments and international agreements for a consistent global response to emissions [231], aiming to balance economic growth with environmental sustainability.

Facts

- The share of trade conducted through nations ranked at Carbon leakage shifts emissions to countries with lax regulations, undermining global climate efforts [213].
- The EU's CBAM mitigates carbon leakage risk by imposing a levy on imports from countries with lower carbon pricing, aligning them with the EU's emissions standards [231].
- Carbon leakage can cause job losses and harm industrial competitiveness, necessitating policies like carbon border adjustments to level the playing field [232].

Key Drivers

- High energy costs in the EU, driven by environmental regulations, push industries to regions with cheaper, less regulated energy, incentivizing relocation and potentially increasing global emissions [233].
- Industries may move to access cheaper, more accessible raw materials in countries with lax environmental standards, indirectly heightening emissions [233].
- Non-EU countries lure EU industries with tax breaks and subsidies, prompting relocation and contributing to carbon leakage. This challenges EU environmental goals and global emission reduction efforts, underscoring the complexity of addressing carbon leakage in a globalized economy [214].

Challenges

- Addressing carbon leakage requires enhanced international cooperation and coordination on climate policies to ensure that efforts to reduce emissions are harmonized globally and do not disadvantage any single country or region [214].
- Despite efforts to quantify and mitigate carbon leakage, attributing emissions embedded in trade to specific causes, such as climate policy differences, remains challenging. Factors influencing trade and investment flows include relative factor prices, raw material availability, non-climate policy differences, and political stability [214].
- Carbon leakage significantly undermines global efforts to combat climate change by merely shifting greenhouse gas emissions from one region to another rather than achieving actual reductions in global emissions [213].

Impact on the Future of Utilities in the Era of AI

Carbon leakage poses significant challenges to the utility sector, impacting operational costs and regulatory compliance. As companies face pressure to reduce emissions, the risk of relocating operations to regions with lower environmental standards looms. This shift can disrupt the utility sector, leading to job losses and decreased competitiveness. However, AI presents opportunities by optimizing energy production and distribution, enhancing efficiency, and facilitating the transition to renewable energy sources. AI-driven predictive analytics can also aid in identifying and mitigating potential carbon leakage risks, enabling utilities to navigate regulatory complexities and maintain sustainability goals amidst changing global dynamics.

HIGH INTEREST RATES

The Fight Against Inflation is Hurting Critical Utility Investments

Raising interest rates is a potent tool central banks employ to combat inflation by slowing the economy. High interest rates disincentivize new investments as taking on debt becomes more expensive, leading to less economic activity and, ultimately, less inflation. While crucial for ensuring economic stability, it also means that significant investments are often postponed. Furthermore, hiring slows down, and stock markets tend to be more volatile during rate changes [234]. Current governments struggle to combat inflation, which implies interest rates will remain higher for longer. Reasons for this include resilient consumer spending attributed to stimulus allocation during the COVID-19 pandemic, high energy prices due to the cutoff of Russian gas, and the issuance of new debt [235]. High interest rates heavily impact critical sectors such as utilities, as they must carefully balance profit orientation with servicing the public's needs. Because the utility sector is capital-intensive, the increased cost of capital deters new investment in infrastructure necessary for the green energy transition. Government-owned utility companies must also navigate an additional layer of complexity, given that higher interest payments on the national debt result in reduced government spending on services and infrastructure.

Facts

- After nearly a decade of ultra-low interest rates set by the European Central Bank (ECB), interest rates have steadily risen over the last two years to 4.5% in the Eurozone [236].
- Germany's inflation dropped from 3.8% in December 2023 to 3.1% in January 2024, sparking speculation about a possible ECB rate cut in Q2 2024 [237].
- Energy costs in Europe have experienced a significant upswing in recent years, spanning from 2021 to 2022, primarily attributed to geopolitical tensions, notably the Ukraine conflict. Throughout EU capitals, there has been a substantial escalation in electricity bills, averaging a 49% increase, while gas bills have surged by an astounding 60% [238].

Key Drivers

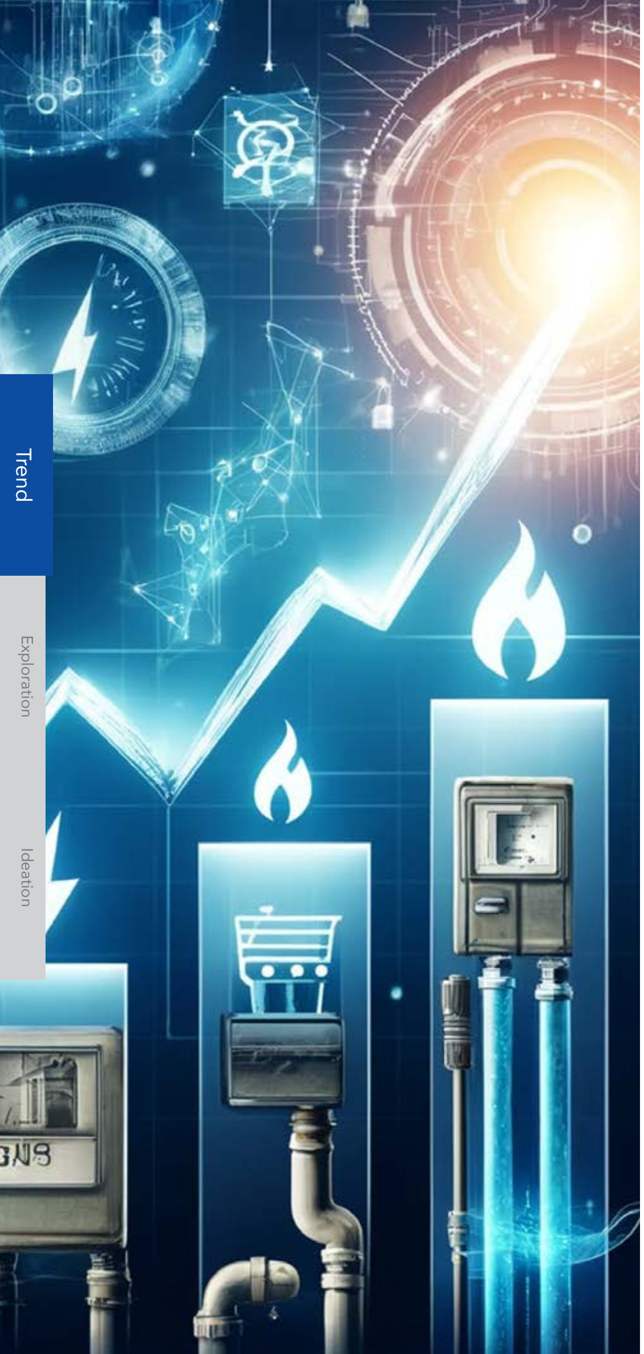
- Interest rate hikes, cyclical in nature, usually follow periods of economic growth and rising consumer spending, leading central banks to increase borrowing costs to stabilize prices [215].
- "Higher for Longer" interest rates are currently due to a stronger-than-expected US economy and significant debt issuance by Western governments [239].
- Inflation in energy prices is susceptible to geopolitical factors, and transitioning grids to new sources in response to quickly evolving tensions is complex and time-consuming.

Challenges

- Despite high interest rates set by central banks, consumer spending is resilient, and the reduction in inflation is slower than expected [235].
- Interest rates may not return to pre-pandemic rates, which means that future borrowing required for the energy sector transition will cost more, ultimately leading to slower progress [239].
- Due to geopolitical tensions worldwide, it is tough to predict interest rates in the next five to ten years, which poses significant challenges for governments and private companies when strategizing and planning future investments.

Impact on the Future of Utilities in the Era of AI

Utilities, as capital-intensive entities, face significant challenges amid rising interest rates. They discourage investment in essential infrastructure such as the hydrogen network and high-voltage lines, which are crucial for transitioning to green energy. Moreover, higher interest payments on national debts limit government spending on services and infrastructure, further complicating the sector's challenges. Utility providers must balance profit motives with serving the public, making it imperative to navigate these financial complexities strategically. Ultimately, the prolonged impact of higher interest rates could hinder the utility sector's ability to innovate and meet evolving energy needs efficiently.



ENERGY PRICE DEVELOPMENT

Volatile Energy Pricing Lies Ahead as the Energy Transformation Comes to Fruition

Energy prices have seen considerable fluctuations due to supply-demand dynamics, with cheaper renewable energy sources like solar and wind power rapidly expanding [240]. These renewables are set to surpass gas and coal capacities thanks to their lower costs, which benefit consumers by reducing average wholesale electricity prices under the Merit Order Policy [241]. Geopolitical tensions, particularly European sanctions on Russian gas, have spiked energy costs in Germany. Hydrogen promises to even out renewable energy supply fluctuations as a sustainable energy source but faces high initial costs, potentially increasing consumer prices in the short term. On the demand side, electricity needs are growing with the shift towards Electric Vehicles (EVs) and the expanding digital infrastructure, such as data centers for AI. For instance, the share of Europe's total electricity consumption from EVs will increase until 2050 [216]. To maintain low prices, the supply must match this demand. Additionally, demand-side management, which optimizes power consumption, is crucial to minimize the reliance on high carbon-emitting and expensive energy sources derived from fossil fuels. Together, these factors will collectively shape the future of energy pricing in the coming decades.

Facts

- IEA expects aggregated installed global photovoltaic and wind capacity to exceed aggregated gas capacity in 2023 and aggregated coal capacity in 2024 [241].
- Annual solar energy prices were forecast to fall 2.6% on average in the decade following 2010, with all forecasts predicting a less than 6% price reduction. However, solar prices fell 15% – more than five times the expected annual rate – during this period, which could have severe implications for investment and policy decisions based on these misleading predictions [240].
- The share of Europe's total electricity consumption from electric vehicles will increase from approximately 0.03% in 2014 to around 4-5% by 2030 and 9.5% by 2050 [216].

Key Drivers

- Internal factors influencing European energy prices include greater renewable energy penetration in the energy mix, increasing electricity demand from the EV transition and AI-powering data centers, a growing emphasis on demand-side management, and new investment in Green Hydrogen as a carbon-neutral, storable fuel source [240].
- The most significant external factor influencing energy prices is the impact of geopolitical tensions on energy sources and the drive for energy independence [216].

Challenges

- Rising geopolitical tensions and an overall deglobalization trend push the European energy market to build internal resilience and rely less on imported energy [242].
- The high investment cost required to build the capacity needed for green energy investment may cause additional turbulence in the upcoming transition.
- Low adoption of smart metering in Germany reduces consumers' ability to make informed decisions about their consumption [243].

Impact on the Future of Utilities in the Era of AI

The development of energy prices plays a crucial role in shaping the utility sector, influencing various aspects of its operation and strategy. Fluctuations in energy prices directly impact utilities' profitability and willingness to invest in new infrastructure. The energy demand is also sensitive to price changes, as high prices may reduce consumption as consumers seek to minimize costs. Energy price trends can also expedite the transition towards alternative energy sources, as utilities pivot towards renewable energy when fossil fuel prices are high to maintain competitiveness. The fluctuations in energy prices are a significant determinant of the utilities sector's financial health, operational strategies, and future direction, affecting topics from investment decisions to consumer behavior.

GREEN HYDROGEN INVESTMENTS

Rising Capital Targets Green Hydrogen as a Game-Changer in Clean Energy

The green energy revolution is driving a surge of investment, with green hydrogen emerging as a promising frontier. Produced by splitting water molecules using renewable sources like solar or wind, green hydrogen offers a near-zero emission alternative to traditional fossil fuel-derived "grey hydrogen". This innovation is crucial for decarbonizing hard-to-electrify sectors such as heavy transportation and high-heat industrial processes [244]. Investors increasingly recognize the potential of green hydrogen, pouring billions into production facilities, infrastructure development, and research worldwide. This focus on green hydrogen marks a potential shift in the energy landscape, offering a versatile, clean energy carrier with vast applications. Revolutionizing transportation, green hydrogen offers extended ranges and faster refueling times for EVs powered by hydrogen fuel cells. Moreover, its ability to be stored and transported over long distances can help balance supply and demand in renewable energy systems. By fostering innovation and navigating policy uncertainties, green hydrogen presents a unique opportunity for investors seeking both financial returns and positive environmental impact [244].

Facts

- Green hydrogen plays a pivotal role in attaining the goal of net-zero carbon emissions by 2050, especially within sectors that are challenging to electrify [244].
- Investments in green hydrogen projects are rapidly increasing, with a projected global market size of 1.4T USD annually by 2050 [217].
- Leading regions like Europe plan to import green hydrogen from countries rich in renewable resources like solar and wind [245].

Key Drivers

- Green hydrogen offers a clean fuel solution, accelerating the transition from fossil fuels and mitigating climate change. Its potential to replace conventional energy sources stands as a beacon of hope in combating environmental degradation [217].
- Growing investments unlock economic opportunities, fostering new markets across the value chain. This surge in activity drives innovation and stimulates sustainable growth.
- Falling costs of renewable energy sources and advancements in electrolysis technology make green hydrogen production more competitive, paving the way for a cleaner and sustainable future [217].

Challenges

- Green hydrogen production costs remain higher than traditional methods, hindering widespread adoption. Ongoing technological advancements and economies of scale are driving down costs, making it more economically viable.
- Developing infrastructure for large-scale green hydrogen production, transportation, and storage requires significant investment. However, with increasing recognition of its potential, investments are gaining momentum [245].
- Uncertain regulations regarding green hydrogen production, transportation, and usage can create investor hesitation. A lack of standardized certification processes can hinder global trade. Clear and supportive policies foster investor confidence and accelerate the transition to a green hydrogen economy [217].

Impact on the Future of Utilities in the Era of AI

By employing green hydrogen technology for energy storage and grid balancing, utilities can enhance grid stability, ensuring consistent electricity supply during fluctuation hours. Investing in green hydrogen enables utilities to transition from fossil fuels, reducing their carbon footprint and supporting global climate goals. This investment drives innovation within the utilities sector, fostering the development of cleaner and sustainable energy solutions. Additionally, as utilities embrace green hydrogen infrastructure and technology, they can generate more jobs and stimulate economic growth in renewable energy, thus benefiting local communities and economies.

BUSINESS MODEL TRENDS

INFLUENCING THE FUTURE OF UTILITIES IN THE ERA OF AI

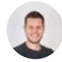
Access to Energy Production

The Zero-Touch Provider

One-Stop-Shops

AI-Driven Dynamic Pricing

Multi-Modal Transport

Anna-Maria Geist 
Christophe Schmit 
Jan Chen 
Raphael Beuter 
Thomas Rother 

BUSINESS MODEL TRENDS

Utility Organizations Reshape Their Value Proposition

The utility industry is an essential backbone of every economy and society, delivering on its promise to ensure the continuous availability of public services. It faces massive disruption as it transitions away from traditional fossil fuels, thus requiring modern control technologies. This complex and multifaceted environment, characterized by the need for digitalization and high infrastructure investment costs, allows new business models to develop. In this evolving landscape, business models play a pivotal role in shaping the trajectory of utility companies. The following five trends have been identified.

The first trend focuses on democratizing modern energy production, highlighting the utility sector's current transformation towards a decentralized production and consumption model. It introduces new energy trading schemes, such as Peer-to-Peer (P2P) trading and consumer aggregation methods, giving individuals full ownership of their energy. The increase in renewables' integration led consumers to participate in production and consumption decisions. This and the need for grid resilience in the face of climate change are the two key drivers that have emerged [246].

The utility industry is rapidly shifting towards zero-touch provision enabled by conversational AI, meeting growing demands for personalized yet low-involvement customer relationships. Due to rising digital disruption, utility companies must automate customer service interactions to enhance customer satisfaction while streamlining their operations to realize efficiencies [247]. Despite current challenges such as skill shortages, lack of relevant data, and AI biases, the long-term impact points towards fundamentally reshaping customer-facing and back-office processes impacted by AI-driven transformations.

Following this discussion, one-stop-shop companies emerge as a pivotal force in the renewable energy sector. These entities excel in facilitating the adoption of green utilities through comprehensive all-in-one solutions for renewable technology [248]. They provide user-friendly solutions and digital platforms coupled with flexible financing to ensure wider access. This strategic approach significantly lowers barriers to renewable energy adoption.
AI-driven dynamic pricing, utilized by one-stop-shops, can revolutionize the utility sector by tailoring tariffs to real-time conditions and consumer behavior. This approach optimizes grid load, promotes energy efficiency, and fosters innovative business models [249]. However, it also faces challenges in consumer awareness and price fluctuations. The integration of dynamic tariffs, mandated by law in Germany, reflects a significant shift towards a more flexible and efficient energy landscape.

Lastly, the rise of new mobility services, fueled by the sustainable transformation of the transport sector, leads to increased multi-modality in urban journeys and thus impacts the business models of utility providers. Integrating various transport modes, including public transport and emerging services like ride-hailing and micro-mobility, is crucial to ensure seamless mobility for citizens [250]. Despite complexities in integration, there is a growing trend towards more synchronized, user-friendly urban transportation systems.
A thorough understanding of these models is crucial for stakeholders in the utilities, energy management, and infrastructure development sectors.

ACCESS TO ENERGY PRODUCTION

Individuals Take Ownership and Access the Digital Energy Market

The shift towards a decentralized energy grid marks a pivotal transformation, primarily driven by the liberation of the energy market and individual access to renewable energies. This trend towards a prosumer model system is characterized by pooling individual consumers into energy communities, offering new energy trading potential on a P2P basis, possibly facilitated by blockchain technologies [251]. This democratization of energy production and consumption significantly contributes to the decarbonization of the power sector. The bottom-up market integration of DERs requires leveraging digital technologies to efficiently manage the higher volatility within the market. In 2023, the net electricity generation from renewables displayed volatility of 40%, which presents an immense challenge, particularly in adapting to demand- and peak-load profiles, underscoring the critical need for grid operators to enhance flexibility [252].The shift to a renewable-focused, decentralized grid requires a digitized infrastructure for implementing AI and IoT solutions. This enables better supply-demand balance, preemptive maintenance, and boosts system efficiency and reliability.

Facts

- Germany leads the EU with an installed prosumer electricity production capacity of 21.5 GW, primarily from rooftop solar, followed by wind energy [253].
- In 2020, the EU led global Virtual Power Plant (VPP) expenditures, with 45% of the total investment and high costs attributed to software licensing and deployment services for aggregation platforms [254].
- Europe has the highest penetration of Advanced Distribution Management Systems (ADMS) globally, with an expected Compound Annual Growth Rate (CAGR) of 5.4% between 2020 and 2030 [255].
- Implementing P2P electricity trading can reduce consumer costs by up to 20% across all German communities and regions [251].

Key Drivers

- The market entry of start-ups focusing on digital services The adoption and progress in digital technologies, including AI algorithms and IoT devices, are facilitating the automation of demand responses and more efficient management of decentralized grids [246].
- The rise of DERs has led to greater consumer involvement, with individuals and communities participating in energy production and consumption decisions [246].
- The need for grid resilience is highlighted by climate change, as extreme weather events prompt a shift towards mitigating its effects through decentralized energy producers and extended flexible storage solutions [256].

Challenges

- Many jurisdictions have not prepared their regulatory frameworks for the integration of prosumers into the market. They lack guidelines for customer-sited storage and demand-response technologies [257].
- 74% of renewable energy professionals report that a lack of new grid investments remains a significant barrier to scaling renewables [246].
- Electricity demand is expected to triple by 2050, driven by electrification. Renewables are set to dominate 50% of the energy mix by 2030 and 85% by 2050 [258].

Impact on the Future of Utilities in the Era of AI

As the energy market transitions towards decentralization, facilitated by AI and IoT advancements, consumer autonomy is enhanced, disrupting traditional utility models and grid financing. This shift, favoring P2P trading and energy communities, poses challenges to conventional grid financing [253]. Meanwhile, VPPs exemplify a model that optimizes small-scale, non-owned energy assets, compelling utility operators to transition from traditional suppliers to dynamic managers of technologically advanced, customer-centric energy systems [259]. These developments offer immense potential for decarbonization and efficiency improvements but pose financial and operational risks to utility operators.

THE ZERO-TOUCH PROVIDER

Conversational AI Transforms Customer Engagement and Increases Efficiency

Engaging with customers is at the core of every business. Customers have increasing expectations for personalized digital experiences that are available 24/7 [260]. While digital-native market actors build in line with these changes, incumbents will be forced to adapt their sales and support models [261]. Since there is limited potential to differentiate through product specifications, utility firms primarily compete on prices and customer experience [261]. Historically, this experience has been supported by self-service portals and chatbots for simple transactions. Advances in AI development open up more sophisticated opportunities. In the future, human-like voicebots will provide customized support and AI-enabled predictive customer assistance [262]. Zero-touch interfaces will enable products and processes to run without input from users and offer new features, such as voice commands or virtual reality, to make typing or dialing obsolete [263]. In parallel, customer acceptance of conversational AI interactions is growing. Therefore, if done well, an AI-enabled transformation of customer service can create significant value for utility firms – increasing customer satisfaction while automating more than 95% of service interactions [260].

Facts

- The conversational AI market is projected to reach 36B USD in revenue by 2032, up from 8.2B USD in 2023, led by growth in advanced virtual assistants and IoT device integrations [264].
- The Boston Consulting Group (BCG) estimates that AI technology, once implemented at scale, can increase productivity by 30% to 50% and improve customer satisfaction [262].
- According to the renewable energy group Octopus Energy, AI-generated emails achieved 18% higher customer happiness scores compared with email responses generated by humans alone [262].

Key Drivers

- The shortage of skilled workers is severely impacting customer service personnel and leads to a need for increased efficiency and productivity [247, 265].
- Conversational AI is revolutionizing the way businesses interact with their customers, allowing new business models to be built on top of newly gathered data [262, 266].
- Increasing competition from uprising digital-first utility providers, shifting customer demand, and limited product differentiation force companies to double down on creating a better, low-touch customer experience, increasing organizational efficiency, and enabling competitive offerings [261].

Challenges

- Many utility providers have yet to establish advanced Many utility providers have yet to establish advanced analytics in customer care that are required to implement AI processes [267].
- The usage of AI reduces the need for customer service representatives. However, this leads to an increase in demand for AI experts, who are challenging to find [260].
- Depending on the type of engagement, customers still have a preference for personal interaction [268].
- AI applications may contain biases that could lead to unfair treatment of certain customers. They also risk revealing undesired information or private customer data [262].

Impact on the Future of Utilities in the Era of AI

The current adoption of AI technologies in the utility industry is still slow, mostly due to a lack of data availability and a well-defined AI strategy [267, 269]. However, the transformation towards a zero-touch provider promises great value for utility organizations. AI-powered solutions are expected to automate many back-office administrative and customer-facing functions. Based on a Roland Berger report, 31% of executives believe that many processes will be changed entirely or even replaced by AI [269]. While most initiatives are still in the pilot phase, a real impact is yet to be seen in the next few years [269].

ONE-STOP-SHOPS

Effortless Customer Experiences Accelerate Green Technology Adoption

In the evolving landscape of renewable energy, companies offering one-stop-shop solutions are revolutionizing access to green utilities. They have identified a crucial market niche: facilitating a transition to renewable energy with user-friendly digital platforms that integrate tailored financing options directly into their service offerings [270]. Through innovative financing arrangements such as Energy Performance Contracts (EPCs), on-bill financing, and green loans, these companies enable consumers to spread the cost over time, democratizing access to sustainable energy solutions by making repayment more manageable [271]. Subscription services, which often include operations and maintenance, further reduce the technical and financial risks for end users. These models are supported by various incentives, including grants, tax rebates, and low-interest loans, making renewable technologies more accessible [272]. By addressing the financial challenges head-on, one-stop-shops are accelerating the adoption of renewable energy and shaping a future where sustainable energy is accessible for all.

Facts

- In the IEA's "Net Zero Emissions by 2030" Scenario, solar PV in households is set to grow from 25M in 2020 to over 100M by 2030 [273], and heat pump installations are expected to surge from 180M to 600M, with electric heat pumps leading the way in heating decarbonization [274].
- Startups offering one-stop-shop solutions allow their customers to rent solar systems and heat pumps with no upfront costs, significantly lowering the entry barrier to residential solar adoption [248].
- Up to 40% of customers would consider purchasing their new utility systems (heating, solar, etc.) through alternative payment options such as subscription or leasing [275].

Key Drivers

- There is a trend toward holistic packages integrating tariffs, installation, maintenance, and optimization, simplifying the consumer experience of owning and operating utility assets [276].
- Government incentives and policies supporting renewable energy adoption make it more attractive for consumers to invest in solar energy and heating solutions [277].
- Integration of smart technology and IoT platforms could enable more efficient energy management and monitoring, as well as additional services like VPPs, allowing consumers to optimize their energy usage and savings [278].

Challenges

- A significant increase in skilled workers is necessary for the development, construction, operation, and maintenance of renewable energy installations and the broader utility infrastructure [279].
- Companies face the challenge of navigating complex regulatory environments that can vary by region, affecting the speed and scalability of their services. A clear regulatory framework will be crucial for driving innovation in the utility sector [280, 281].
- Disruptions in the supply chain can cause delays in obtaining critical components like solar panels and energy storage systems, which are vital for renewable energy projects [282].

Impact on the Future of Utilities in the Era of AI

Integrating AI in the utility sector, especially in one-stop-shop models for green technology, will revolutionize the utility landscape. AI's predictive analytics and data management enhance personalized energy solutions, optimizing the consumption of renewable sources. These one-stop shops also enable VPPs, offering dynamic pricing and energy trading, increasing the appeal of their offerings. Additionally, AI-driven platforms streamline the customer journey, ensuring a seamless transition to renewable energy, while innovative financing will improve accessibility. This marks a significant move towards a more sustainable, efficient, and customer-centric utility sector, meeting the demands of modern energy consumers.

AI-DRIVEN DYNAMIC PRICING

Real-time Demand and Behavior Transformation Revolutionizes Pricing Strategies

Dynamic pricing has the potential to reshape the utility sector by leveraging AI algorithms to adapt tariffs according to real-time conditions and consumer behavior [283]. This transformation is particularly pronounced in the energy domain, where electricity prices fluctuate in response to changes in demand and supply throughout the day. The primary objective is incentivizing consumers to shift their energy usage to off-peak periods, optimizing grid load, and promoting energy efficiency [249]. By deploying smart meters, utility operators can utilize data analytics to tailor personalized rate plans for individual customers [284]. This pricing strategy is applicable across various utility sectors. For instance, heating costs can be dynamically adjusted based on demand or external temperature variations, while waste management systems could implement variable pricing models based on waste volume or weight. In mobility, ride-sharing and public transport services can dynamically adjust fares in response to demand fluctuations and traffic conditions, facilitating congestion management and promoting off-peak travel.

Facts

- In Germany, startups predominantly offer dynamic tariffs (e.g., Tibber, Rabot Charge, Octopus Energy) [285].
- Available electricity tariffs in Germany include Time of Use (ToU) structures, where each period corresponds to a price level, as well as hourly rates linked to day-ahead wholesale market prices, allowing direct transmission of spot market prices [249].
- Scientific studies have shown that dynamic electricity tariffs can yield financial benefits for household customers, with potential savings averaging between 3.5 to 4.9 cents per kWh. These results depend on the assumption of perfect forecasting of load and generation [249].

Key Drivers

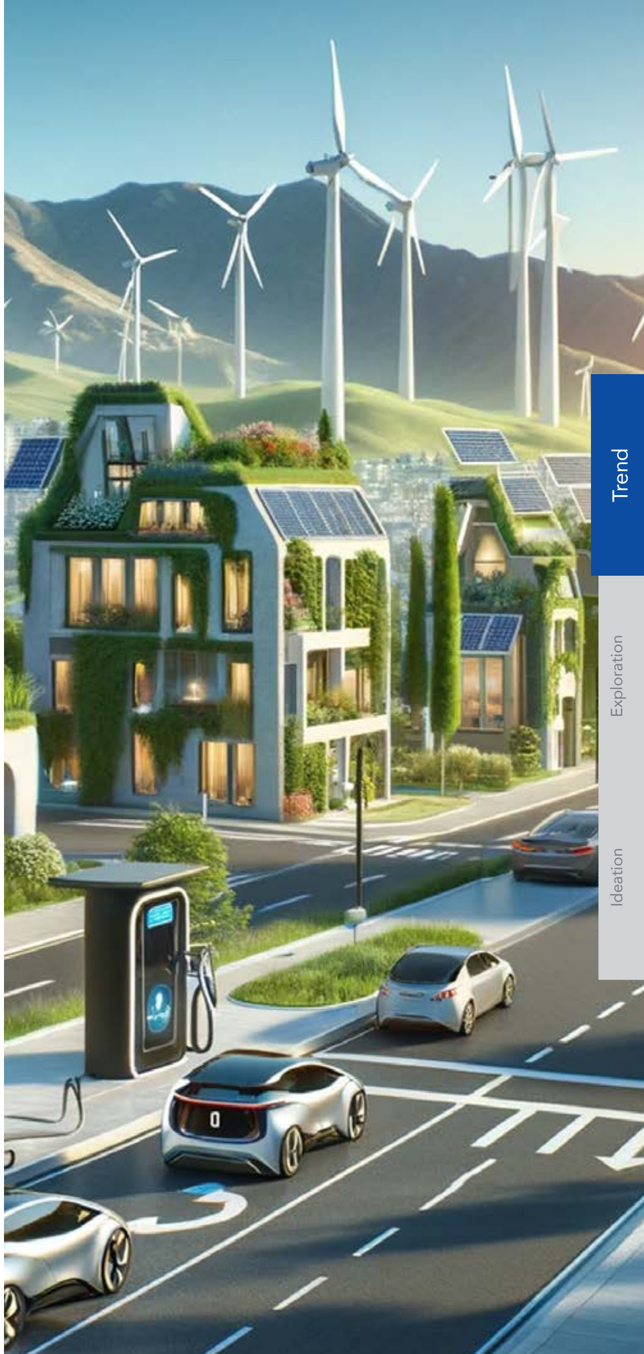
- According to the Smart Meter Law (2023), all electricity providers in Germany will be required to offer dynamic tariffs beginning in 2025 [250].
- The increasing demand from household consumers, driven by the electrification of mobility and heating sectors and the expansion of renewable energies, necessitates dynamic pricing as an incentive for flexible electricity use, aiming to enhance grid efficiency [249].
- With the continued deployment of Intelligent metering systems and Heating Energy Management Systems (HEMS), the potential for offering and utilizing dynamic tariffs is anticipated to expand significantly in the future [284].

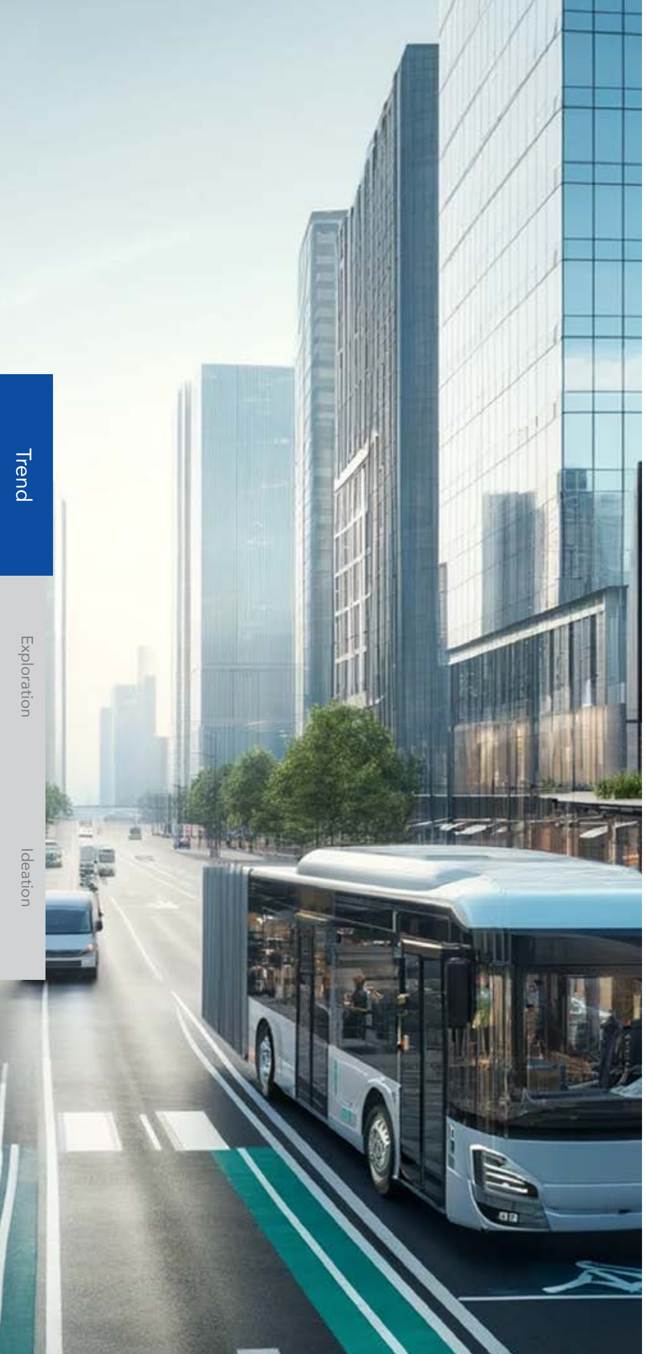
Challenges

- Dynamic tariffs entail substantial price fluctuations, transferring the cost risk entirely to the customer, although future integration of AI-driven solutions may mitigate this variation [286].
- Ensuring consumer awareness, comprehension, and acceptance of dynamic pricing structures poses a challenge, as indicated by a representative survey by Verivox, where only 35% of German electricity customers are familiar with such tariffs [286].
- The implementation of dynamic tariffs is hindered by the requirement for smart meters, with only around 500,000 smart meters installed in Germany by the end of 2022, leading to a limited number of households meeting the necessary technical prerequisites [287].

Impact on the Future of Utilities in the Era of AI

Dynamic electricity tariffs reduce the reliance on conventionally generated electricity, thereby accelerating the pace of the energy transition [285]. In addition, these rates foster an environment that is conducive to innovative business models, such as demand response programs. These encourage consumers to adjust their energy use during peak demand periods, and allow utilities to reward them appropriately [288]. Dynamic pricing initiatives are not exclusive to the electricity sector; they also hold significant potential for future implementation in other utility sectors. However, the electricity sector is expected to be the pioneer in adopting dynamic pricing strategies.





MULTI-MODAL TRANSPORT

Seamless Urban Journeys Require Integrated Mobility Services

Given the ongoing urbanization, cities face many challenges, such as significant traffic congestion, pollution, and increased urban sprawl, creating additional urgency for the sustainable transformation of the mobility sector [289, 290]. Fueled by electrification, the sharing economy, and restricted use of private vehicles, this transformation has led to a surge in new mobility services like ride-hailing and micro-mobility services. Additionally, urban air mobility and new autonomously delivered transport services like robo-shuttles are on the horizon [291]. For public transport, these new offerings lead to a growing multi-modality of urban journeys [290]. As citizens are looking for affordable, time-effective, and convenient travel options, they increasingly use different means of transportation to reach their final destination [291]. Integrating various transport services can address gaps in the infrastructure and thus contribute to a more user-friendly and sustainable urban transit system [292]. However, in most cities, the mobility solutions landscape is still scattered due to the complexity of integration between different providers. Hence, better interoperability is required to ensure seamless multi-modality for customers [290, 293].

Facts

- Global demand for urban mobility services is expected to grow from 25.8T in 2010 to 48.4T passenger–kilometers by 2050 [294].
- Consumers took more than 15B hailed-mobility trips in 2019, with revenues reaching 130B USD. By 2030, total revenues from hailed mobility are expected to increase to 450-860B USD. At the same time, the market for micro-mobility is expected to grow from 1-3B USD to about 50-90B USD in size by 2030 [291].
- A 2022 survey by micro-mobility provider Bolt has shown that within 15 out of 17 countries studied, more than 35% of its users took an e-scooter to connect to public transport [295].

Key Drivers

- In 2021, the European Commission adopted the European Green Deal, which also sets ambitious targets for the mobility sector: to reduce greenhouse gas emissions by 55% in 2030 and by 90% in 2050 compared to 1990 levels [296].
- Advancements in autonomous driving will lead to the establishment of new forms of mobility, such as pooled on-demand services delivered by self-driving vehicles. Urged by a lack of drivers for public means of transport, but depending on the evolution of the regulatory environment, these autonomous transportation forms might cater for up to 8% of global mobility in 2035 [297, 298].

Challenges

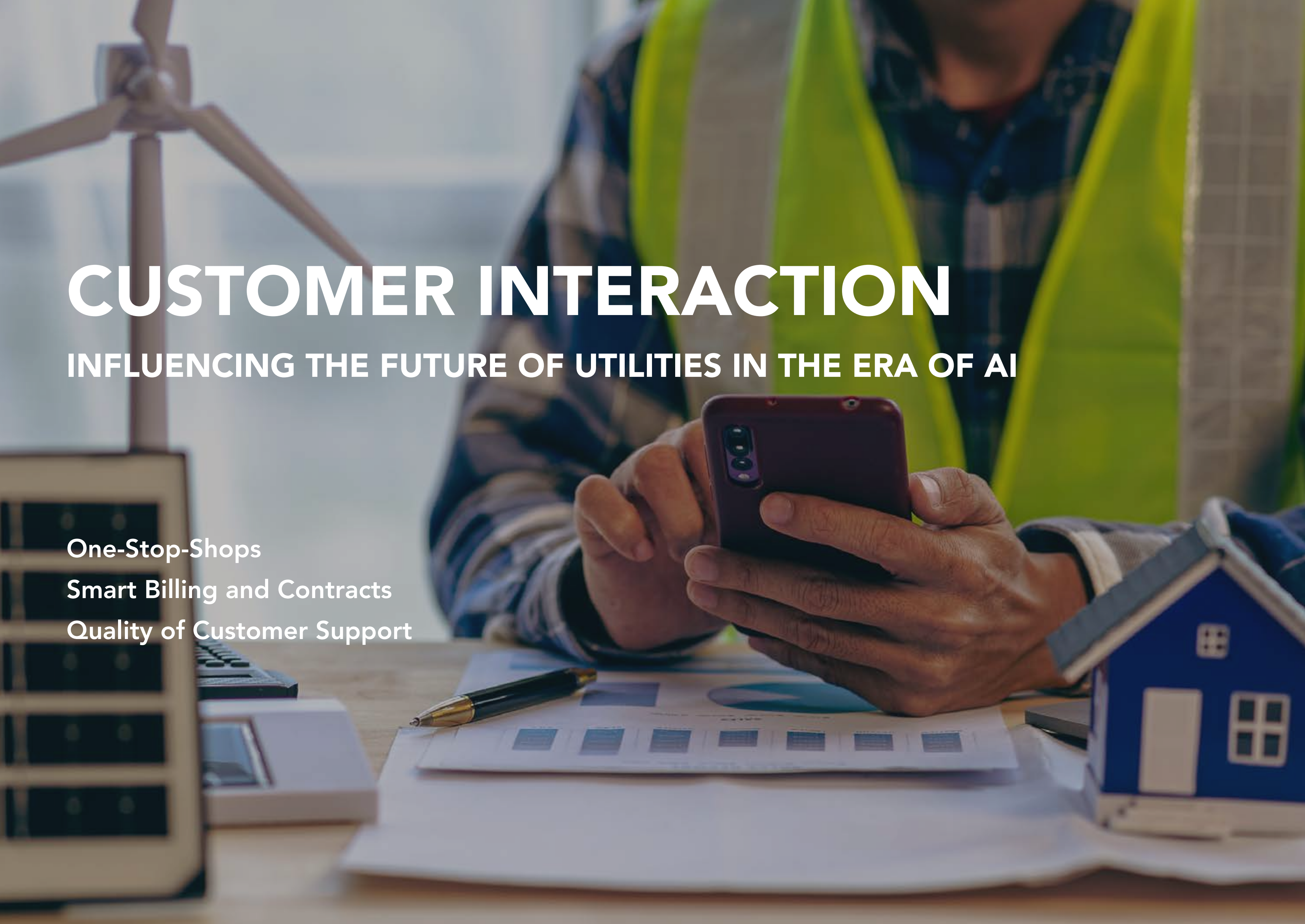
- The shared mobility market is fragmented, with many large, established companies competing. Efficient multi-modal transportation relies on real-time data sharing between service providers for accurate scheduling, routes, and availability. However, technical integration is very complex and costly, requiring access to granular spatiotemporally and appropriately anonymized data [292, 298, 299].
- A survey found that up to 65% would still buy a private vehicle even with cheaper robo-taxis available, highlighting persistent consumer preference for car ownership [300].

Impact on the Future of Utilities in the Era of AI

Integrating public transport with shared mobility providers is crucial for facilitating multi-modal transport. This can be achieved by offering services directly or partnering with established providers, contingent on the utility provider's capability to offer specific services and the ease of integration with external offerings [289]. Despite the fragmented current landscape, there is a rising trend towards multi-modal transportation platforms, simplifying journeys by providing comprehensive mobility packages and single-payment solutions [301]. This evolution signifies a shift towards more integrated, sustainable, and user-friendly urban transportation systems.

EXPLORATION

In the upcoming chapter, the outcomes of the process for validating market hypotheses and problem statements are explored. This phase primarily revolves around the discovery of white spaces and opportunity areas in the established sector of utilities. Through the clustering of the topic, findings are distilled into five key opportunity spaces, and the most critical problems and opportunities within the chosen domain are identified. The exploration phase places a priority on the testing and re-evaluation of hypotheses with expert insights, alongside an examination of the existing landscape to pinpoint key market players.



CUSTOMER INTERACTION

INFLUENCING THE FUTURE OF UTILITIES IN THE ERA OF AI

One-Stop-Shops

Smart Billing and Contracts

Quality of Customer Support

Annemarie Schimkat

Finn Kosina

Jan Jakob

Niko Pallas

Thomas Rother


CUSTOMER INTERACTION

Raising Customer Experience and Loyalty to a new Level

The utility sector is no exception to the emphasis on customer experience (CX), which has risen in importance across various industries. It is transforming from its traditional monopolistic tendencies and primary focus on reliability and basic customer satisfaction towards a more dynamic, participatory, and personalized model. This change is primarily motivated by customers' increasing expectations. Customers demand a CX that is as seamless and personalized as the experiences they receive from other service sectors [302]. CX can be a significant differentiator in the utility market and an essential factor in the business model [303].

In an era of digital advancements and global challenges posed by the COVID-19 pandemic, customers expect reliable utility services, seamless digital interactions, personalized service offerings, and proactive communication. Meeting these expectations is crucial to ensure customer satisfaction [302]. The customer's expectations reflect the evolving consumer landscape where digital convenience and personalized touch points define brand loyalty. A compelling CX can significantly reduce churn rates, thereby increasing customer lifetime value and fostering loyalty [303, 304, 305]. Research indicates that customer satisfaction can lead to lower operating costs. A study on utility providers highlights how satisfaction can enhance market efficiency by reducing complaints, increasing customer trust, and ultimately leading to lower service costs and higher employee productivity [306].

The energy transition is reshaping the utility industry, requiring customers to navigate complex interactions with various stakeholders for investments like setting up PV systems. This leads to the growing demand for streamlined experiences, requiring energy providers to verticalize and shift towards all-in-one solutions or so-called "one-stop-shops", integrating assets, services, and financing [307, 308].

Furthermore, customers demand smart billing and contracts. With the rise in the volatility of energy prices, electrification, and the adoption rate of flexible electrical devices in households, consumers are increasingly seeking personalized energy services. This includes dynamic pricing models and contracts offering static and dynamic components. Yet, traditional billing systems struggle with this complexity, often resulting in customer dissatisfaction and churn [309].

High-quality customer support remains a key challenge for most customer-facing organizations, particularly for utilities, due to their large and diverse customer base. Embracing advanced service technologies and evolving support strategies offers a way to meet rising customer expectations and turn this challenge into a strategic advantage [310].

The utilities sector's efforts to improve CX are necessary and complex. By prioritizing integrated service experiences, transparent contracts and billing options, and superior customer support, utilities can redefine their value proposition [302]. This strategic focus aligns with evolving consumer expectations and positions utility providers for success in a competitive landscape defined by the quality of CX [308].

ONE-STOP-SHOPS

Streamlining Interactions With Prosumers Through Vertical Integration

The energy transition and the corresponding market decentralization catalyze profound shifts in the utility market, prompting customers to make significant investments and requiring interactions beyond conventional energy contracts [307]. For example, setting up a PV system at home requires identifying and interacting with hardware manufacturers or distributors, installation and maintenance companies, energy suppliers, energy management system providers, and potentially a financial lender [314, 315].

In response to this complexity, customers increasingly seek more convenient and streamlined experiences, preferring a single point of contact rather than engaging with multiple players. This preference drives a notable trend towards all-in-one solutions that seamlessly integrate technology assets, financing, required services, and energy tariffs. Emerging players that cater to these demands are rapidly capturing market share in the energy and heating sector.

To remain competitive in this evolving landscape, energy providers must transform into comprehensive one-stop-shops, offering end-to-end solutions [308]. However, this evolution presents challenges for established and new market players. Traditional providers may struggle to overcome organizational silos and to quickly adapt their business models, while new entrants face the daunting task of building trust and credibility with customers who have long-standing relationships with established players [315, 316].

> “We are observing a major trend towards holistic solutions and one-stop-shops.”

Moritz von Klot, Investment Manager at Earlybird [311]

Selected Players

Neura
octopus energy
ostrom
1KOMMA5°
Reel
tibber

SMART BILLING & CONTRACTS

Meeting Personalization and Transparency Demands of Customers

Consumer demands are evolving in times of increasing volatility, with a growing desire for personalization and transparency in energy services. This includes offerings like dynamic tariffs, mixed contracts with static baselines and flexible components (e.g., own production), and the ability to react to market fluctuations [317].

However, traditional billing systems are ill-equipped to handle this complexity. The widely adopted annual billing model cannot be adapted to ongoing market conditions and often leads to a "bill shock" for residential customers. This frustration point triggers roughly 85% of churns regarding contracts' renewal and suppliers' change [318]. Furthermore, poor communication surrounding these bills creates additional friction in the customer relationship.

On the Business-to-Business (B2B) side, the need for price stability coexists with the desire for flexibility. Large industrial players might utilize Power Purchase Agreements (PPAs) to secure long-term production conditions. Still, these options are often unavailable to small and medium-sized enterprises for complexity reasons in the adoption cycle [319]. In addition, flexible contract systems allow business customers to buy energy in tranches during the year based on their individual needs and ongoing price dynamics [320].

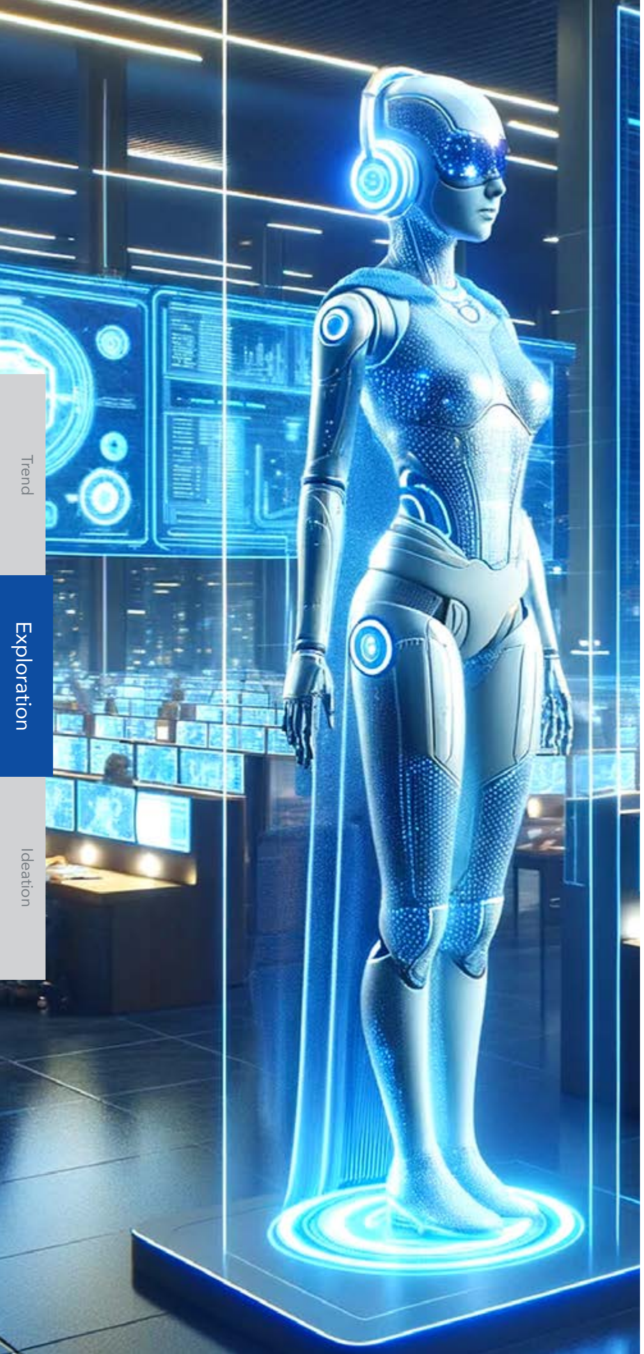
In conclusion, the utility industry must move beyond the one-size-fits-all model to unlock the full potential of a dynamic energy market, fostering customer satisfaction through better communication and steering consumption based on capacities. It is being limited by software constraints in the billing/trading sector and a lack of customer education about the complex dynamics of the energy market [321].

> "The increasing adoption of flexible pricing models is depending on an increasing education for the energy market on the consumer side."

Dr. Oliver Schoppe, Principal at UVC Partners [312]

Selected Players

1KOMMA5°, Enpal, tado°, VIESSMANN, EnBW, octopus energy, thermondo, zolar



QUALITY OF CUSTOMER SUPPORT

Navigating Customer Support Challenges in the Utility Sector

The utility industry is confronting a major challenge in ensuring the delivery of high-quality customer support given its large customer base. This issue leads to lengthy wait times on calls or delayed email responses, thus diminishing customer satisfaction [310]. The root of this problem lies in the overwhelming volume of support requests surpassing support teams' capacity, coupled with the complex nature of inquiries requiring a specialized resolution [322].

This situation is exacerbated by a slow adaptation to efficient customer service technologies and a traditional focus on infrastructure over CX [323]. However, the future looks promising as utility companies are expected to adopt advanced computing technologies including AI to automate responses and manage inquiries more effectively [324]. Investments in improved customer relationship management systems and staff training are also anticipated [324].

Addressing poor customer service is critical; it affects trust, satisfaction, and a company's ability to retain customers amidst growing competition. As customer expectations for quick and high-quality support rise, utility companies must evolve to meet these demands. Failing to improve customer support could lead to significant customer loss and reputational damage, highlighting the need for a transformative approach in the sector's customer service strategies [325].

> "The potential to revolutionize the utility customer experience through digital and data-driven solutions is clear."

John Hutchins, Director of Client Services at Slalom [313]

Selected Players

COGNIGY · kore.ai · IBM Watson · enneo ingeniería · parloa

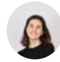
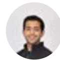
SHORTAGE OF SKILLED LABOR

RECHARGING THE WORKFORCE WITH TECHNOLOGY-DRIVEN COMPANIONS

Attracting and Retaining Workers

Enabling Workers

Advancing Towards a More Automated Future

Anna Rode 
Jan Chen 
Johann Stürken 
Muneeb Ahmed 
Raphael Beuter 

SHORTAGE OF SKILLED LABOR

Recharging the Workforce With Technology-Driven Companions

The utility industry stands at a critical juncture, confronted with an acute workforce shortage that threatens its operations and growth. This challenge, rooted in an aging workforce and waning interest in manual labor, presents a complex dilemma with widespread implications [326]. A staggering 40% of the global workforce is contemplating a change in employment in the near future. This statistic underscores the urgency for sectors reliant on specialized skills and is emphasized by projections indicating the renewable energy sector's need to influx over 2.8M blue-collar workers by 2030 for its development, construction, and maintenance endeavors [327].

At the heart of this crisis is the scarcity of skilled workers, which hampers the utility industry's efforts to maintain productivity, reliability, and technological innovation. The predicament is particularly dramatic in Germany, where 80% of utility providers expect an exacerbating skills shortage [328]. To navigate this scarcity, societal reevaluation of blue-collar jobs is required, propelled by enhanced employment conditions and innovative recruitment strategies that leverage digital platforms and benefits programs.

Bridging this skills gap necessitates the adoption of cutting-edge training methodologies, such as AR and VR, for immersive and effective learning experiences [329]. Additionally, utility firms can tap into the skilled labor pool from declining industries, such as coal and steel, and upskill these workers to replenish the utility workforce [330].

To adapt to these workforce challenges, the industry increasingly uses technology-driven solutions to streamline operations and reduce reliance on human labor. Automation and digitalization not only boost efficiency but also require retraining for advanced roles, shifting focus to analytical and strategic tasks [331]. The deployment of AI and robotics for maintenance and field operations heralds a future in which technology complements human expertise, facilitating sustainable progress and laying the groundwork for a resilient, versatile, and future-proof workforce.

Facing these challenges head-on, the utility sector must champion a multifaceted strategy that revitalizes the appeal of blue-collar jobs, deploys cutting-edge training, and harnesses technology to enhance efficiency and adaptability. This proactive approach is essential not just for addressing the immediate labor shortage but also for ensuring the utility sector's resilience and competitive edge in a rapidly evolving utility landscape. Through fostering innovation and flexibility, the utility industry can navigate its current predicaments, setting a benchmark for sustainable and efficient operation in the future economy [332].

ATTRACTING AND RETAINING WORKERS

Addressing the Talent Shortage for Blue-Collar Jobs

The utilities sector is witnessing a significant shift towards renewable energy sources. To achieve ambitious decarbonization goals, solar capacity must increase 30-fold and wind capacity four-fold. Achieving these targets requires an additional 1.1M blue-collar workers to develop and construct wind and solar plants, plus another 1.7M by 2030 to take care of operations and maintenance [333]. The younger generation's interest in blue-collar jobs has waned, deterred by, e.g., long hours, challenging weather conditions, or bad societal perception [334]. Also, representation of women remains at a low level. In 2023, one in five blue-collar workers left their jobs, which means they were 36% more likely to quit than their white-collar counterparts [335].

This growing skilled worker shortage creates challenges with regard to the safety, compliance, and customer satisfaction of utility companies. Replacing workers incurs substantial costs, posing short-term difficulties [336].

There are two primary strategies to address this challenge. First, to improve the sector's societal perception and boost employee retention by enhancing working conditions, including salary increases. Secondly, to bridge the gap of skilled workers by attracting and integrating international talent [337]. Introducing models enabling relocating workers between companies in response to demand fluctuations could fulfill the demand for more flexibility, leading to greater satisfaction. Furthermore, developing recruitment strategies aimed explicitly at blue-collar candidates could renew the industry's appeal. Utilizing WhatsApp-based marketing for hiring and implementing AI into the screening process could accelerate the process [338].

> "Reskilling and upskilling will be ongoing processes as the pace of technological adoption quickens, so companies will need to create a culture of continuous learning."

The Good Work Framework: A new business agenda for the future of work - World Economic Forum [339]

Selected Players

EGYM WELLPASS, Heyjobs, Jobware, kollabo, PowerUs, smalt, Gojob, HELDENJOBS, FIXED, indeed, stepstone, JOBRAD, MONA AI, salfy easy benefits, temper, yulife

Trend
Exploration
Ideation

ENABLING WORKERS

Minimizing Skill Gaps Through Advanced Training and Upskilling

The utility sector faces a stark skills gap exacerbated by rapid technological evolution. This gap, widened by limited, tailored education and a disconnect between existing skills and job requirements, demands innovative solutions [340]. AR and VR technologies are pivotal in addressing this challenge, providing immersive learning experiences seamlessly integrated with theoretical knowledge and practical application. Incorporating AR and VR into training protocols offers a dual advantage. It substantially reduces training-related expenditures and diminishes the dependency on physical trainers while simultaneously facilitating personalized, flexible learning environments that can be tailored to individual schedules [341, 342].

Additionally, the recruiting talent is increasingly coupled with targeted training programs to enhance integration and job readiness. Leading companies are launching academies providing multi-week training to ease the transition of future employees to their new countries. Furthermore, the approach to training is evolving, with new entrants adopting a mix of in-person sessions and interactive apps. These methods enhance engagement through gamification and introduce AI-driven learning platforms for a more immersive experience [343].

In conclusion, addressing the skills gap within the utility sector demands a comprehensive and innovative approach. The strategic application of AR and VR technologies for targeted and efficient training represents a forward-thinking solution to this challenge. At the same time, the sector's capacity to draw skilled labor by customizing training for blue-collar workers will be crucial in navigating the challenges of the ever-changing technological environment [344].

> "The urgency of reskilling in the EU is already being felt in certain sectors [...] – the rollout of heat pumps, for example, requires a rapid recruitment and retraining of installation engineers.

Overall Strategic Analysis of Clean Energy Technology in the European Union - European Commission [340]

Selected Players

AERONES, TÜVRheinland® Genau. Richtig., montamo, Meta Quest, Sana, AKAD UNIVERSITY, craftguide, NSFLOW®, Vision Pro

ADVANCING TOWARDS A MORE AUTOMATED FUTURE

Harnessing Emerging Technologies for Workforce Efficiency and Replacement

Digitalizing existing hardware and integrating cutting-edge emerging technologies to propel its infrastructure represent a significant transformation for utility firms. Traditionally, the sector has relied on skilled blue-collar workers, each trained in specific disciplines. However, retraining this existing workforce to meet emerging job demands poses significant challenges, both time-consuming and costly. Moreover, lacking interest and motivation often hampers professional transitions [345].

The increasing adoption of digital technologies, influenced by regulatory pushes like the EU Clean Energy Package, fosters a growing degree of automation and connectivity across utility processes. The widespread deployment of IoT devices facilitates remote monitoring and control, collecting essential data to drive efficiencies in utility operations [346]. While digitalization is set to enhance the productivity of utility workers in the short term, it also signals a future where traditional roles may change, possibly shifting towards prosumer-oriented models [347]. This shift indicates a profound redefinition of job responsibilities within the industry.

In conclusion, the utility sector's embrace of advanced technologies, including AI for strategic analysis and sophisticated robotics for hands-on tasks, marks a pivotal stride towards minimizing traditional labor dependency. Innovations akin to AI for predictive maintenance and autonomous robots for field operations are streamlining processes, significantly reducing the demand for conventional workers. This transformation not only bolsters operational efficiency but also foreshadows a new era where the integration of human insight and machine precision fuels sustainable industry advancement [348].

> "We estimate that about half of all the activities people are paid to do in the world's workforce could potentially be automated by adapting currently demonstrated technologies. That amounts to almost $15T in wages."

McKinsey Global Institute report: Harnessing automation for a future that works [349]

Selected Players

atmio, SIEMENS, greyparrot, remberg, TESLA, DASSAULT SYSTEMES, FERNRIDE, INMOX Intelligent monitoring systems, Skydio, Boston Dynamics, ENERGY ROBOTICS, FIGURE, kwest, Reonic

DATA ENABLED SMART CITIES

INFLUENCING THE FUTURE OF UTILITIES IN THE ERA OF AI

Predictive Infrastructure Maintenance

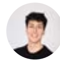
Interoperable Platforms and Services

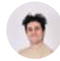
Cyber-Resilient Cities

Elisabeth Goebel 

Ju-Shan Chao 

Christophe Schmit 

Marcelo Rohn 

Ruslan Mammadov 

DATA ENABLED SMART CITIES

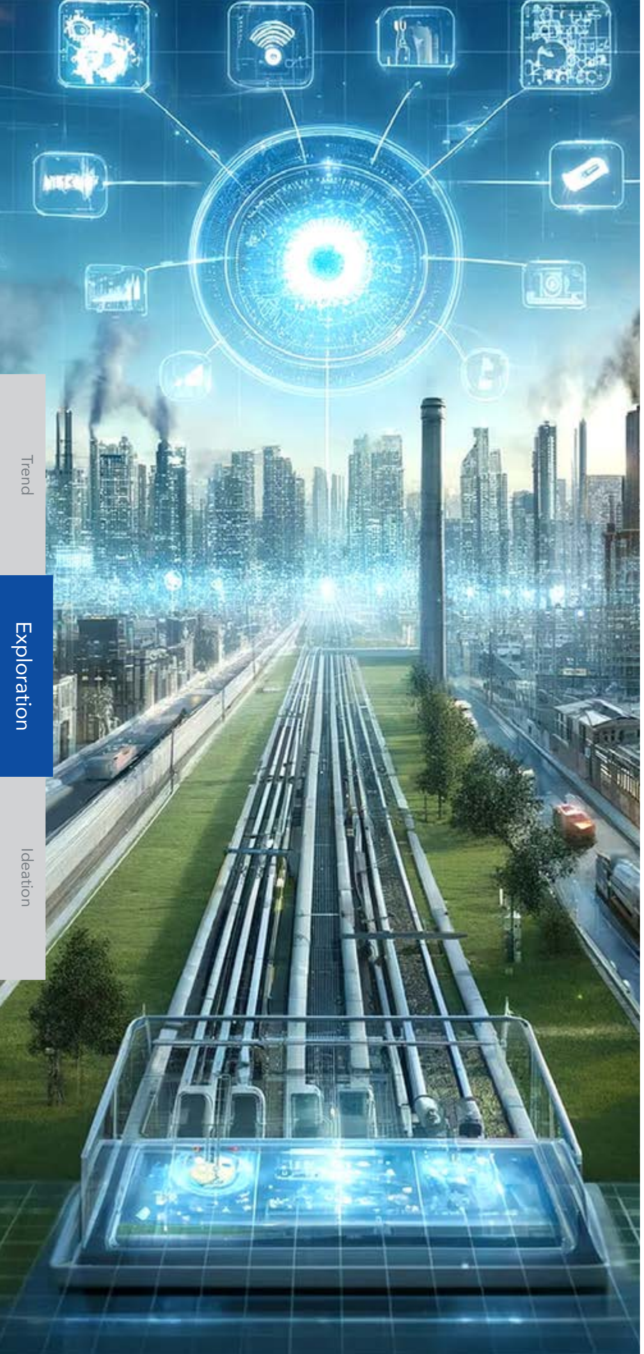
Harnessing Big Data to Craft Revolutionary and Sustainable Smart Cities

Smart cities revolutionize urban living by integrating digital technologies into infrastructure and services, focusing on efficiency, interconnectivity, and sustainability [350]. For example, smart energy grids and waste management systems rely on real-time data and intelligent sensors to dynamically respond to energy demands and optimize waste collection, aligning with sustainability goals and thus providing better services for their citizens [351]. Governance in smart cities should be agile to protect public safety and implement needed strategies for an aging population. Furthermore, data privacy is essential to promoting digital and transparent city management and gaining citizens' trust. This is supported by the World Economic Forum, which emphasizes the importance of data privacy, security, equity, and ethics in smart city governance, noting that these factors significantly impact public trust and willingness to use data for public good [352].

A study by Roland Berger on smart cities indicates that the utility sector could spearhead this transformation, particularly in medium-sized cities. Utility providers earmark about 14% of their investment budget for such initiatives. With over 280 medium-sized cities across Europe, utility companies have the potential to serve as the data infrastructure layer that enables innovative city development [353].

For digitalization to thrive, certain structural technological conditions are essential, including connectivity, networking, harmonization, interfaces, platforms, and the secure handling of data. City administrations increasingly leverage data to enhance social planning, mobility, and crisis management services. While commercial entities have long harnessed data's potential, many cities are just beginning to explore its benefits [354].

Smart cities represent the forefront of urban development, where predictive infrastructure maintenance, interoperable platforms, and cyber-resilient frameworks converge to enhance the quality of life, ensure sustainability, and boost economic growth. By leveraging smart data for predictive maintenance, cities can address infrastructure issues before they escalate. Interoperability among diverse digital platforms and services is critical, enabling seamless integration and expanding smart city innovations beyond isolated projects. Furthermore, prioritizing cybersecurity with a privacy-first approach ensures the protection of sensitive data, fostering public trust in digital urban ecosystems. An example of these principles in action is Estonia, which stands out in Europe for its comprehensive public digital services [355]. With a diversified energy sector, advanced telecommunications infrastructure, and projects like the Balticconnector enhanced gas network integration, Estonia embodies the smart city vision, offering valuable insights into the future's sustainable and connected urban environments [356].



PREDICTIVE INFRASTRUCTURE MAINTENANCE

Leveraging Smart Data to fix Problems Before They Appear

In smart cities, predictive maintenance addresses critical infrastructure problems, thus creating significant opportunities for improved urban development, quality of life, and sustainability. Traditional reactive maintenance approaches often lead to unexpected infrastructure failures [357]. When this maintenance is optimized, environmental sustainability is among the beneficiaries due to lower energy consumption and smaller carbon footprints, aligning company incentives with global sustainability goals [358].

These disruptions additionally cause inconveniences for residents and strain the providers' budgets with high emergency repair costs and ongoing resource allocation. Leveraging existing data and building new data pools, e.g., installing new sensors, enables companies and institutions to uncover infrastructure use and failure patterns, allowing for predictive maintenance [359]. This opportunity spans from energy and water supply to waste management and mobility. Drilling deeper, especially in the pipe segment, shows great potential for this technology since up to 23% of water is lost before arrival in case of leakage [360]. Similarly, the losses from gas leakages account for 80% of methane emitted into the atmosphere in Europe, so companies such as Prevention, Hulo.ai, and Atmio have emerged in recent years, trying to tackle predictive pipe maintenance [361, 362]. The benefits are, therefore, clear but often can not be harnessed by incumbent organizations, not only due to missing data infrastructure but also because of siloed supply chain functions, inflexible maintenance strategies, and insufficient employee qualifications [363].

> "We are seeing new businesses for predictive pipeline maintenance emerge all over the world."

Alexander Worbs, Investor at Picus Capital [362]

Selected Players

STREAMETRIC | INMOX Intelligent monitoring systems | HULO | SMART Intelligence of EveryTHING | ASPIRE WATER SOLUTIONS | atmio

INTEROPERABLE PLATFORMS AND SERVICES

Connecting Platforms and Data Systems for Smart Cities

For the past decade, smart city initiatives have been championed globally as solutions to urban challenges, with a belief in the transformative potential of digital technologies. Yet, progress in implementing smart city innovations has fallen short of expectations [364]. A significant barrier to their success lies in the challenge of interoperability and integration among various platforms, data systems, and service providers. Smart city initiatives often lead to isolated islands and pilot projects of innovation that struggle to expand into broader applications. This is highlighted by the fact that in 2020, 92% of smart city investments used private platforms, which could lead to public services being controlled by private companies. Furthermore, using private platforms also makes expanding and connecting different city services harder [364].

Public-private partnerships (PPPs) emerge as a viable opportunity to bridge the gap between standalone solutions, thereby accelerating the interoperability of platforms [365]. Utilities can provide startups and innovation hubs with valuable data access via Application Programming Interfaces (APIs), enabling them to create interconnected products tailored to urban challenges [366].

Utilities can drive smart city interoperability forward by connecting existing players in the ecosystem and leveraging existing solutions. Through strategic partnerships, data-driven initiatives, and advocacy for open standards, utilities can contribute significantly to realizing interconnected cities. By advancing the vision of smarter, more connected urban environments, utilities can reduce operating costs and increase citizen satisfaction.

> “Cooperation between public and private institutions has big potential since the government spends every second euro.”

Dr. Oliver Schoppe, Principal at UVC Partners [367]

Selected Players

FREENOW, zapier, GOVDATA, influxdata, vialytics, DATA, interop.io, coneva, X-ROAD, polyteia, PHILIPS hue

CYBER-RESILIENT CITIES

Applying a Privacy-First Approach to Build Cybersecure Cities

Striking a balance between data leverage and resilient security mechanisms is critical for smart cities, as protecting sensitive information is essential for public trust [368]. Between 2020 and 2022, the average number of cyberattacks against utilities per week doubled globally [369]. Therefore, a security-focused approach must be adopted to ensure the safe growth of digital urban ecosystems. Investing in robust cybersecurity infrastructure is crucial. Integrating increasingly decentralized IoT devices into the network increases the exposure to cyber threats, necessitating proactive security measures [370].

By adhering to the "security by design" principle, utility providers ensure secure integration with legacy systems and facilitate safe data sharing across departments [371]. System security must be integrated across three layers: the edge layer, the data-processing core, and the communication layer for seamless data flow. Using such a framework represents an opportunity to make underutilized data, currently isolated in silos, accessible to others. The development of digital services for critical infrastructure must follow the CIA triad: confidentiality, integrity, and availability. Applying these design principles ensures that data is accessible only to authorized users, remains accurate and reliable, and is available when needed. Furthermore, these principles are fundamental in safeguarding digital systems against data breaches and service disruptions, highlighting the importance of a resilient cybersecurity strategy for any data-driven smart city [372].

> "Cyberattacks from inside and outside the organization pose the greatest risk of security incidents with edge systems. Whether for personal, financial or geopolitical reasons, malicious insiders stealing sensitive data and intellectual property is a growing threat."

S&P Global [373]

Selected Players

betterdata, CLAROTY, deep instinct, DRATA, tropicsquare, LACEWORK, netskope, SIEMENS, snyk, syntonym, zscaler, illumio

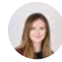
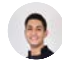
DECENTRALIZATION AND DEMOCRATIZATION

INFLUENCING THE FUTURE OF UTILITIES IN THE ERA OF AI

Leveraging Distributed Energy Resources

Harmonizing the Energy Sector

Enhancing Grid Stability

Christina Hudgens 
Khola Raja 
Hamze Al-Zamkan 
Shouvik Ghosh 
Thomas Kaar 

DECENTRALIZATION AND DEMOCRATIZATION

Enabling Distributed, Green Energy Generation

The energy sector is on the verge of a transformative shift, moving from centralized production to a more decentralized system. This evolution is crucial for addressing the modern world's energy challenges, including sustainability, reliability, and accessibility. Aggregated prosumers' PV generation via VPPs, storage solutions such as V2G technology, and sophisticated software platforms are pivotal in the transition toward decentralized energy [374]. These components must work together to optimize the interaction between the increasing number of stakeholders and create an ecosystem benefiting the energy supply chain and the planet.

The journey towards a decentralized energy system has its challenges. The conventional energy mix relies heavily on fossil fuels, such as gas, often imported from countries like Russia. When geopolitical tension rises, and supply is scarce, this reliance exposes consumers to volatility in energy prices [375]. Energy price hikes breed a desire for more autonomy and price certainty among consumers, thus creating an opportunity for their contribution to decentralization [376].

Consumers can enter the arena of democratization and become prosumers by generating PV energy for self-consumption and feeding it into the grid for additional revenues. The German government has implemented auxiliary measures through the EEG 2023 amendment to incentivize the growth of PV power and meet their target of 215 GW of PV power by 2030 [377, 378].

Another challenge to grid stability in a decentralized energy market is storage capacity, which is needed to balance supply and demand [379]. One opportunity to overcome this barrier is to utilize bidirectional flows of energy via V2G technology.

Lastly, communities must leverage software solutions to connect diverse energy resources, including solar panels, battery storage, and EVs, creating a unified system that benefits all stakeholders. These digital platforms simplify the energy market's complexity and bring transparency and accessibility to consumers, enabling them to make well-informed decisions.

The decentralization of energy represents a paradigm shift towards a more sustainable and consumer-centric system. By harnessing decentralized energy sources, embracing technologies like V2G, and utilizing software to synchronize market players, we can overcome the current limitations and move towards a future where energy is more affordable and clean for everyone. This transition promises environmental benefits and empowers consumers, giving them more control over their energy use and contributing to a more equitable energy landscape.

LEVERAGING DISTRIBUTED ENERGY RESOURCES

Unlocking Value in Distributed Renewable Energy Markets

The rapid increase in small and mid-size PV energy producers, driven by EU targets for 600 GW of PV capacity by 2030 and German government subsidies, highlights a significant opportunity and challenge in the energy sector [380, 381]. With producers currently selling energy back to the grid at rates around 8.11 to 12.87 ct per kWh [382] and the local energy aggregation market in Europe is expected to be 200 GW, including 75 GW in Germany, poised to double by 2030 [383], there exists a substantial opportunity to attract more customers by offering them higher compensation for their renewable energy contributions [382, 383].

Moreover, conventional centralized energy generation hinders the effective utilization of renewable energy sources and risks grid stability and sustainability. The gap between the 26% surge in PV capacity in 2022 and the updated feed-in tariffs under the EEG for producers highlights a compelling opportunity to drive market entry and attract customers by offering a superior compensation solution [384]. Aggregating these distributed renewable energy sources, for instance, with VPPs, not only contributes to grid stability through expanded generation capacity but also allows prosumers to reap rewards from participating in the new energy market. Without addressing these challenges, the true potential of distributed energy resources remains unrealized, complicating the transition toward a more sustainable and efficient energy system.

> “Now that energy prices have become a bigger discussion in the last years, I think more consumers are looking more critically at their options.”

Sophia Escheu, Investor at SpeedInvest [385]

Selected Players

1KOMMA5° | gridX | next THE POWER OF MANY | Power Nature | Enpal. | sonnen | node.energy

HARMONIZING THE ENERGY SECTOR

Overcoming Fragmentation and Building a Unified Energy Ecosystem

The energy sector is transforming significantly as utilities shift towards a digitized, decentralized, and democratized landscape [401, 402]. This shift offers opportunities for new players to enter the energy market. This results in a more distributed energy generation, mainly through technologies like solar PV, which can create a market segment with millions of small-scale producers. Looking ahead, a report by CE Delft suggests that prosumers could provide 30-70% of the total electricity demand depending on the EU member state by 2050 [403]. These producers may have a negligible individual impact but can collectively influence the market if they act in unison, facilitated by interconnected digital technologies [404].

On the other hand, the silo structures of software architecture development make the process slower. For instance, the absence of a public information platform, as seen in China's power sector, can prevent the sharing of real-time electricity supply and demand data, which is crucial for market development and matching supply with demand [405].

Embracing openness in the energy sector fosters greater transparency in energy pricing, supply, and demand, creating an inviting environment for private sector participation and fueling the development of energy markets [406]. By ensuring that information is accessible and exchanges are transparent, we can pave the way for innovation, efficiency, and sustainability while building a collaborative and decentralized utility market.

> "The fragmentation of the energy sector is undeniable, presenting a unique opportunity. By creating an open platform, we can streamline this diversity, bringing stakeholders together to foster collaboration."

Dr. Oliver Schoppe, Principal at UVC Partners [407]

Selected Players

axle, Enode, GS_y (GridSingularity), OpenEMS, SPiNE, SPOT MY ENERGY, tibo energy

ENHANCING GRID STABILITY

Turning Idle Wheels Into Active Energy Allies for a Greener Tomorrow

Projections suggest that by 2030, the EU will have approximately 30M EVs, indicating a transformative shift in energy management looming on the horizon [386, 387]. These EVs, empowered to store and release renewable energy, are poised to mitigate critical challenges, including synchronizing electricity demand with renewable supply and addressing the inefficiencies in power plant utilization [388]. As renewable energy's share grows, balancing fluctuations with flexible storage becomes crucial, emphasizing EVs' key role [389, 390].

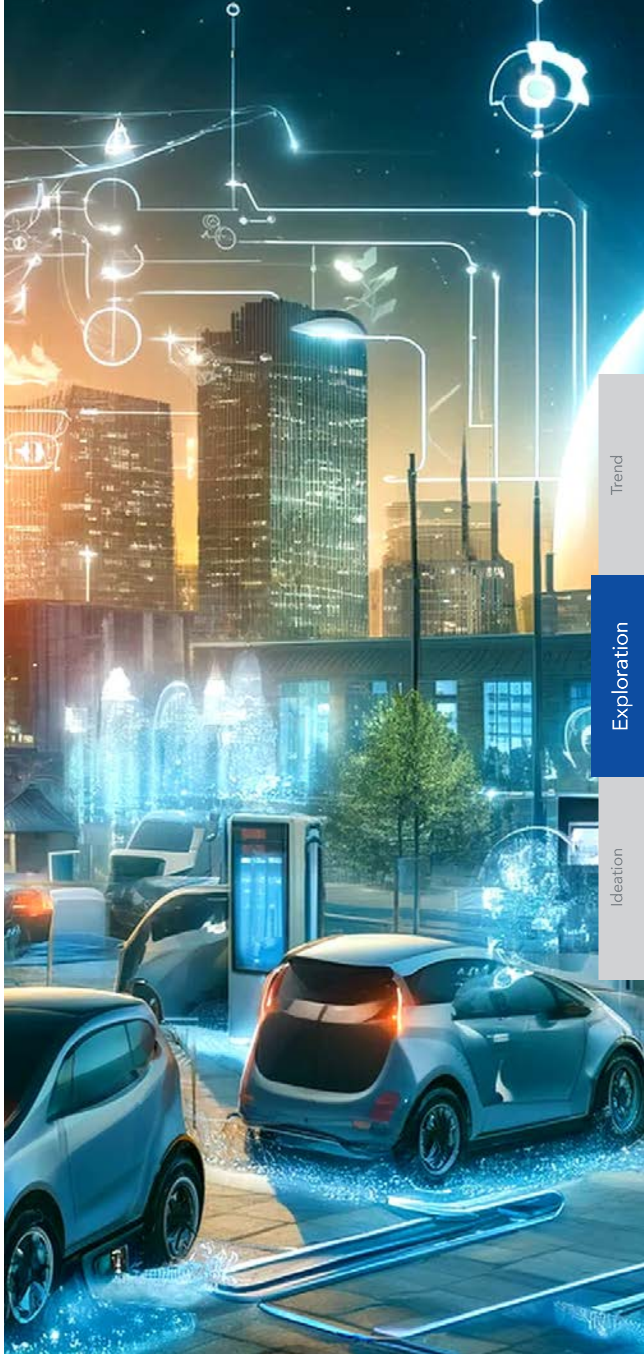
With most personal vehicles lying idle most of the day, the shift towards V2G exploits this latent potential, advocating for a move to bidirectional charging [391, 392]. V2G technology can transform EVs into vital energy grid components [393]. By facilitating EVs to discharge electricity back to the grid, the intertwined challenges of environmental sustainability and energy efficiency can be directly addressed [394, 395]. Additionally, V2G enhances grid resilience and efficiency by providing crucial ancillary services, such as frequency and voltage regulation, which are imperative for maintaining grid stability [396, 397]. Notably, if V2G were to meet peak demand instead of fossil fuels, it could avert 330M tonnes of CO_2 emissions globally by 2030 [398]. V2G's role in advancing towards a sustainable energy future is undeniable, promising a cleaner, more resilient energy ecosystem where renewable power takes precedence [399].

> "Selling power stored in EV batteries back to the grid during periods of peak demand, not only lessens maximum loads on the grid but also allows EV owners to capitalize on high electricity prices."

Rob Bland, McKinsey & Company [400]

Selected Players

AQUA superPower · JEDLIX · LADE · POCITYF · octopus energy · NEX2



ENERGY STORAGE

INFLUENCING THE FUTURE OF UTILITIES IN THE ERA OF AI

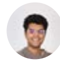
Energy Demand Shifting

Adoption of Energy Storage Systems

Maintenance of Energy Storage Systems

Anna-Maria Geist 

Ben Ta 

Het Dave 

Valentin Gölz 

Zaid Efraij 

ENERGY STORAGE

Navigating the Evolving Landscape of Energy Storage: Strategies for Grid Optimization and Technological Advancements

The future of energy storage presents an increasingly pressing challenge that can be addressed from two distinct yet complementary perspectives: enhancing storage capacity and optimizing demand to foster a more efficient grid.

One avenue of exploration involves addressing demand dynamics. Striving for greater stability in renewable energy sources aims to mitigate the peaks and troughs that often characterize their output. Additionally, it is argued that aligning electricity price forecasts with industrial consumption patterns could facilitate strategic energy usage adjustments, thereby promoting load balancing and peak shaving. The integration of dynamic pricing with smart metering technology represents another promising avenue for enhancing grid equilibrium. By incentivizing consumption during off-peak hours, such initiatives hold the potential to mitigate the need for extensive energy storage infrastructure, thus driving down associated costs. Therefore, leveraging storage systems as a means to stabilize the grid emerges as a complementary strategy [408, 409].

Turning attention to storage technologies, the focus includes both hardware and software innovations. This encompasses not only the technical aspects but also considers grid integration for battery systems, the viability of decentralized storage solutions, and the potential benefits of diversifying energy storage methodologies to optimize efficiency and affordability. Consequently, the demand for predictive maintenance of these complex systems integrated into the grid would become much more challenging, which presents opportunities for several solutions in the same space [412, 413, 414].

Adopting energy storage solutions is also a major issue in the utility industry, which presents a huge opportunity in this area. By leveraging banking and financing tools, the adoption of batteries can be increased, benefiting both the end user and the grid operators. The combination of storage products and financing solutions from the grid operators themselves would significantly increase adoption, as costs continue to fall gradually with ongoing research into storage technologies [416, 417, 418].

Finally, as the task of transporting vast quantities of energy across geographical distances is faced, the economic realities of this endeavor are confronted. Balancing the need for grid capacity against transmission costs underscores the critical role of storage infrastructure in optimizing energy systems. Looking ahead, the landscape of energy storage is poised for transformation. Pioneering efforts, such as establishing large-scale lithium battery parks in Germany, signal a shift towards more robust and efficient storage solutions. Navigating this evolving terrain, innovation and collaboration will be essential in realizing a future where energy storage is not just a necessity but a cornerstone of sustainable development [418, 419, 420].

ENERGY DEMAND SHIFTING

Seeing Variable Energy Prices as an Opportunity

Obtaining vast amounts of energy storage is still expensive as supply cannot match demand in the near future. Furthermore, only a handful of players in the market use variable energy prices to their advantage - the vast majority of companies and private households pay fixed prices for their energy usage [408].

This creates plenty of opportunities for stakeholders willing to adjust their energy consumption depending on current market conditions. As energy prices rise over the next decades, the ability to bring forward or postpone energy-intensive processes will bring significant cost savings [409].

In the space of private customers, many possibilities are not yet being leveraged. For example, heat pumps and good insulation can be used as temporary energy storage by preheating during off-peak hours. EVs can be leveraged for flexible electricity storage at night, potentially replacing stationary batteries. Large AI models could be trained during times when energy is very cheap. The same is true for carbon removal schemes that are energy-intensive. One of the biggest problems is the unwilling-ness of consumers to adapt to their behavior. Significant cost savings would be needed to change the status quo. This, along with the fact that utility companies have no real incentive to offer dynamic pricing options, means that development has been lacking in the past [408].

> “Shifting large amounts of energy from one location to another is very expensive and remains to be a big challenge in general.”

Dr. Oliver Schoppe, Principal at UVC Partners [421]

Selected Players

ecoplanet
axle
Reel
octopus energy
granular energy
LAKI POWER

ADOPTION OF ENERGY STORAGE SYSTEMS

Tackling Adoption Issues of Energy Storage Systems for Faster Energy Transition

The growth of renewable energies is a key driver for the energy transition. Nevertheless, the existing electricity infrastructure is not equipped to handle its intermittent nature, leading to grid instability, elevated prices, and increased congestion [416]. Energy storage systems provide the ability to stabilize the flow of electricity originating from renewable sources, guaranteeing the optimal utilization of the grid network [423].

While energy storage systems projects are becoming widespread in countries like the UK, the storage strategy in Germany is unlikely to meet the expectations of the renewable energy sector due to the relatively low adoption of such systems [417]. This is mostly influenced by Germany's regulatory environment and the project's financial viability.

One way to address this issue lies in focusing not only on the availability and affordability of battery resources but also on introducing new financial and banking incentives combined with industrial and commercial energy storage systems to incentivize people to adopt them. Projects that prioritize the recycling of lithium batteries can also support the lowering of costs. With the reduction of the price and further financial incentives that currently do not exist, an opportunity is observed to increase the adoption of these systems. This would lead to a quicker and smoother energy transition [418].

> "Companies and financial institutions are moving slow, which has led to a slower adoption of energy storage solutions."

Dr. Oliver Schoppe, Principal at UVC Partners [422]

Selected Players

BAVERTIS, betteries, HARMONY ENERGY, KYON ENERGY, tozero, CIRCU LI-ION, TERRA ONE, octave .energy, Voltfang

MAINTENANCE OF ENERGY STORAGE SYSTEMS

Optimizing Energy Storage with Advanced Analytics and Predictive Maintenance

Due to the energy transition to renewable energy sources, the relevance of different storage systems such as battery energy storage systems, compressed air energy storage systems, or gravity energy storage systems is increasing [419, 420, 424]. One major reason is that they aid in reducing the volatility in the electricity grid [412]. However, the different energy storage systems can be sensitive to various environmental conditions, such as temperature and humidity, affecting their failure rates, longevity, performance, and safety profiles. Beyond external factors, maximizing the effectiveness of energy storage systems also necessitates tracking internal conditions, including signs of deterioration and damage.

Overseeing these data points presents a significant challenge, particularly for extensive operations and large-scale energy storage facilities. The diversity of systems available, such as lithium-ion, lead-acid, flow batteries, and non-battery energy storage systems, each produced by various manufacturers without standardization, complicates matters further. These systems exhibit distinct degradation behaviors, adding to the complexity [413].

Predictive maintenance tools can allow for a detailed insight into the state of the systems and their automatic management based on environmental parameters and their internal state, thereby facilitating the optimal timing for repair and replacement. Different software vendors on the market currently offer solutions for optimizing charging and discharging. However, their maintenance remains a crucial process [414].

> "The maintenance of battery energy storage systems is a crucial process to avoid costly downtime and risk long-term health of storage units."
>
> Alexander Worbs, Investor at Picus Capital [414]

Selected Players

CATL, yAI lab, TWAICE, Bib batteries, FLUENCE (A Siemens and AES Company), cru AIR+GAS, Heimdalytics, SIEMENS Gamesa Renewable Energy, WATT MORE

IDEATION

The following chapter describes five novel business models that are of great relevance for *The Future of Utilities in the Era of AI*, especially in view of the identified future trends. Each of the business models are developed to solve a specific problem in the identified problem spaces.

Annemarie Schimkat

Finn Kosina

Jan Jakob

Niko Pallas

Thomas Rother


YOUtility

We Empower Energy Providers to be Dynamic Market Leaders

Energy suppliers face enormous challenges in fundamentally realigning their business models and IT landscapes in the face of advancing regulation and the resulting changes in market dynamics and customer demands [425]. One major area of change is the increasing dynamization and personalization of energy tariffs. This development is fueled by the increasing share of renewable energy sources, which leads to a growing need for mechanisms that balance volatility and discrepancy between energy production and consumption [426]. In Germany, the adoption of smart meters and, hence, the prevalence of dynamic electricity pricing has been very low compared to other European countries. However, starting in 2025, German energy providers will be mandated by law to offer dynamic tariffs using smart meters [427]. An increasing demand for dynamic pricing options can, therefore, be expected. Other European countries have shown a similar pattern in which an increase in Smart Meter adaption results in a rising share of dynamic pricing contracts [428].

Realizing smart, real-time pricing requires seamless integration of various data sources like smart meters and energy markets with the operating system of utility providers. However, adjusting existing Enterprise-Resource-Planning (ERP) tools like SAP IS-U requires substantial consulting effort, compounded by the fact that support for IS-U is set to end in 2027. In general, many energy suppliers face a situation where IT systems have been in operation for a long time with many proprietary developments and highly individualized processes in use. Additionally, many current ERP and billing systems have grown over the past 15-20 years and, hence, lack the flexibility and modularity required for the transition. Therefore, many energy suppliers are reorienting themselves regarding their deployed software solutions [425].

Introducing dynamic electricity tariffs offers numerous opportunities for energy suppliers. It is important to note that this is not only a legal obligation, despite any challenges they may face. With the help of dynamic pricing, suppliers can diversify their product portfolios and appeal to customers whose needs are not met by a standard tariff.

YOUtility revolutionizes the energy sector by providing an innovative IT solution that enables suppliers to offer and manage dynamic tariffs effectively while also simplifying energy procurement. The core features of the YOUtility Engine include seamlessly connecting to energy markets for AI-powered procurement based on real-time demand, offering a modular no-code platform for hyper-personalized contracts, and automatically forwarding current market prices to consumers while providing real-time insights into consumption. Initially focusing on integrating with legacy systems to enhance capabilities, YOUtility's vision is to establish an agile ERP system capable of meeting all demands of the energy transformation in the long term.

Problem

- Starting in 2025, energy providers will be legally required to offer dynamic tariffs using smart meters [427].
- The increasing installation of smart meters in Germany is expected to drive customers' demand for smart tariffs [429, 430]. Countries such as Spain and Norway have already widely adopted smart meters. In 2018, 75% of final energy consumption in Spain was based on dynamic pricing, and in Norway, approximately 71% of households and 88% of small and medium-sized enterprises (SMEs) have chosen Real-Time Pricing tariffs [428].
- German legislation also enforces this trend, with the "Gesetz zur Digitalisierung der Energiewende" (GDEW) Act of 2016 laying the foundation for the digital transformation of the energy industry. The "Messstellenbetriebsgesetz" (MsbG) Act was introduced to provide for the widespread use of smart metering systems by 2032 [431, 432].
- Smart metering can only be integrated with SAP IS-U, with significant consulting effort [433], while support for SAP IS-U will end in 2027 [434, 435, 436].

Utility companies must prepare for the widespread implementation of dynamic pricing

Solution

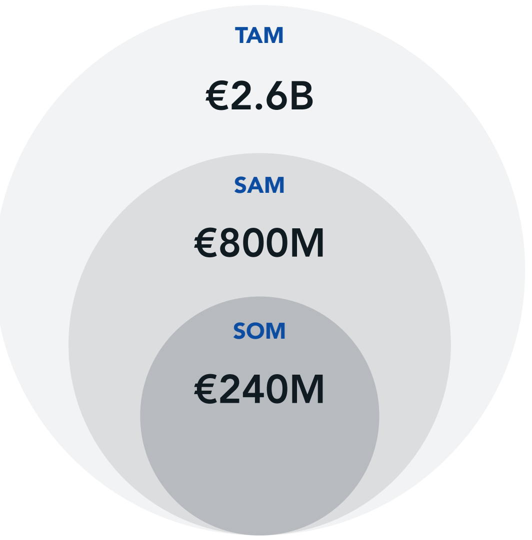
- YOUtility is addressing the need for a new IT infrastructure to enable dynamic pricing by offering a tailor-made operating system for utility companies.
- Connecting the energy market with its dynamic prices and the existing IT legacy systems, YOUtility modernizes the tech stack of utility companies.
- Core functionalities include forwarding market prices from procurement to the customer, a modular software architecture, and automated energy purchasing based on actual consumption.
- To enable a seamless end-to-end journey, YOUtility covers the whole tech stack from the backend to customer-facing interfaces: AI-supported procurement, CRM with complex contract structures, automated billing, and customer interfaces with real-time consumption optimization and monitoring.
- While, initially, integration with legacy systems is intended to expand existing capabilities, the long-term vision of YOUtility is to become the leading agile ERP system fueling the energy transformation.

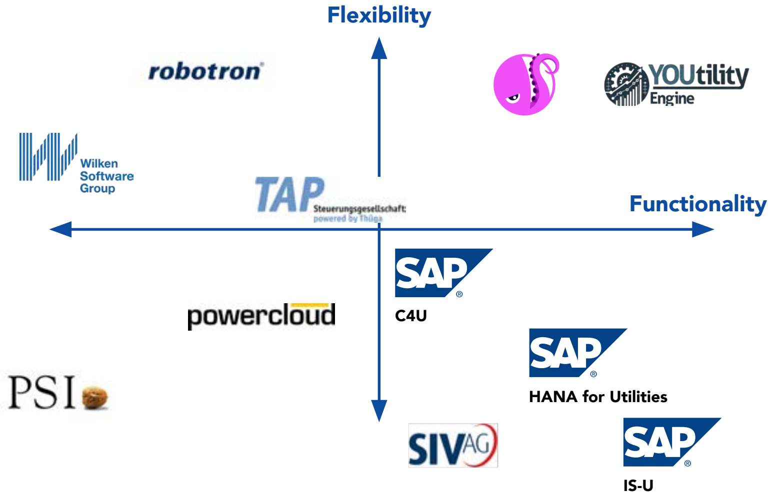
YOUtility is the operating system that enables dynamic pricing contracts for utility companies by providing a flexible IT infrastructure

Market

- YOUtility aims to charge energy providers a fee of 2% of the cost per kWh for every (dynamic) contract managed by the YOUtility Engine. The model is, therefore, a pay-as-you-go model.
- With an average of 38k contracts per energy supplier and an average energy consumption of 3,100 kWh [437], this translates to an Annual Recurring Revenue (ARR) of 600k EUR per supplier when assuming an average price of 26 ct per kWh. [438]
- Considering the advancement of dynamic pricing in other EU countries, with the Total Adressable Market (TAM) being 2.6B EUR for 4,400 energy suppliers [439], YOUtility targets the 1,300 German suppliers [440], aiming for a 30% market share and a potential 240M EUR in ARR.
- In the long term, there is a high potential to optimize energy purchases on the day-ahead and intraday markets depending on current consumption patterns, creating an additional source of revenue by participating in gained savings.

YOUtility steps into the emerging dynamic pricing market and participates in the long term by supporting discounted energy purchasing





Competition

- Existing market players struggle to deliver software products that are flexible enough to support individual and highly dynamic solutions while fully covering the end-to-end customer journey.
- Market experts indicate that German utility providers rely heavily on large ERP software providers like SAP, which are known for rigidity, forcing utilities to seek external consulting support when enlarging product portfolios [441].
- The sector's dominating software, SAP SI-U, will see its maintenance discontinued by 2027 [442].
- As a subsidiary of Octopus Energy, Kraken's market-leading software offers extensive functionalities and flexibility but is not a strategic choice for competing energy suppliers [443].
- Therefore, utility companies need access to flexible and modular software solutions that their customers and law will soon demand [427].
- This market gap represents a pivotal moment for the sector, potentially redefining how energy providers meet their customer base's complex and evolving needs.

Current market solutions either provide a full spectrum of functionalities or prioritize high flexibility, but not both effectively

Assumption Tree

Updating Legacy Systems is Costly

Modifying legacy systems to meet current demands can pose a significant financial challenge. They may not be sustainable for companies as the solutions are built on top of existing software, which can be restrictive in the implementation and possible features. The costs associated with updating or replacing these outdated infrastructures can strain budgets and divert resources from innovation, hindering long-term growth and adaptability.

Legacy Systems Limit Customization

Utility providers encounter challenges adapting and customizing their services due to antiquated infrastructures. Outdated legacy systems hinder flexibility and innovation in this field because external experts and internal IT capacities are required to implement specific features. This slows down the rapid deployment of customized offerings, leaving providers unable to meet the evolving demands of the market.

Dynamic Tariffs: The 2025 Obligation

By 2025, German legislation will require energy providers to implement dynamic tariffs that reflect real-time consumption and market fluctuations. The aim of this regulatory push is to increase energy efficiency and foster innovation across the sector. Consumers will be motivated to adjust their usage in response to variable pricing, potentially leading to significant cost savings and promoting more sustainable energy practices.

Customers Demand for Dynamic Tariffs

Customers, both in B2B and B2C markets, are increasingly seeking tailored tariff options that align with their unique consumption patterns. This shift towards personalized energy solutions emphasizes the desire to leverage lower energy costs during off-peak hours. It also underscores a growing awareness and demand for flexibility and cost savings in utility services.

Energy Providers are not Ready

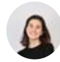
In today's rapidly evolving energy market, traditional utility providers face a disadvantage due to their inflexible infrastructure. Their outdated legacy systems challenge their competitiveness and innovation, lacking the agility to adapt to changing consumer demands and technological advancements. This inflexibility hinders their quick introduction of adaptable services and meeting the increasing demand for customized energy solutions.

Holistic Flexibility Demand

The demand for flexible contracts, adaptive pricing, and customized billing is expected to increase as consumers seek more control over their energy usage and spending, as well as their adoption of smart meters. This change emphasizes the increasing demand for customized services that can adjust to individual consumption patterns and market fluctuations, indicating a significant shift in the delivery and management of energy services.

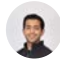
Operating System for a Dynamic Future

Utility providers are at a critical juncture as they require new operating systems capable of supporting the emerging demand for dynamic tariffs. These advanced systems will be key in enabling providers to quickly adapt to the shift in consumer expectations towards more flexible and personalized energy pricing and offer the innovative services that modern users demand.

Anna Rode 

Jan Chen 

Johann Stürken 

Muneeb Ahmed 

Raphael Beuter 

visioncraft

Make Every Generalist a Specialist

Following several disruptions in recent years, a chance exists to create a fresh outlook on the future of employment and address the issue of closing the skills divide among employees. visioncraft supports the transition away from unsustainable sectors and assists their workforce in learning new skills using a cutting-edge AR solution supported by AI.

The utility industry, a backbone of modern infrastructure, faces a daunting shortage of skilled blue-collar workers. With a projected demand for 1.1M specialized workers by 2030, the sector is at a crossroads [225]. Specialists command a premium, with salaries 20% higher than their generalist counterparts, exacerbating the problem [444, 445]. Traditional training methods have proven time-consuming and less effective, particularly for hands-on skills, which are crucial in the field.

visioncraft introduces an AR copilot designed to transform generalists into specialists, empowering utility companies to deploy low-skilled blue-collar workers for more sophisticated tasks. By utilizing AR glasses to provide real-time instructions, visioncraft facilitates on-the-job execution, thereby significantly reducing the need for prolonged training periods and specialist sourcing. This not only boosts workforce efficiency but also turns every worker into a potential specialist ready to tackle the most demanding tasks.

The solution integrates LLMs with industry-specific datasets synthesized through advanced AI algorithms to generate actionable insights displayed on the AR interface. This integration is combined in products like the HoloLens, powered by GPT-4, which supports guided operation interfaces and intelligent overlay displays, ensuring comprehensive support and real-time AI guidance.

visioncraft's market potential is vast, addressing a global AR market in blue-collar industries valued at 49B EUR [446]. With a focus on the utility sector, visioncraft targets a specific European market with significant growth potential, underscored by a 10.8% CAGR in AR innovation and adoption for the period 2024-28 [447].

visioncraft is poised to disrupt the market with a sales-led go-to-market strategy, emphasizing affordability and efficiency. By initiating co-development with selected partners and launching tailored pilots across diverse utility companies, visioncraft aims to optimize its solution and scale across Europe, leveraging testimonial-driven sales.

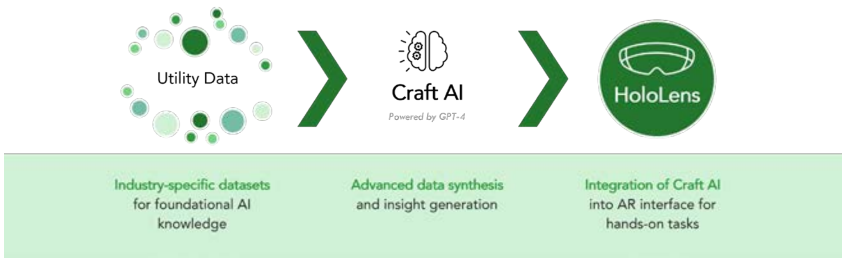
visioncraft distinguishes itself from competitors by offering a utility-specific, on-site solution that goes beyond traditional off-site training methods. With a pricing model designed to be accessible to every utility company, visioncraft ensures that companies can readily adopt its technology, promising a transformative impact on workforce efficiency and skill development.

As visioncraft prepares for its launch in Q4 2024, it stands at the forefront of technological innovation in the utility sector, promising a future where every generalist can become a specialist, thereby revolutionizing workforce efficiency and capability in an industry critical to our daily lives.

Problem

- Utility companies require highly specialized training of workers with training times of up to three years. Flexibility to change tasks later is limited and requires additional upskilling [343].
- By 2030, the worldwide renewable energy sector will require an extra 1.1M blue-collar workers solely for the development and construction of wind and solar power facilities [225].
- 80% of utility companies expect a worsening of the skills gap, while 85% expect this to delay the energy transition, leading to 53% of surveyed companies expecting rising costs [448].
- Salaries for specialists are, on average, 20% higher than for generalists [444].
- Traditional training methods are ineffective as they are not individualized, use outdated approaches, and do not assure an adequate skills transfer [449].
- The shortage of workers is caused by demographic changes, the energy transition, and the rising complexity of work [448, 450].

Specialized workers constitute a significant bottleneck for utility companies and the speed at which the energy transition can occur



Solution

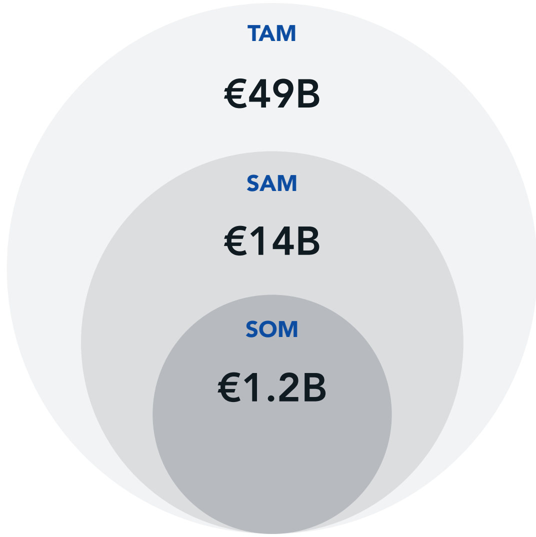
- visioncraft empowers untrained workers in the utility sector, enabling rapid on-site learning and converting generalists into specialists.
- Through AI, visioncraft's copilot transforms utility data into actionable insights displayed via an AR interface.
- The system integrates visioncraft's advanced data synthesis for enhanced decision-making, providing an intelligent overlay that guides workers through procedures in real time.
- The product combines a comprehensive support system with AI guidance and remote video consultations, ensuring immediate access to expert advice and facilitating more efficient workforce utilization.
- Critical equipment information and step-by-step procedural assistance are presented through a guided operation interface, streamlining task execution and minimizing the need for specialist outsourcing.
- visioncraft's approach boosts workforce efficiency, leveraging existing employees for specialist tasks and rapidly shifting training.

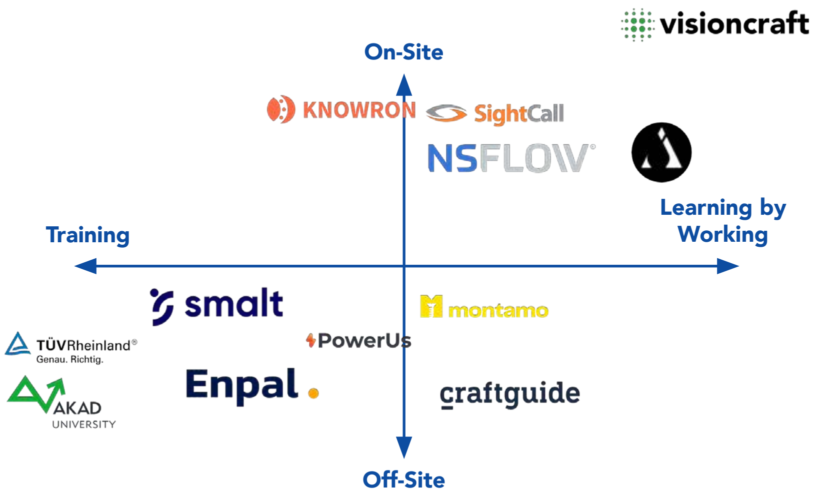
visioncraft offers expertise at your fingertips, transforming the workforce with the Craft AI copilot

Market

- In 2019, the EU utility sector employed 4.6M blue-collar workers. Worldwide, the number of utility blue-collar workers amounted to 7.8M [446].
- In 2019, the energy sector employed about 41M workers worldwide, within which the power generation sector hired 11.3M and the transmission, distribution, and storage sectors employed 8.5M combined [451].
- The global AR market is expected to grow at a CAGR of 11% between 2024 and 28 with China and the US leading in innovation and adoption. The COVID-19 pandemic has fostered the adoption of AR technologies since they offer remote collaboration, replacing in-person interactions [447].
- 82% of companies integrating AR technologies report that benefits meet or surpass their expectations. Moreover, 38% of companies think AR will become mainstream in their organizations in the next three to five years, with 29% currently using it for repair and maintenance purposes [452].

visioncraft is addressing a fast-growing 49B EUR global market for blue-collar





Competition

- The demand for skilled workers in the utility sector is increasing, creating a vibrant market for the opportunity for providers of innovative, utility-specific upskilling solutions that can be easily integrated into the workplace [453, 454, 455].
- visioncraft is uniquely positioned to excel in the growing utility industry because it focuses on flexible and fast upskilling solutions. It offers utility-specific on-site solutions, enabling "learning by working" directly on the job [456].
- Traditional training companies provide time-consuming, costly, and non-digital upskilling solutions, which may not meet the evolving needs of the utility industry [330].
- Competitors like Smalt and Montamo offer off-site training solutions, leaving a gap in on-site utility-specific training [457, 458].
- While other utility-specific solutions exist, such as Knowron, they lack on-site usability, limiting their integration into day-to-day operations [459].

visioncraft is the answer to the limitations of traditional off-site training

Assumption Tree

Growing Skills Gap

With swift progress in renewable energy and smart grid technologies, the utility industry is grappling with a significant skills shortage. This highlights an urgent need for specialized training [225]. visioncraft is in charge of tackling this issue and is ready to create and offer training programs to arm the workforce with the critical technical skills needed in this rapidly changing sector.

AR and AI Advancements

The advancements in AR and AI can revolutionize training for blue-collar workers, turning generalists into skilled specialists. This approach leverages AR and AI's immersive and interactive capabilities to provide innovative, effective training experiences. Through this, utility workers can be equipped with the skills needed to navigate their industry's challenges, surpassing traditional training methods' limitations [460].

Market Demand for AR Solutions

The utility sector is experiencing a growing interest in adopting AR-based training solutions, reflecting a broader trend toward leveraging technology to enhance workforce development. This surge in demand underscores the sector's recognition of AR's potential to deliver innovative, immersive training experiences. This growing demand showcases the industry's belief in AR's ability to make learning more interactive and transformative [461].

Integration Into Existing Processes

visioncraft's AR copilot promises seamless integration into existing utility workflows and work environments. Additionally, it helps boost operational effectiveness and workforce efficiency without disrupting daily operations. Pilot programs with early adopters can help gather feedback on its specific usability and impact, focusing on ensuring the solution fits effortlessly into work environments.

Cost and Time Efficiency

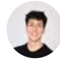
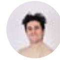
Integrating AR and AI technologies for task execution is expected to significantly reduce the time and costs associated with traditional training methods. This approach reduces the gap between knowledge acquisition and its application in a real-world scenario. Effectiveness is measured by comparing success metrics, which include reduced execution time, operational costs, and improved task accuracy before and after the implementation.

Enhancement of Worker Performance

The deployment of visioncraft's AR solution is expected to enhance utility workers' performance and satisfaction. By integrating AR into daily tasks, workers will likely experience an uptick in job efficiency and an improvement in morale and satisfaction. visioncraft's technology could redefine workplace dynamics, offering the dual benefit of boosting productivity while elevating worker engagement and contentment.

Widespread Adoption

Visioncraft is anticipated to become a crucial and widely adopted tool across the utility sector that is integral to companies' operations. Its innovative AR solutions are aimed at solving some of the most pressing challenges within the industry, which is expected to drive its adoption as a norm. As visioncraft's technology tackles major industry challenges, it is set to become a standard resource across the utility sector.

Elisabeth Goebel 
Ju-Shan Chao 
Christophe Schmit 
Marcelo Rohn 
Ruslan Mammadov 

datacase.ai

Make Data Management Easy

In an era where AI is reshaping industries, the importance of data has never been more evident. Data has the power to transform processes, enhance efficiency, and provide insights for more sophisticated offerings. As we venture deeper into the age of smart cities and intelligent solutions, users' expectations for smart management and superior services are increasing. Yet, companies face many challenges on the way to intelligent data usage due to the sheer volume of data, compounded by privacy issues, a lack of transparency, and internal communication barriers. This complicates identifying possible use cases for the data since it requires a clear understanding of the available information. A staggering statistic highlights the scope of the problem: approximately 80% of valuable data remains unused in Germany, representing a significant loss of potential insights [462].

datacase.ai solves this problem by generating a comprehensive data catalog that acts as the single source of truth regarding the data available within an organization. This feature provides detailed information about the datasets rather than the data itself, enhancing organizational transparency and facilitating the identification of data assets without compromising privacy or security. Additionally, the platform offers a sophisticated data tool that generates synthesized versions based on actual datasets. This allows for the safe exploration and sharing of data within the company, ensuring that sensitive information remains protected, further accelerating the identification of use cases.

datacase.ai doesn't stop there; it revolutionizes generating and assessing use cases. Through automated generation and a sophisticated evaluation system, our platform sifts through various data combinations to spotlight the most promising opportunities, ranking them for user consideration. Once a valuable use case is identified, datacase.ai simplifies the approval process for accessing real data. Our system streamlines compliance checks and provides a standardized way for data access.

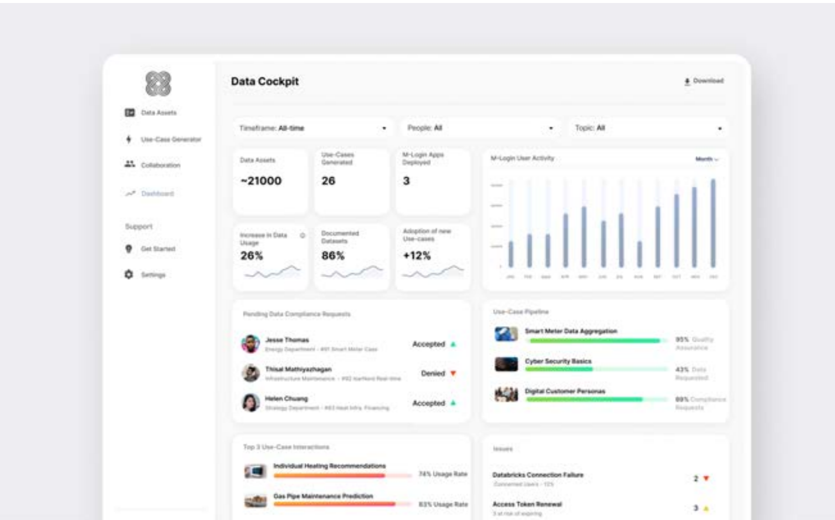
Our solution caters to mid-sized and large enterprises and operates on a B2B Software as a Service (SaaS) business model with a monthly subscription model that varies based on the number of users. We offer tailored plans, ensuring that businesses at every stage can leverage our platform to maximize their data's potential.

datacase.ai empowers companies to exploit their data entirely, from initial exploration to final use case implementation. By addressing and eliminating the hurdles to data utilization, we pave the way for smarter, more efficient use of information, unlocking new avenues for innovation and growth. With datacase.ai, enterprises can transcend traditional limitations, harnessing their data to drive unparalleled advancements.

Problem

- 85% of participating German energy providers' C-level executives state that digitalization and data security are significant topics for the coming years [462].
- Companies are overwhelmed with data; roughly 80% of valuable data goes unused in Germany [462].
- 42% reported to the Deutsche Industrie- und Handelskammer a lack of in-house expertise on data as an obstacle to leveraging it [462].
- Incumbents do not have a fully transparent overview of the exact data points they can harness throughout their daily operations [463].
- Data exchange is often lengthy and complicated in companies that divide operations into different departments because of regulations and company politics [463].
- The potential to improve operations or monetize unused data by identifying promising use cases often remains untapped due to the lack of data transparency [463].

Collected data is not currently leveraged due to a lack of transparency, regulatory hurdles, and structural barriers within utility organizations



Solution

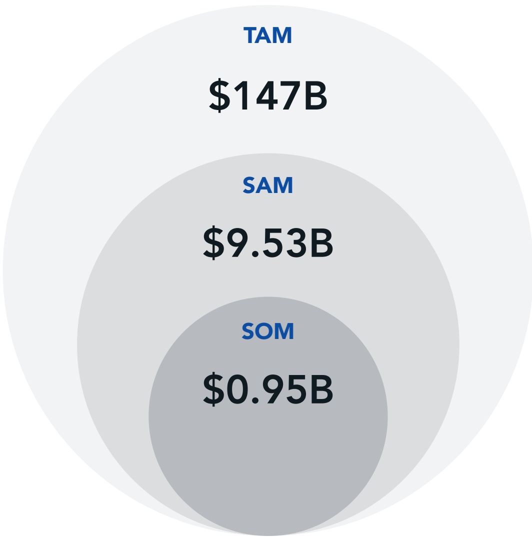
- datacase.ai creates an extensive data catalog for teams, serving as a unified source of truth for organizational data.
- The platform creates synthetic versions of datasets with confidential data, allowing for data exchange without exposing sensitive information.
- datacase.ai features a use-case generation tool that explores various data combinations to identify potential business opportunities.
- For each identified use case, datacase.ai automatically evaluates its viability, considering feasibility, profitability, and cost-effectiveness factors.
- The application simplifies data approval by implementing a standardized protocol for data access requests and automating compliance checks.
- datacase.ai facilitates efficient data governance and collaboration, promoting a systematic approach to data management that supports compliance and organizational objectives.
- The application provides tools for tracking project progress and managing data assets, promoting a systematic approach to data management.

Transform your data into profit: unveil the hidden value of every sensor, form, and smart meter with datacase.ai's revolutionary solution

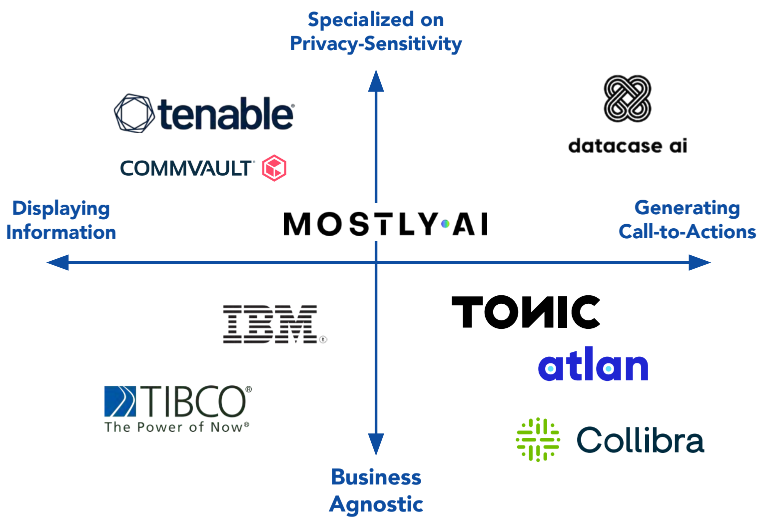
Market

- datacase.ai targets the enterprise business analytics market, valued at 147B USD in 2023 and is expected to reach 321B USD by 2028, with a CAGR of 13.8% during the forecast period [464].
- The European business intelligence market, valued at 9.53B USD, exhibits a growth rate of 7.5% [465].
- 71% of utility companies plan to invest more than 10M USD, and 21% plan to invest more than 50M USD into data ecosystem initiatives [466].
- datacase.ai aims to secure a significant market share of approximately 10% within the European business intelligence market, translating to an estimated value of 953M USD.
- For market entry, datacase.ai focuses on mid-sized and large enterprises and targets companies operating across industry boundaries e.g., energy and mobility, with high-security standards and sensitive data.
- The increasing demand for data proficiency positions datacase.ai to drive customers' competitiveness.

datacase.ai's innovative and value-added approach puts it in pole position to capture significant market share in the data analytics market



Trend
Exploration
Ideation



Competition

- In recent years, the competitive landscape has demanded that companies use their data to make data-driven decisions. This positions datacase.ai to innovate and excel in this dynamic landscape.
- datacase.ai's solution is designed to meet the industry's need for head-to-tail solutions. We identify quality use cases to unlock the potential of existing data.
- Current solutions revolve around cutting-edge data analytics and data governance platforms. Notable startups in the space include Tonic.ai and atlan from India [467, 468].
- Companies like Tibco and IBM offer products that provide a comprehensive and data-driven analytics toolset for data visualization [469, 470].
- Startups like mostly.ai offer synthesizers for artificial data in privacy-sensitive industries [471].
- While these solutions effectively address the lack of data understanding and privacy concerns, there is untapped potential in unlocking data that has not been used due to a lack of identified use cases.

From collection to insight, we have got you covered. Opt for datacase.ai's head-to-tail solution

Assumption Tree

Data Collection and Analysis

The quality and frequency of data collected are vital for achieving insightful results. Proper data analysis informs strategic planning and operational decision-making, enhances efficiency, and reduces operational costs for utility providers. This foundation is essential for identifying potential synergies in delivering utility services like electricity, gas, water, and telecommunications.

Strict Regulations on Data Usage

Under the EU's General Data Protection Regulation (GDPR), utility providers face restrictions on data usage, which adds additional complexity to how this software can be utilized. Balancing data utility with privacy compliance is paramount; therefore, innovative data management approaches are needed to capitalize on these services within the GDPR constraints. Close collaboration with legal and regulatory experts is required to mitigate this complexity.

Poor Data Knowledge Management

As a critical service provider, utility companies often have long-established processes for handling their data management systems. This challenge hampers retaining, accessing, and effectively using historical data for operational improvements and strategic planning. Utility companies may face repeated inefficiencies and lose valuable insights over time without a robust system for managing and preserving institutional knowledge.

Ineffective Horizontal Alignment

The lack of data transparency across different teams leads to ineffective horizontal alignment. This siloed approach to data management prevents insight sharing and best practices, hindering collaborative problem-solving and innovation. Addressing this issue requires fostering a culture of open communication and implementing integrated data systems that promote inter-departmental collaboration and transparency.

Existing AI Modeling Capability

The readiness and availability of advanced AI modeling and data analysis solutions present a significant opportunity for improvement and innovation. The existing technological feasibility means utilities can leverage new data tools and analysis systems to enhance efficiency, reliability, and customer service. The digital transformation approach streamlines operations and sets the foundation for future advancements and sustainable growth.

Extensive Collected Data

Utilities often have vast amounts of data at their disposal that can be utilized. This resource could drive operational improvements and customer service enhancements if adequately leveraged. Addressing this lack of data usage involves adopting data-driven decision-making processes and investing in analytics capabilities to transform raw data into actionable insights, fostering more efficient and responsive strategies.

Untapped Potential

Utilities have significant untapped potential with advanced data and technology. Challenges like GDPR compliance, knowledge management, and data silos hinder potential realization. The sector is ripe for digital transformation to enhance organizational and service efficiencies. Embracing a data-driven culture and leveraging technologies are key to unlocking this potential for growth and improved customer satisfaction.

Christina Hudgens

Khola Raja

Hamze Al-Zamkan

Shouvik Ghosh

Thomas Kaar


SolarSync

Pioneering a Sustainable Future with Unused Rooftops

In an era where the imperative to shift towards renewable energy sources is more pressing than ever, SolarSync stands at the forefront of transforming the energy generation landscape. Its mission is two-fold: To revolutionize the utilization of Commercial and Industrial (C&I) rooftops by installing solar panels and to leverage this untapped potential by aggregating solar energy into VPPs. This innovative approach propels the commercial real estate sector into a sustainable future and serves as a beacon for the global transition to clean energy.

At the heart of SolarSync's strategy is the recognition of the vast, unused rooftop spaces atop C&I buildings, a resource that, until now, has been largely overlooked. In Germany alone, a staggering 363M m^2 of rooftop space lies dormant, representing a potential market for PV systems worth over 1.1B USD [472]. By renting these underutilized spaces, SolarSync introduces a new paradigm wherein C&I real estate owners can transform dormant assets into sources of revenue, all while contributing to the planet's health.

The first stage of the solution involves the strategic installation of solar panels on these rooftops. The unique business model eliminates complexities for property owners, offering them a seamless transition to becoming contributors to the green economy. The second stage focuses on the innovative aggregation of the generated solar power. By employing VPPs as a backup generation source, SolarSync supports grid stability and can participate in the energy trading market by capitalizing on peak demand and shaping energy consumption behavior.

SolarSync is more than a company; it is a movement towards a sustainable and democratized energy future. Bavaria's potential market for PV installations, valued at 171M USD, presents SolarSync with an opportunity to secure a significant share and generate an impressive ARR while revolutionizing energy consumption and production [472]. The company's vision is underpinned by robust market analysis, regulatory support, and technological advancements. This includes government-subsidized feed-in tariffs and growing demand for renewable energy sources driven by the rise in electric vehicle use and the mandatory installation of solar technologies in new buildings starting in 2027 [473].

The backdrop to the mission is a landscape marked by urgent environmental and economic drivers, such as Germany's ambitious target of a 55% CO_2 reduction by 2030. These targets are only possible through integrating renewable energy sources, especially considering the forecasted increase in energy consumption driven by technological advancements and EVs [474]. SolarSync's solutions are crafted with the future in mind, leveraging lower costs of PV modules and the anticipated decrease in energy storage systems costs, enabling SolarSync to navigate the energy market more flexibly [475].

In conclusion, SolarSync is not just installing solar panels but laying the groundwork for a sustainable future where clean energy is accessible, efficient, and economically viable for all. Its commitment to innovation, environmental stewardship, and empowering C&I real estate owners with new revenue streams marks the beginning of a new era in energy production.

Problem

- According to the German government, there should be 15M EVs on German roads by 2030 [476], which will require smart algorithms and technologies such as VPPs to balance the grid [477, 478].
- Starting in 2027, public and non-residential buildings will have to gradually install technically, economically, and functionally feasible solar technologies, while solar energy installations will become the norm for all new buildings [473]. Therefore, especially business owners have to find solutions that can be rapidly implemented.
- Germany's target for solar energy is 215 GW by 2030 [479], while the current production lies around 82 GW [480]. Therefore, major investments are still needed to fulfill those targets.
- Despite major efforts to reduce energy consumption, such as increasing the energy efficiency of buildings [473, 481], the German government estimates that energy consumption might increase to 750 TWh by 2030 [479].

There is an impending urgency to accelerate DERs, and thereby generate additional capacity to reach ambitious renewable energy targets

Solution

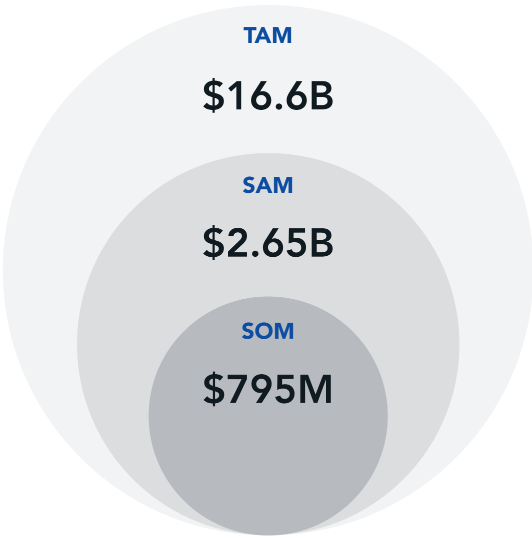
- SolarSync's business model consists of a two-staged approach: the first stage involves installing solar panels on C&I roofs, while in the second stage, SolarSync aggregates the PV generation, contributing to overall grid efficiency.
- SolarSync targets the rooftops of C&I buildings as the generation potential with respect to the required installation is marginally less labor-intensive than smaller PV systems.
- SolarSync rents the customer's unused rooftop area, coordinates the installation of solar panels, and provides the upfront investment. Therefore, SolarSync can offer the customer a revenue-generating asset while being compensated for contributing to the grid through government-funded feed-in tariffs.
- SolarSync aggregates and stores this energy in a VPP network in the second stage. The energy produced will be utilized as a green alternative to fossil fuel power plants to meet peak demand. The generation data collected will be used to train forecasting algorithms for power trading.

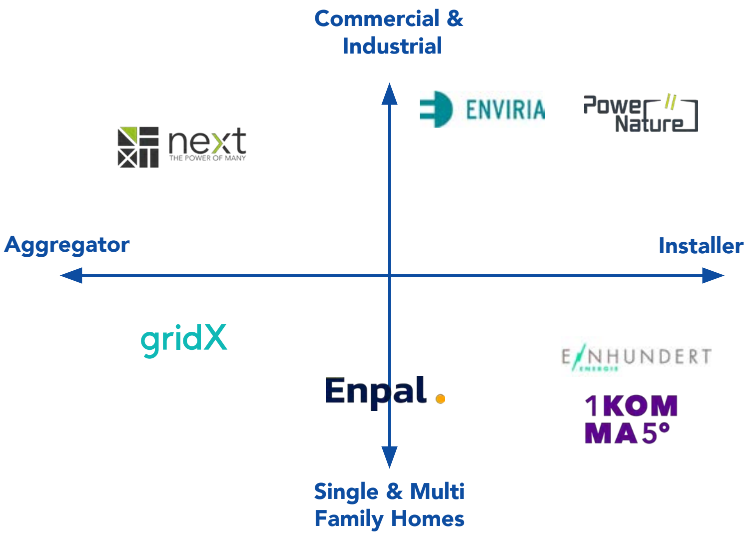
SolarSync cultivates unused roof space to generate green energy while generating revenue for its customers and contributing to grid stability

Market

- SolarSync specifically targets unused C&I rooftops due to huge unused potential.
- According to a report from Garbe, there are 362.8M square meters of unused rooftop space in C&I buildings in Germany, leading to a potential market for PV systems of 16.6B USD if the generated energy is completely fed back to the grid [472, 482].
- Solar PV capacity growth in Germany from 2022 was an astounding 92%, reaching 14.4 GW in 2023 [483].
- Bavaria has 16% of the total unused roof space in Germany. However, only 50% of the total roof space could be used for PV installations [472].
- The feed-in tariff for transferring the total electricity produced ranges from 13 ct per kWh for energy levels up to 10kWh to 6 ct per kWh up to 750 kW [484]. This results in a potential market in Bavaria of 2.65B USD.
- Assuming that SolarSync will be able to capture one-third of the total market in Bavaria, the obtainable market size in 2024 will exceed 795M USD, thus highlighting a significant opportunity.

Unleash the power of solar: realize your building's untapped potential and contribute to the future of green energy generation with SolarSync





Competition

- The competition can be classified according to two key factors: firstly, the target demographic, distinguishing between single, multi-family homes and C&I buildings. Secondly, the type of service offered encompasses either installing PV systems or aggregating existing installations.
- Enpal and 1KOMMA5° are leading players for single-family homes, with Enpal serving as both an installer and aggregator and 1KOMMA5° focusing mainly on installation [485].
- GridX and Next Kraftwerke are purely aggregator platforms using already installed PV systems [486, 487].
- Despite being the primary service providers for the C&I sector, Power2Nature and Enviria predominantly focus on installation activities.
- SolarSync adopts a two-stage approach to engage the C&I sector. In the first stage, the focus is on installing PV systems. Following this, SolarSync serves as an aggregator, aiming to establish a VPP to feed the electricity back to the grid.

Not only does SolarSync see C&I rooftop PV generation as the way of the future, but as a unique opportunity to bring generation to those who use it most

Assumption Tree

Subsidized Feed-in Tariffs

As of 2024, the German government is subsidizing feeding back energy to the grid with guaranteed rates per kWh [488]. Especially during the first stage of SolarSync, the team expects the feed-in tariffs to not drastically change. To verify that, the team is staying in close contact with policymakers of the German government and trying to ramp up the VPP as quickly as possible to reduce the risk to external sources.

Workforce for Solar Installation

SolarSync assumes a robust and scalable workforce will be available to manage the entire process, from solar consultation to installation on C&I rooftops. This includes sourcing skilled labor for technical work and customer service personnel for consultations. Extensive market research on the availability of skilled labor and training programs must be conducted to verify this assumption.

Steady PV Installation Costs

This assumption entails that the cost of purchasing solar panel systems will either remain stable or decrease over time, making solar energy a more accessible option. Additionally, it assumes a steady and reliable supply chain for these systems, mitigating any risks of delays or shortages that could impact the project timelines or costs.

Reduction in Energy Storage Cost

The cost of ESSs is anticipated to decrease in the foreseeable future. This reduction will enable SolarSync to manage the demand-side energy curve more effectively, enhancing its flexibility and participation in the energy trading market and providing a competitive edge in offering integrated renewable energy solutions.

Solar Farms' Environmental Impact

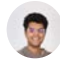
The conversion of farmlands and lake areas into solar farms could lead to significant environmental consequences, including the potential depletion of local biodiversity due to reduced exposure to sunlight. This assumption emphasizes the importance of considering the ecological impacts when planning large-scale solar installations.

Solar Installation Regulations

SolarSync operates under the premise that tenant legislation will continue to be robust, adding layers of complexity to installing PV systems on residential buildings. Conversely, it is assumed that codes governing C&I structures will maintain or enhance their support for rooftop PV installations. Reviewing current building codes and consultations with legal experts on potential future changes are needed to verify this.

C&I Rooftops is a Lucrative Sector

The assumption is that the most effective and strategic sector for deploying solar panel systems is on the rooftops of C&I buildings. This decision is based on the combined factors of available space, the potential for large-scale energy production, and the comparative ease of installation in these settings, positioning C&I rooftops as the optimal focus for solar energy initiatives.

Anna-Maria Geist 
Ben Ta 
Het Dave 
Valentin Gölz 
Zaid Efraij 

WattsUp

Finding the Space for Future Energy Storage Systems

Efficient energy storage systems have become essential in the global utility market, given the increasing rate of decentralization and the rapid adoption of renewable energy sources [489]. Projections indicate that by 2030, 80% of all electricity supply will be sourced from renewables in Germany [490]. Renewable energy sources are inherently intermittent, often resulting in surplus production during periods of low demand and shortages when demand peaks [491]. As a result, guaranteeing grid stability has become an important challenge for utility operators. The fluctuation in electricity production necessitates robust solutions for storing excess energy to stabilize the grid and provide a reliable energy supply. However, the scarcity of suitable locations, especially in densely populated urban areas, remains a potential hurdle in scaling up energy storage capabilities to match this demand [492].

WattsUp is a groundbreaking solution designed to address the complexities of urban energy storage in the face of increasing demand for renewable energy integration. WattsUp's focus is overcoming spatial limitations that currently impede the expansion of energy storage infrastructure in densely populated regions. By utilizing the potential of small, flexible storage units, WattsUp is uniquely positioned to improve grid stability at the local level, even in restricted spaces where conventional large-scale storage systems are unfeasible. WattsUp offers an adaptable energy storage solution that meets the needs of communities and utility companies in urban spaces.

WattsUp stands out by additionally addressing the challenge of space scarcity, a crucial obstacle to the scalability of energy storage solutions. As land is scarce in densely populated areas and the need for renewable energy storage is increasing, WattsUp's approach of identifying unused space coupled with an integrated service to provide all-in-one storage systems differentiates it from other players on the market. This approach addresses the need for more energy storage options while leveraging existing infrastructure and locations, maximizing efficiency, and minimizing the ecological footprint of scaled storage systems.

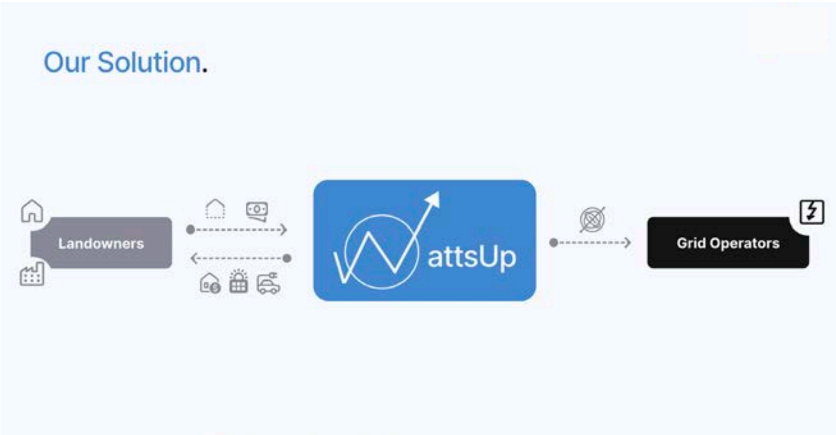
WattsUp's integrated energy trading strategy is a crucial aspect of its business model, purchasing energy at low prices and selling it at peak energy demand, maximizing the system's operational efficiency. Furthermore, WattsUp provides the option for on-premise self-consumption to its customers (e.g., furniture stores, discounters, or wholesale centers), which generate their own energy but are subject to grid fees without their own energy storage system. This approach lowers their energy costs and grid dependency, demonstrating WattsUp's dedication to sustainable energy solutions and economic efficiency.

In conclusion, WattsUp is an innovative energy storage solution that is scalable, efficient, and economically viable. Its focus on utilizing small spaces in urban areas and existing infrastructure, coupled with a profitable energy trading model, positions WattsUp as a competitive solution to today's energy storage problems and a forward-thinking approach to the future of renewable energy management.

Problem

- Projections indicate that by 2030, 80% of all electricity supply will be sourced from renewables in Germany [489]. However, the lack of efficient energy storage systems threatens to undermine these efforts, leading to significant wastage of renewable energy.
- Fluctuating energy prices add another layer of complexity. Without the infrastructure for dynamic pricing and smart meters, trading solutions are limited to spot market futures, hindering optimal utilization [490].
- Urban centers like Munich face a unique dilemma due to limited space for energy storage infrastructure. This scarcity presents an obstacle to scaling up storage capacity, exacerbating the challenge of integrating renewable energy into densely populated areas [491].
- Collaboration among stakeholders is essential to ensure the efficient utilization and storage of renewable energy, paving the way toward a sustainable future.

Germany must innovate in energy storage systems to leverage renewable energy sources by overcoming storage space challenges immediately



Solution

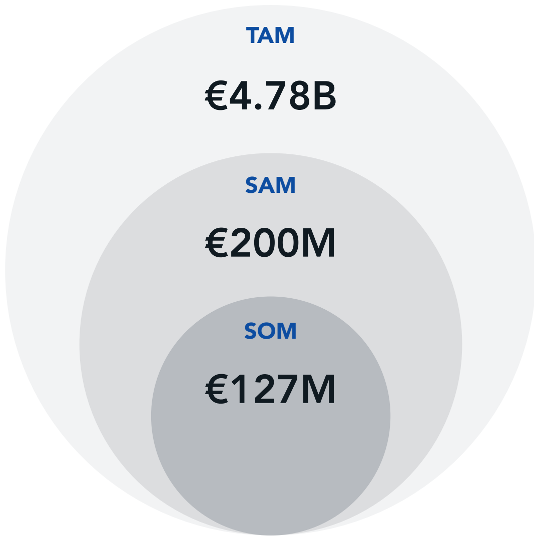
- The modern space offering platform connects individuals and companies with surplus space to those needing locations for energy storage infrastructure, thus providing a decentralized network for energy storage deployment.
- By collaborating with partners such as supermarkets, WattsUp leverages unused spaces within their compounds to install energy storage systems. This allows WattsUp to utilize idle areas in dense cities while offering revenue-sharing opportunities.
- The strategy capitalizes on the variability of energy prices by strategically buying energy during low demand and selling it during peak demand when prices are high.
- WattsUp empowers participating organizations to harness renewable energy through initiatives like solar rooftops. By storing excess energy generated from solar panels, these entities can offer affordable electricity options to their customers, such as discounted rates for electric vehicle charging.

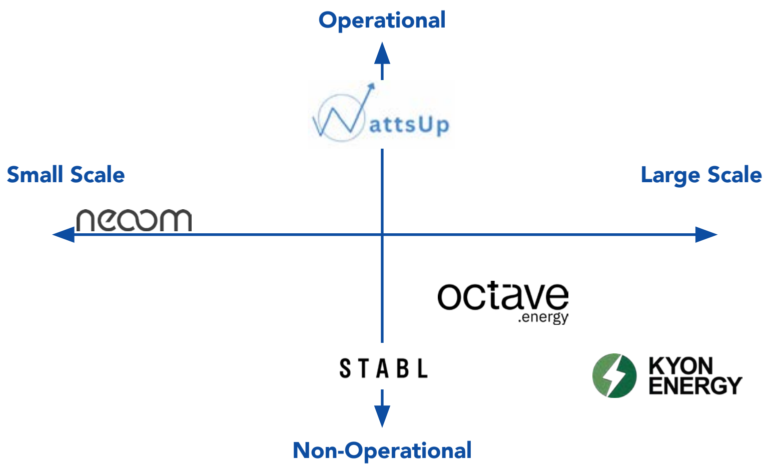
WattsUp leverages underused spaces for energy storage, optimizing renewable power use and enhancing urban energy efficiency

Market

- TAM spread impact analysis: In the TAM scenario, leveraging global renewable energy consumption of 8,539 TWh in 2022, with 4.5% representing 384 TWh, and at an average price margin of 12.5M EUR per TWh, yields a TAM revenue estimate of approximately 4.78B EUR [493, 494, 495].
- Serviceable Addressable Market (SAM): Focusing on the German market with 8 TWh of lost renewable energy in 2022, at a fixed price margin of 25M EUR per TWh, the SAM revenue projection is 200M EUR [494].
- Serviceable Obtainable Market (SOM): Assuming the construction of 2,000 facilities, each with a daily trade capacity of 7 MWh, leading to an annual generation of 255 GWh or 5.1 TWh, and utilizing the same 25 EUR margin per MWh, the SOM revenue forecast stands at approximately 127M EUR [495].

By transforming energy storage, WattsUp captures lost energy to redefine market dynamics and unlock billions in revenue





Competition

- Project scale differentiation: Focusing on medium-scale projects sets WattsUp apart from Kyon Energy, which targets large-scale installations, and Neoom, which specializes in small household setups [496, 497].
- Energy trading capabilities: Unlike Neoom and Octave Energy, we possess robust energy trading capabilities. This strategic advantage optimizes energy procurement and maximizes revenue generation through smart trading practices, offering added value to clients [497, 498].
- Comprehensive operational support: Competitors, such as Kyon Energy and Octave Energy, solely focus on selling energy storage solutions, whereas we offer comprehensive operational support services [496, 497, 498].
- Innovative space offering platform: The unique space offering platform revolutionizes the industry by providing a marketplace for surplus space.

WattsUp leads with medium-scale projects, advanced trading, and unique space solutions, outpacing its competitors in energy storage

Assumption Tree

Sufficient Incentives

WattsUp's value proposition, offering battery storage access and allowing customers to capitalize on the financial spread of energy prices, creates a compelling incentive for partners. These partners recognize not only the immediate financial gains but also the enduring value of promoting energy independence and sustainability. Furthermore, engaging with WattsUp allows partners to be part of a broader movement towards environmental sustainability.

Financial Spread

WattsUp's business strategy fundamentally hinges on the belief that a consistent 25 EUR per MWh spread in the day-ahead markets, which accurately reflects the difference between the buying and selling prices of energy, is achievable. The sustainability of this financial model hinges critically on the predictability and relative stability of energy price fluctuations, thereby allowing WattsUp to capitalize on these variations without assuming significant risk.

Space Availability

Adequate space for constructing small to medium-sized energy storage systems is available in Germany. The space can be used for energy storage, adhering to regulatory frameworks that include obtaining permits, meeting environmental and safety standards, and following land use regulations. Moreover, these spaces are strategically positioned to facilitate seamless integration with the existing energy grid.

Connection to Grid and Markets

Integrating privately owned energy storage systems into the existing electrical grid will be a straightforward process, not hindered by excessive technical challenges or stringent regulatory barriers. Concurrently, it is anticipated that gaining access to energy markets for the purpose of trading will be a manageable endeavor, allowing private energy storage operators to flexibly buy and sell energy.

Cooperative Partnerships

Numerous potential collaborators, from the automotive sector, including industry leaders such as BMW to retail giants such as Aldi, show strong interest in partnering with WattsUp. This broad spectrum of interest, coupled with the expected minimal resistance from these companies, provides a solid foundation for strategic alliances, subject to thorough empirical validation to demonstrate such partnerships' viability and mutual benefits.

Straightforward Implementation

The deployment of WattsUp's energy storage solutions is streamlined and facilitated by a large number of market players specializing in installation services. This allows us to focus on identifying prime locations and optimizing our energy trading software. By working with experienced industry experts, we gain valuable insight and anticipate potential obstacles to ensure efficient and effective system implementation.

Financial Arbitrage in Energy Markets

WattsUp exploits financial arbitrage in energy markets by integrating small to medium-scale energy storage systems into urban infrastructure, optimizing the balance between energy supply and demand. Our model, anchored in the realities of financial viability, space efficiency, regulatory navigation, and collaborative partnerships, positions us to exploit price differentials and ensure a sustainable and profitable venture in the energy sector.

LIST OF CONTRIBUTORS


Muneeb Ahmed
Politics and Technology


Hamze Al-Zamkan
Information Systems


Raphael Beuter
Psychology


Ju-Shan Chao
Data Engineering and Analytics


Jan Chen
Information Systems


Het Dave
Computer Science and Statistics


Zaid Efraij
Robotics, Cognition, Intelligence


Anna-Maria Geist
Management and Technology


Shouvik Ghosh
Computer Science


Elisabeth Goebel
Management and Technology


Valentin Gölz
Mathematics


Christina Hudgens
Management


Jan Jakob
Mathematics

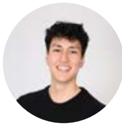

Finn Kosina
Medicine


Thomas Kaar
Computer Science
Management and Technology


Ruslan Mammadov
Robotics, Cognition, Intelligence


Niko Pallas
Media Informatics and Human-Computer Interaction


Anna Rode
Management and Technology


Marcelo Rohn
Management and Technology


Thomas Rother
Management and Technology


Khola Raja
Environmental Engineering


Annemarie Schimkat
Management and Technology


Christophe Schmit
Robotics, Cognition, Intelligence


Johann Stürken
Aerospace and Business


Ben Ta
Management and Technology

CDTM MANAGEMENT TEAM

Samuel Valenzuela
M.Sc. Computer Science

Amelie Pahl
M.A. Management

Martin Wessel
M.Sc. Data Science

Charlotte Kobiella
M.Sc. Management and Technology

Felix Dörpmund
M.Sc. Information Systems

Franz Waltenberger
M.A. Economics and Philosophy

Julia Balowski
M.Sc. Neuro Engineering

Vera Eger
M.Sc. Psychology

Jose Vega
M.Sc. Robotics, Cognition, Intelligence

Ferran Pla Cardona
M.Sc. Electrical Engineering

Florian Wiethof
M.Sc. Mechanical Engineering (Robotics)

BOARD OF DIRECTORS

Prof. Dr. Albrecht Schmidt
Chair for Human-Centered Ubiquitous Media
Ludwigs Maximilians University

Prof. Dr. Alexander Pretschner
Chair of Software Engineering
Technical University of Munich

Prof. Dr. Andreas Butz
Chair for Media Informatics
Ludwigs Maximilians University

Prof. Dr. Dres h.c. Arnold Picot †
Chair for Information, Organization and Management
Ludwigs Maximilians University

Prof. Dr. Hana Milanov
Entrepreneurship Research Institute
Technical University of Munich

Prof. Dr. Heinz-Gerd Hegering
Munich Network Management Team
Ludwigs Maximilians University

Prof. Dr. Helmut Krcmar
Chair for Information Systems
Technical University of Munich

Prof. Dr. Isabell Welpe
Chair for Strategy and Organisation
Technical University of Munich

Prof. Dr. Klaus Diepold
Chair for Data Processing
Technical University of Munich

Prof. Dr. Dr. h.c. Manfred Broy
Chair for Software and Systems Engineering
Technical University of Munich

Prof. Dr. Martin Spann
Chair for Electronic Commerce and Digital Markets
Ludwigs Maximilians University

Prof. Dr. Pramod Bhatotia
Chair for Decentralized Systems Engineering
Technical University of Munich

Prof. Dr. Bernd Brügge
Chair for Applied Software Engineering
Technical University of Munich

Prof. Dr. Dieter Kranzlmüller
Chair for Communication Systems and Systems Programming, Ludwigs Maximilians University, Munich Network Management Team, Leibniz Supercomputing Center

Prof. Dr. Dietmar Harhoff
Director at the Max Planck Institute for Innovation and Competition

Prof. Dr. Jelena Spanjol
Chair for Innovation Management
Ludwigs Maximilians University

Prof. Dr. Jörg Claussen
Chair for Strategy, Technology and Organization
Ludwigs Maximilians University

Prof. Dr. Jörg Eberspächer
Chair for Communication Networks
Technical University of Munich

Prof. Dr. Reiner Braun
Chair for Entrepreneurial Finance
Technical University of Munich

Prof. Dr. Stefanie Rinderle-Ma
Information Systems and Business Process Management
Technical University of Munich

Prof. Dr. Thomas Hess
Chair for Information Systems and New Media
Ludwigs Maximilians University

Prof. Dr. Tobias Kretschmer
Chair for Strategy, Technology and Organization
Ludwigs Maximilians University

Prof. Dr. Wolfgang Kellerer
Chair for Communication Networks
Technical University of Munich

OTHER PUBLICATIONS

2023

The Future of Digital Solutions for Sustainable Aviation
ISBN: 978-3-9822669-6-1

2023

The Future of Maritime Shipping
ISBN: 978-3-9822669-7-8

2023

The Future of Communication Technology
ISBN: 978-3-9822669-5-4

2022

The Future of Mittelstand
ISBN: 978-3-9822669-4-7

2022

Tackling Climate Change in the AI Era
ISBN: 978-3-9822669-3-0

2021

The Future of Waste Management
ISBN: 978-3-9822669-2-3

2021

Smart Living of the Future
ISBN: 978-3-9822669-1-6

2020

Independent Living for the Elderly
ISBN: 978-3-9822669-0-9

2020

Public Administration in the Digital Era
ISBN: 978-3-9818511-9-9

SOURCES

[1]: European Commision. (2023). The 2023 European Deep Tech Report. Retrieved Mar 12, 2024, from https://ec.europa.eu/newsroom/rtd/items/812679/en

[2]: Seo, J., Kim, S., Jalalvand, A., et al. (2024). Avoiding fusion plasma tearing instability with deep reinforcement learning. nature, 626, 746. https://doi.org/10.1038/s41586-024-07024-9

[3]: IGH2A. (2023). AI-Powered Revolution: Driving the Green Hydrogen Economy. Retrieved Mar 11, 2024, from https://igh2a.org/news/ai-powered-revolution-driving-the-green-hydrogen-economy/

[4]: Ramos, H. M., Kuriqi, A., Besharat, M., et al. (2023). Smart Water Grids and Digital Twin for the Management of System Efficiency in Water Distribution Networks. Water, 15(6), 1129. https://doi.org/10.3390/w15061129

[5]: Feng, C., Wang, Y., Chen, Q., et al. (2021). Smart grid encounters edge computing: opportunities and applications. Advances in Applied Energy, 1, 100006. https://doi.org/10.1016/j.adapen.2020.100006

[6]: Tao, F., Xiao, B., Qi, Q., et al. (2022). Digital twin modeling. Journal of Manufacturing Systems, 64, 372-389. https://doi.org/10.1016/j.jmsy.2022.06.015

[7]: Zheng, Y., Yang, S., Cheng, H. (2018). An application framework of digital twin and its case study. Journal of Ambient Intelligence and Humanized Computing , 10, 1141-1153. https://doi.org/10.1007/s12652-018-0911-3

[8]: Ford, D. N., Wolf, C. M. (2020). Smart Cities with Digital Twin Systems for Disaster Management. Journal of Management in Engineering, 36(4), 4020027. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000779

[9]: Chasiotis, A., Piromalis, D., Papageorgas, P., et al. (2023). A Smart Integrated Platform for Leakage Detection in the Water Supply Network of Aigio, Greece. Environ. Sci. Proc., 26(1), 184. https://doi.org/10.3390/environsciproc2023026184

[10]: Fernandes, S. V., João, D. V., Cardoso, B., et al. (2022). Digital Twin Concept Developing on an Electrical Distribution System—An Application Case. Energies, 15(8), 2836. https://doi.org/10.3390/en15082836

[11]: Abdo, E., Baronio, E., Mauro, S., et al. (2023). Case Study of the Use of a Digital Twin for Leak Detection and Quantification in Underground Gas Storage Wells. SPE Journal, 28(5), 2415–2424. https://doi.org/10.2118/214357-PA

[12]: Ye, X., Du, J., Han, Y., et al. (2022). Developing Human-Centered Urban Digital Twins for Community Infrastructure Resilience: A Research Agenda. Journal of Planning Literature, 38(2), 187-199. https://doi.org/10.1177/08854122221137861

[13]: Wu, Z. Y., Chew, A., Meng, X., et al. (2023). High Fidelity Digital Twin-Based Anomaly Detection and Localization for Smart Water Grid Operation Management. Renewable and Sustainable Energy Reviews, 91, 104446. https://doi.org/10.1016/j.scs.2023.104446

[14]: Teng, S. Y., Touš, M., Leong, W. D., et al. (2021). Recent advances on industrial data-driven energy savings: Digital twins and infrastructures. Renewable and Sustainable Energy Reviews, 135, 110208. https://doi.org/10.1016/j.rser.2020.110208

[15]: Attaran, M., Celik, B. G. (2023). Digital Twin: Benefits, use cases, challenges, and opportunities. Decision Analytics Journal, 6, 100165. https://doi.org/10.1016/j.dajour.2023.100165

[16]: Suffia, G. (2022). Legal issues of the digital twin cities in the current and upcoming European legislation: Can digital twin cities be used to respond to urbanisation problems? Retrieved Mar 17, 2024, from https://doi.org/10.1145/3560107.3560188

[17]: National Renewable Energy Laboratory. (2022). From the Bottom Up: Designing a Decentralized Power System. Retrieved Mar 17, 2024, from https://www.nrel.gov/news/features/2019/from-the-bottom-up-designing-a-decentralized-power-system.html

[18]: Holmes, T., McLarty, C., Shi, Y., et al. (2022). Energy Efficiency on Edge Computing: Challenges and Vision. Retrieved Mar 17, 2024, from https://doi.org/10.1109/IPCCC55026.2022.9894303

[19]: Vattenfall. (2023). Yes, AI will improve energy efficiency – "Essentially all buildings can benefit from this technology". Retrieved Mar 17, 2024, from https://group.vattenfall.com/press-and-media/newsroom/2023/yes-ai-will-improve-energy-efficiency--essentially-all-buildings-can-benefit-from-this-technology

[20]: Nokia. (2020). Nokia confirms 5G as 90 percent more energy efficient. Retrieved Mar 17, 2024, from https://www.nokia.com/about-us/news/releases/2020/12/02/nokia-confirms-5g-as-90-percent-more-energy-efficient/

[21]: Eurostat. (2022). Smart technologies in EU enterprises: AI and IoT. Retrieved Mar 17, 2024, from https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220609-1#:~:text=Enterprises%20using%20IoT%2C%202021&text=Among%20EU%20Member%20States%2C%20more,%25

[22]: Statista. (2023). Smart Cities - Europe. Retrieved Mar 17, 2024, from https://www.statista.com/outlook/tmo/internet-of-things/smart-cities/europe

[23]: European Commission, Directorate-General for Energy, Jakeman A, Achtelik C, Makwana V. (2020). Digital technologies and use cases in the energy sector. Retrieved Mar 17, 2024, from https://data.europa.eu/doi/10.2833/006724

[24]: McKinsey & Company. (2021). The impact of electromobility on the German electric grid. Retrieved Mar 17, 2024, from https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/the-impact-of-electromobility-on-the-german-electric-grid

[25]: Die Bundesregierung. (2022). Nicht weniger fortbewegen, sondern anders. Retrieved Mar 17, 2024, from https://www.bundesregierung.de/breg-de/schwerpunkte/klimaschutz/nachhaltige-mobilitaet-2044132#:~:text=15%20Millionen%20E%2DAutos%20bis,die%20Bundesregierung%20mit%20einem%20Umweltbonus

[26]: Zishan, A. A., Haji, M. M., Ardakanian, O. (2021). Adaptive Congestion Control for Electric Vehicle Charging in the Smart Grid. IEEE Transactions on Smart Grid, 12(3), 2439-2449. https://doi.org/10.1109/TSG.2021.3051032

[27]: European Commision. (2024). Smart grids and meters. Retrieved Mar 17, 2024, from https://energy.ec.europa.eu/topics/markets-and-consumers/smart-grids-and-meters_en

[28]: McKinsey & Company. (2022). McKinsey Technology Trends Outlook 2022. Retrieved Mar 17, 2024, from https://www.mckinsey.com/~/media/mckinsey/business%20functions/mckinsey%20digital/our%20insights/the%20top%20trends%20in%20tech%202022/mckinsey-tech-trends-outlook-2022-full-report.pdf

[29]: International Renewable Energy Agency. (2022). Grid Codes for Renewable Powered Systems. Retrieved Mar 17, 2024, from https://www.irena.org/publications/2022/Apr/Grid-codes-for-renewable-powered-systems

[30]: Handelsblatt. (2022). Halbherziger Start: Energieunternehmen kritisieren die deutsche Smart-Meter-Strategie. Retrieved Mar 17, 2024, from https://www.handelsblatt.com/unternehmen/energie/intelligente-stromzaehler-halbherziger-start-energieunternehmen-kritisieren-die-deutsche-smart-meter-strategie/28033840.html

[31]: Deloitte. (2022). 2023 Power and Utilities industry outlook. Retrieved Mar 08, 2024, from https://www2.deloitte.com/content/dam/Deloitte/tw/Documents/energy-resources/2023-power-and-utilities-industry-outlook-en.pdf

[32]: Arthur D. Little. (2022). Unleashing the business potential of Quantum Computing. Retrieved Mar 08, 2024, from https://www.adlittle.com/en/insights/report/unleashing-business-potential-quantum-computing

[33]: Xu, X., Zhang, Z., Feng, S., et al. (2023). LmPa: Improving Decompilation by Synergy of Large Language Model and Program Analysis. Retrieved Mar 11, 2024, from https://doi.org/10.48550/arXiv.2306.02546

[34]: Knerl, L. (2024). Role of LLMs and Advanced AI in Cybersecurity. Retrieved Mar 12, 2024, from https://www.hp.com/us-en/shop/tech-takes/llms-advanced-ai-cybersecurity

[35]: Zografopoulos, I., Hatziargyriou, N. D., Konstantinou, C. (2023). Distributed Energy Resources Cybersecurity Outlook: Vulnerabilities, Attacks, Impacts, and Mitigations. IEEE Systems Journal, 17(4), 6695 - 6709. https://doi.org/10.1109/JSYST.2023.3305757

[36]: Satter, R. (2024). Satellite outage caused 'huge loss in communications' at war's outset -Ukrainian official. Retrieved Mar 11, 2024, from https://www.reuters.com/world/satellite-outage-caused-huge-loss-communications-wars-outset-ukrainian-official-2022-03-15/

[37]: International Energy Agency. (2021). Enhancing Cyber Resilience in Electricity Systems. Retrieved Mar 03, 2024, from https://iea.blob.core.windows.net/assets/0ddf8935-be23-4d5f-b798-3aad1f32432f/Enhancing_Cyber_Resilience_in_Electricity_Systems.pdf

[38]: International Energy Agency. (2022). Unlocking the potential of distributed energy resources. Retrieved Mar 02, 2024, from https://www.iea.org/reports/unlocking-the-potential-of-distributed-energy-resources

[39]: ENODA harmonising energy. (2023). Exactly What are Balancing Costs? Retrieved Apr 02, 2024, from https://enodatech.com/news-insight/exactly-what-are-balancing-costs

[40]: Xie, L., Huang, T., Zheng, X., et al. (2022). Energy system digitization in the era of AI: A three-layered approach toward carbon neutrality. Patterns, 3(12), 100640. https://doi.org/10.1016/j.patter.2022.100640

[41]: Organisation for Economic Co-operation and Development. (2023). Electricity Grids and Secure Energy Transitions. Retrieved Mar 08, 2024, from https://www.oecd.org/publications/electricity-grids-and-secure-energy-transitions-455dd4fb-en.htm

[42]: Paletta, Q., Terrén-Serrano, G., Nie, Y., et al. (2023). Advances in solar forecasting: Computer vision with deep learning. Advances in Applied Energy, 11, 100150. https://doi.org/10.1016/j.adapen.2023.100150

[43]: Lam, R. (2023). GraphCast: AI model for faster and more accurate global weather forecasting. Retrieved Mar 08, 2024, from https://deepmind.google/discover/blog/graphcast-ai-model-for-faster-and-more-accurate-global-weather-forecasting/

[44]: Elkin, C. (2019). Machine learning can boost the value of wind energy. Retrieved Mar 08, 2024, from https://deepmind.google/discover/blog/machine-learning-can-boost-the-value-of-wind-energy/

[45]: Stecyk, A., Miciuła, I. (2023). Harnessing the Power of Artificial Intelligence for Collaborative Energy Optimization Platforms. Energies, 16(13), 5210. https://doi.org/10.3390/en16135210

[46]: Executive Office of the President, Council of Economic Advisers. (2023). Economic Report of the President. Retrieved Mar 08, 2024, from https://www.whitehouse.gov/wp-content/uploads/2023/03/ERP-2023.pdf

[47]: Russo, M. A., Carvalho, D., Martins, N., et al. (2022). Forecasting the inevitable: A review on the impacts of climate change on renewable energy resources. Sustainable Energy Technologies and Assessments, 52, 102283. https://doi.org/10.1016/j.seta.2022.102283

[48]: World Meteorological Organization. (2023). 2022 year in review: Climate-Driven global renewable energy, potential resources and energy demand. Retrieved Mar 08, 2024, from https://mc-cd8320d4-36a1-40ac-83cc-3389-cdn-endpoint.azureedge.net/-/media/Files/IRENA/Agency/Publication/2023/Dec/IRENA_WMO_2022_year_in_review_2023.pdf

[49]: Ghalehkhondabi, I., Ardjmand, E., Weckman, G. R., et al. (2016). An overview of energy demand forecasting methods published in 2005–2015. Energy Systems, 8, 411-447. https://doi.org/10.1007/s12667-016-0203-y

[50]: Eurostat. (2023). Energy statistics - an overview. Retrieved Mar 11, 2024, from https://ec.europa.eu/eurostat/statistics-explained/index.php

[51]: Geothermal Rising. (2024). Geothermal Energy in the Era of Artificial Intelligence. Retrieved Mar 11, 2024, from https://www.geothermal.org/our-impact/success-stories/geothermal-heating-project-tapping-old-mine-soon-start-operation-northern-spain

[52]: Boutelet, C. (2022). Germany wants to speed up nuclear fusion. Retrieved Mar 11, 2024, from https://www.lemonde.fr/en/economy/article/2023/06/17/germany-wants-to-speed-up-nuclear-fusion_6033031_19.html#:~:text=No%20disasters%20nor%20long%2Dterm,Free%20Democratic%20Party%20(FDP)

[53]: Wettengel, J. (2023). Germany aims to accelerate hydrogen market ramp-up with strategy update. Retrieved Mar 11, 2024, from https://www.cleanenergywire.org/news/germany-also-support-hydrogen-made-co2-capturing-under-upcoming-strategy-update-media

[54]: Hockenos, P. (2020). Geothermal energy – Germany's largely untapped renewable heat source. Retrieved Mar 11, 2024, from https://www.cleanenergywire.org/factsheets/geothermal-energy-germanys-largely-untapped-renewable-heat-source#:~:text=And%20they%20show%20starkly%20how,heat%20per%20year%20by%202050

[55]: Sai Ramesh, A., Vigneshwar, S., Vickram, S., et al. (2022). Artificial intelligence driven hydrogen and battery technologies – A review. Fuel, 337, 126862. https://doi.org/10.1016/j.fuel.2022.126862

[56]: Ball, P. (2023). What Is the Future of Fusion Energy? Retrieved Mar 11, 2024, from https://www.scientificamerican.com/article/what-is-the-future-of-fusion-energy/#:~:text=Most%20experts%20agree%20that%20we,might%20add%20on%20another%20decade

[57]: German Energy Solutions Initiative. (2019). GIGS – Geothermal energy in the granite of Saxony. Retrieved Mar 11, 2024, from https://www.german-energy-solutions.de/GES/Redaktion/EN/News/2019/20190531-gigs.html

[58]: Eavor. (2024). Eavor-Loop für Wärme und Strom in der Region. Retrieved Mar 11, 2024, from https://eavor-geretsried.de/

[59]: DNV. (2024). The Energy Transition Outlook 2023. Retrieved Mar 11, 2024, from https://www.dnv.com/energy-transition-outlook/download

[60]: Muhammed, S. N. V. (2023). How AI can accelerate the transition to Green hydrogen. Retrieved Mar 11, 2024, from https://blog.se.com/industry/mining-metals-minerals/2023/07/12/ai-accelerating-transition-green-hydrogen/

[61]: Jakimowicz, A. (2022). The Future of the Energy Sector and the Global Economy: Prosumer Capitalism and What Comes Next. Energies, 15(23)(9120), https://doi.org/10.3390/en15239120

[62]: Aruta, G., Ascione, F., Bianco, N., et al. (2023). From consumers to prosumers: the rise of Energy Communities and their role in the energy transition. IEEE Explore, https://doi.org/10.23919/SpliTech58164.2023.10193292

[63]: Climate Partner. (2022). Climate Action Awareness Report 2022. Retrieved Mar 10, 2024, from https://www.climatepartner.com/en/knowledge/insights/climate-action-awareness-report-2022

[64]: Cao, Y., Dhahad, H. A., Togun, H., et al. (2022). Development and transient performance analysis of a decentralized grid-connected smart energy system based on hybrid solar-geothermal resources; Techno-economic evaluation. Sustainable Cities and Society, 76, https://doi.org/10.1016/j.scs.2021.103425

[65]: Sánchez, A. (2022). Decentralized Composting of Food Waste: A Perspective on Scientific Knowledge. Frontiers in Chemical Engeneering, 4, https://doi.org/10.3389/fceng.2022.850308

[66]: Bruni, C., Akyol, Ç., Cipolletta, G., et al. (2020). Decentralized Community Composting: Past, Present and Future Aspects of Italy. Sustainability, 12(8)(3319), https://doi.org/10.3390/su12083319

[67]: de Souza, L. C. G., Drumond, M. A. (2022). Decentralized composting as a waste management tool connect with the new global trends: a systematic review. Int. J. Environ. Sci. Technol., 19, https://doi.org/10.1007/s13762-022-04504-1

[68]: Jackson, J. (2023). One in eight German households already use air conditioning – survey. Retrieved Mar 17, 2024, from https://www.cleanenergywire.org/news/one-eight-german-households-already-use-air-conditioning-survey#:~:text=Around%20one%20in%20eight%20German,by%20price%20comparison%20website%20Verivox.

[69]: Stott, P. (2016). How climate change affects extreme weather events. Science, 352(6293), 1517-1518. https://doi.org/10.1126/science.aaf7271

[70]: Zhang, Y., Long, M., Chen, K., et al. (2023). Skilful nowcasting of extreme precipitation with NowcastNet. Nature, 619, 526-532. https://doi.org/10.1038/s41586-023-06184-4

[71]: Heikkiläarchive, M. (2023). Google DeepMind's weather AI can forecast extreme weather faster and more accurately. Retrieved Mar 17, 2024, from https://www.technologyreview.com/2023/11/14/1083366/google-deepminds-weather-ai-can-forecast-extreme-weather-quicker-and-more-accurately/

[72]: Bi, K., Xie, L., Zhang, H., et al. (2023). Accurate medium-range global weather forecasting with 3D neural networks. Nature, 619, 533-538. https://doi.org/10.1038/s41586-023-06185-3

[73]: Gil, J. (2019). Micropollutants in wastewater irrigation systems: Impacts and perspectives. Annals of Advances in Chemistry, (3)11–13. https://dx.doi.org/10.29328/journal.aac.1001019

[74]: Ziani, K., Ioniță-Mîndrican, C.-B., Mititelu, M., et. al. (2023). Microplastics: A Real Global Threat for Environment and Food Safety: A State of the Art Review. Nutrients, 15(3), 617. https://doi.org/10.3390%2Fnu15030617

[75]: Post, C., Heyden, N., Reinartz, A., et. al. (2022). Possibilities of Real Time Monitoring of Micropollutants in Wastewater Using Laser-Induced Raman & Fluorescence Spectroscopy (LIRFS) and Artificial Intelligence (AI). Sensors, 22(13), 4668. https://doi.org/10.3390/s22134668

[76]: McKinsey. (2022). The state of AI in 2022 — and a half decade in review. Retrieved Mar 13, 2024, from https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-state-of-ai-in-2022-and-a-half-decade-in-review

[77]: Glikson, E., Woolley, A. W. (2020). Human Trust in Artificial Intelligence: Review of Empirical Research. Academy of Management Annals, 14(2), 627 - 660. https://doi.org/10.5465/annals.2018.0057

[78]: Scientific Computing World. (-). The true cost of AI innovation. Retrieved Mar 10, 2024, from https://www.scientific-computing.com/analysis-opinion/true-cost-ai-innovation

[79]: Leffer, L. (2023). The AI Boom Could Use a Shocking Amount of Electricity. Retrieved Mar 10, 2024, from https://www.scientificamerican.com/article/the-ai-boom-could-use-a-shocking-amount-of-electricity/

[80]: IEA50. (2024). Electricity 2024. Retrieved Mar 10, 2024, from https://www.iea.org/reports/electricity-2024

[81]: Calma, J. (2023). Microsoft is going nuclear to power its AI ambitions. Retrieved Mar 10, 2024, from https://www.theverge.com/2023/9/26/23889956/microsoft-next-generation-nuclear-energy-smr-job-hiring

[82]: Kersting, S. (2021). Globaler Klimastreik: Diese drei Punkte treiben die Demonstranten auf die Straße. Retrieved Mar 10, 2024, from https://www.handelsblatt.com/technik/thespark/fridays-for-future-globaler-klimastreik-diese-drei-punkte-treiben-die-demonstranten-auf-die-strasse/27641090.html

[83]: Deloitte. (2022). The energy transition: from the traditional energy system to a service model. Retrieved Mar 10, 2024, from https://www2.deloitte.com/nl/nl/pages/energy-resources-industrials/articles/energy-as-a-service.html

[84]: Lotfi, M., Catalão, J. P. S., Gabbar, H. A. (2020). The Rise of Energy Prosumers and Energy Democracy: History and Future Prospects. Retrieved Mar 10, 2024, from https://smartgrid.ieee.org/bulletins/july-2020/the-rise-of-energy-prosumers-and-energy-democracy-history-and-future-prospects

[85]: Koirala, B. P., Araghi, Y., Kroesen, M., et al. (2018). Trust, awareness, and independence: Insights from a socio-psychological factor analysis of citizen knowledge and participation in community energy systems. Energy Research & Social Science, 38, 33-40. https://doi.org/10.1016/j.erss.2018.01.009

[86]: BCG. (2022). Sense and Sustainability. Retrieved Mar 10, 2024, from https://www.bcg.com/publications/2022/why-sustainability-in-global-retail-banking-matters

[87]: McKinsey. (2023). Consumers care about sustainability—and back it up with their wallets. Retrieved Mar 10, 2024, from https://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/consumers-care-about-sustainability-and-back-it-up-with-their-wallets

[88]: Forschungsgruppe Solarspeichersysteme. (2022). Dezentrale Solarstromspeicher für die Energiewende. Retrieved Mar 10, 2024, from https://solar.htw-berlin.de/studien/solarspeicherstudie/

[89]: Pasquini, G., Spencer, A., Tyson, A., et al. (2023). Why Some Americans Do Not See Urgency on Climate Change. Retrieved Mar 10, 2024, from https://www.pewresearch.org/science/2023/08/09/why-some-americans-do-not-see-urgency-on-climate-change/

[90]: Umweltbundesamt. (2023). Umweltbewusstsein in Deutschland. Retrieved Mar 13, 2024, from https://www.umweltbundesamt.de/themen/nachhaltigkeit-strategien-internationales/umweltbewusstsein-in-deutschland

[91]: Arthur D. Little. (2022). Disruption is now - How decarbonization, decentralization, and digitalization transform the energy and resources sector. Retrieved Mar 13, 2024, from https://www.adlittle.com/sites/default/files/reports/ADL_Disruption_is_now_2_0.pdf

[92]: Die Bundesregierung. (2023). Klimafreundlich und krisensicher. Retrieved Mar 13, 2024, from https://www.bundesregierung.de/breg-de/schwerpunkte/klimaschutz/energieversorgung-sicherheit-2040098

[93]: Holl, F. (2021). Die Akzeptanz von Smart Metern durch Endverbraucherinnen und Endverbraucher im Kontext von Smart Grids in Deutschland. Retrieved Mar 13, 2024, from https://smartgrids-bw.net/public/uploads/2021/03/Die_Akzeptanz_von_SmartMetern.pdf

[94]: European Environment Agency. (2021). Energy prosumers and cities. Retrieved Mar 13, 2024, from https://www.eea.europa.eu/publications/energy-prosumers-and-cities

[95]: Parker, S. (2021). The Decentralized Utility is Coming. Are You Ready to Make the Shift? Retrieved Mar 13, 2024, from https://blog.ifs.com/2021/12/the-decentralized-utility-is-coming-are-you-ready-to-make-the-shift/

[96]: World Economic Forum. (2021). Harnessing Artificial Intelligence to Accelerate the Energy Transition. Retrieved Mar 13, 2024, from https://www3.weforum.org/docs/WEF_Harnessing_AI_to_accelerate_the_Energy_Transition_2021.pdf

[97]: Petrick, S., Rehdanz, K., Tol, R. S. J. (2010). The impact of temperature changes on residential energy consumption. EconStor, (Kiel Working Paper No. 1618)1-34. https://hdl.handle.net/10419/30253

[98]: Crownhart, C. (2022). The legacy of Europe's heat waves will be more air conditioning. That's a problem. Retrieved Mar 10, 2024, from https://www.technologyreview.com/2022/07/20/1056271/europe-heat-waves-air-conditioning/

[99]: Kang, J., Reiner, D. M. (2022). What is the effect of weather on household electricity consumption? Empirical evidence from Ireland. Energy Economics, 2022, 106023. https://doi.org/10.1016/j.eneco.2022.106023

[100]: Deutscher Wetterdienst. (2024). Klimawandel - Ein Überblick. Retrieved Mar 17, 2024, from https://www.dwd.de/DE/klimaumwelt/klimawandel/klimawandel_node.html

[101]: Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz. (2022). Hitze, Dürre, Starkregen: Über 80 Milliarden Euro Schäden durch Extremwetter in Deutschland. Retrieved Mar 17, 2024, from https://www.bmuv.de/pressemitteilung/hitze-duerre-starkregen-ueber-80-milliarden-euro-schaeden-durch-extremwetter-in-deutschland

[102]: Energy5. (2024). The influence of dams and reservoirs on riverine natural hazard mitigation. Retrieved Mar 01, 2024, from https://energy5.com/the-influence-of-dams-and-reservoirs-on-riverine-natural-hazard-mitigation

[103]: Watson, J. T., Gayer, M., Connolly, M. A. (2007). Epidemics after Natural Disasters. Emerging Infectious Diseases, 13(1), 45413. https://doi.org/10.3201/eid1301.060779

[104]: Exner, M. (2022). Ahrtal: Das Netz kommt zurück – mit Glasfaser. Retrieved Mar 17, 2024, from https://www.telekom.com/de/blog/netz/artikel/ahrtal-das-netz-kommt-zurueck-mit-glasfaser-1009130

[105]: Umweltbundesamt. (2021). New study shows risks of climate change in Germany. Retrieved Mar 17, 2024, from https://www.umweltbundesamt.de/en/press/pressinformation/new-study-shows-risks-of-climate-change-in-germany

[106]: Umweltbundesamt. (2021). Klimawirkungs- und Risikoanalyse 2021 für Deutschland. Teilbericht 1: Grundlagen. Retrieved Mar 17, 2024, from https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/kwra2021_teilbericht_1_grundlagen_bf_211027_0.pdf

[107]: Collins, J. (2024). Germany's 2023/24 winter unusually wet and third warmest on record – meteorological service. Retrieved Mar 17, 2024, from https://www.cleanenergywire.org/news/germanys-2023-24-winter-unusually-wet-and-third-warmest-record-meteorological-service#:~:text=Clean%20Energy%20Wire%20%2F%20Die%20Zeit,%2F2007%20and%202019%2F2020.

[108]: European Environment Agency. (2023). Economic losses from weather- and climate-related extremes in Europe. Retrieved Mar 17, 2024, from https://www.eea.europa.eu/downloads/8efbbcb2360a484fb04b56f993c1517c/1675773941/economic-losses-and-fatalities-from.pdf

[109]: Zurich Insurance. (2023). Zurich Insurance Annual Report 2022. Retrieved Mar 17, 2024, from https://www.zurich.com/-/media/project/zurich/dotcom/investor-relations/docs/financial-reports/2022/annual-report-2022-en.pdf?v=2

[110]: NASA. (2024). Extreme Weather and Climate Change. Retrieved Mar 17, 2024, from https://climate.nasa.gov/extreme-weather/#:~:text=As%20Earth's%20climate%20changes%2C%20it,more%20frequent%20and%20more%20intense.

[111]: Kuglitsch, M. M., Pelivan, I., Ceola, S., et. al. (2022). Facilitating adoption of AI in natural disaster management through collaboration. nature Communications, 13(1579), 45352. https://doi.org/10.1038/s41467-022-29285-6

[112]: Jain, H., Dhupper, R., Shrivastava, A., et al. (2023). AI-enabled strategies for climate change adaptation: protecting communities, infrastructure, and businesses from the impacts of climate change. Computational Urban Science, 3(25), 1-17. https://doi.org/10.1007/s43762-023-00100-2

[113]: World Meteorological Organization. (2021). WMO Atlas of Mortality and Economic Losses from Weather, Climate and Water Extremes (1970–2019). Retrieved Mar 17, 2024, from https://library.wmo.int/viewer/57564/download?file=1267_Atlas_of_Mortality_en.pdf&type=pdf&navigator=1

[114]: Ghaffarian, S., Taghikhah, F. R., Maier, H. R. (2023). Explainable artificial intelligence in disaster risk management: Achievements and prospective futures. International Journal of Disaster Risk Reduction, 98(November 2023, 104123), 1-22. https://doi.org/10.1016/j.ijdrr.2023.104123

[115]: Velev, D., Zlateva, P. (2023). Challenges of artifical intelligence application for disaster risk management. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLVIII-M-1-2023, 387-394. https://doi.org/10.5194/isprs-archives-XLVIII-M-1-2023-387-2023

[116]: Bundesnetzagentur. (2024). Versorgungssicherheit. Retrieved Mar 17, 2024, from https://www.bundesnetzagentur.de/DE/Fachthemen/ElektrizitaetundGas/Versorgungssicherheit/start.html

[117]: Abbasi N. A., Shahid S. U, Majid M., et. al. (2022). Chapter 17 - Ecotoxicological risk assessment of environmental micropollutants. Environmental Micropollutants, 331-337. https://doi.org/10.1016/B978-0-323-90555-8.00004-0

[118]: United Nations Environment Programme. (2019). Microplastics. Retrieved Mar 10, 2024, from https://www.unep.org/resources/report/microplastics

[119]: European Parliament. (2018). Microplastics: sources, effects and solutions. Retrieved Mar 10, 2024, from https://www.europarl.europa.eu/topics/en/article/20181116STO19217/microplastics-sources-effects-and-solutions

[120]: Ziani, K., Ioniță-Mîndrican, C.-B., Mititelu, M., et. al. (2023). Microplastics: A Real Global Threat for Environment and Food Safety: A State of the Art Review. Nutrients, 15(3), 617. https://doi.org/10.3390%2Fnu15030617

[121]: Gil, J. L. (2019). Micropollutants in wastewater irrigation systems: Impacts and perspectives. Annals of Advances in Chemistry, (3)11–13. https://dx.doi.org/10.29328/journal.aac.1001019

[122]: Sattar, S., Hussain, R., Mukarram Shah, S. M., et al. (2022). Chapter 20 - Bioremediation of micropollutants. Retrieved Mar 10, 2024, from https://doi.org/10.1016/B978-0-323-90555-8.00020-9

[123]: Laskar, N., Kumar, U. (2019). Plastics and microplastics: A threat to environment. Environmental Technology & Innovation, 14, https://doi.org/10.1016/j.eti.2019.100352

[124]: Chavoshani, A., Hashemi, M., Mehdi Amin, M., et al. (2020). Chapter 1 - Introduction. Retrieved Mar 10, 2024, from https://doi.org/10.1016/B978-0-12-818612-1.00001-5

[125]: Kumar, A., Deepika, Tyagi, D., et. al. (2024). Organic Micropollutants and Their Effects on the Environment and Human Health. Retrieved Mar 10, 2024, from https://doi.org/10.1007/978-3-031-48977-8_5

[126]: Parker, L. (2024). The world's plastic pollution crisis, explained. Retrieved Mar 10, 2024, from https://www.nationalgeographic.com/environment/article/plastic-pollution

[127]: Hanak, S. (2024). AI detects river pollution. Retrieved Mar 10, 2024, from https://rudolphina.univie.ac.at/en/artificial-intelligence-detects-river-pollution

[128]: Eurostat. (2024). Municipal waste by waste management operations. Retrieved Mar 10, 2024, from https://doi.org/10.2908/ENV_WASMUN

[129]: Our World In Data. (2024). Microplastics in the surface ocean, 1950 to 2050. Retrieved Mar 10, 2024, from https://ourworldindata.org/grapher/microplastics-in-ocean

[130]: Veterinärmedizinische Universität Wien. (2022). Gesundheitsrisiko durch Mikro- und Nanoplastik in Lebensmitteln. Retrieved Mar 10, 2024, from https://www.vetmeduni.ac.at/en/universitaet/infoservice/presseinformationen-2022/gesundheitsrisiko-durch-mikro-und-nanoplastik-in-lebensmitteln

[131]: Van Cauwenberghe, L., Janssen, C. R. (2014). Microplastics in bivalves cultured for human consumption. Environmental Pollution, 193, 65-70. https://doi.org/10.1016/j.envpol.2014.06.010

[132]: European Commission. (2019). Special Eurobarometer 501 Attitudes of European citizens towards the environment. Retrieved Mar 10, 2024, from https://europa.eu/eurobarometer/api/deliverable/download/file?deliverableId=72400

[133]: Ritchie, H., Samborska, V., Roser, M. (2024). Plastic Pollution. Retrieved Mar 10, 2024, from https://ourworldindata.org/plastic-pollution

[134]: Chavoshani, A., Hashemi, M., Amin, M. M. (2020). Chapter 7 - Conclusions and future research. Retrieved Mar 10, 2024, from https://www.sciencedirect.com/topics/earth-and-planetary-sciences/micropollutant-occurrence#:~:text=Micropollutants%20may%20comprise%20uncontaminated%20synthetic,%2C%20and%20pesticides%20%5B26%5D

[135]: Félix, R. M. (2023). How to fight the microplastics and micropollutants health hazard. Retrieved Mar 10, 2024, from https://impact.economist.com/sustainability/circular-economies/how-to-fight-the-microplastics-and-micropollutants-health-hazard

[136]: Kompetenzzentrum Spurenstoffe Baden-Württemberg. (2021). Micropollutants in wastewater action recommendation for municipalities. Retrieved Mar 10, 2024, from https://koms-bw.de/cms/content/media/Projektbroschuere%20Spurenstoffe%20KomS%20Englisch_Ansicht.pdf

[137]: Chavoshani, A., Hashemi, M., Amin, M., et. al. (2020). Micropollutants and Challenges. Retrieved Mar 10, 2024, from https://doi.org/10.1016/C2018-0-03939-0

[138]: Pronk, T. E., Fischer, A., van den Berg, A. E. T., et. al. (2023). Prioritization of micropollutants based on removal effort in drinking water purification treatment. Water Quality Research Journal, 58(3), 184–198. https://doi.org/10.2166/wqrj.2023.032

[139]: Wang, Z., Walker, G. W., Muir, D. C. G., et. al. (2020). Toward a Global Understanding of Chemical Pollution: A First Comprehensive Analysis of National and Regional Chemical Inventories. Environmental Science and Technology, 54(5), 2575–2584. https://dx.doi.org/10.1021/acs.est.9b06379?ref=pdf

[140]: United Nations. (2022). 2022 United Nations Conference to Support the Implementation of Sustainable Development Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development. Retrieved Mar 10, 2024, from https://sdgs.un.org/sites/default/files/2022-05/ID_1_Addressing_marine_pollution.pdf

[141]: Post C., Heyden N., Reinartz A., et. al. (2022). Possibilities of Real Time Monitoring of Micropollutants in Wastewater Using Laser-Induced Raman & Fluorescence Spectroscopy (LIRFS) and Artificial Intelligence (AI). Sensors, 22(13), 4668. https://doi.org/10.3390/s22134668

[142]: Gillespie, N., Lockey, S., Curtis, C. (2021). Trust in artificial Intelligence: a five country study. Retrieved Mar 13, 2024, from https://doi.org/10.14264/e34bfa3

[143]: Vincent, J. (2023). Elon Musk and top AI researchers call for pause on 'giant AI experiments'. Retrieved Mar 13, 2024, from https://www.theverge.com/2023/3/29/23661374/elon-musk-ai-researchers-pause-research-open-letter

[144]: Future of Life Institute. (2023). Pause Giant AI Experiments: An Open Letter. Retrieved Mar 13, 2024, from https://futureoflife.org/open-letter/pause-giant-ai-experiments/

[145]: Bundesverband der Energie- und Wasserwirtschaft e.V. (2021). Digital@EVU 2021: Energieversorger setzen auf digitalbasierte Produkte. Retrieved Mar 13, 2024, from https://www.bdew.de/service/publikationen/digitalevu-2021-energieversorger-setzen-auf-digitalbasierte-produkte/

[146]: Middleton, S. E., Letouzé, E., Hossaini, A., et al. (2022). Trust, regulation, and human-in-the-loop AI. Communications of The ACM, 65(4), 64 - 68. https://doi.org/10.1145/3511597

[147]: Wirtz, B. W., Weyerer, J. C., Geyer, C. (2018). Artificial Intelligence and the Public Sector—Applications and Challenges. International Journal of Public Administration, 42(7), 596 - 615. https://doi.org/10.1080/01900692.2018.1498103

[148]: Gerlich, M. (2023). Perceptions and Acceptance of Artificial Intelligence: A Multi-Dimensional Study. Social sciences, 12(9), 502. https://doi.org/10.3390/socsci12090502

[149]: World Economic Forum. (2021). Harnessing Artificial Intelligence to Accelerate the Energy Transition. Retrieved Mar 13, 2024, from https://www3.weforum.org/docs/WEF_Harnessing_AI_to_accelerate_the_Energy_Transition_2021.pdf

[150]: Deutsche Energie-Agentur GmbH (dena). (2022). Künstliche Intelligenz in der Energiewirtschaft. Retrieved Mar 13, 2024, from https://www.dena.de/fileadmin/dena/Publikationen/PDFs/2022/dena-Umfrage_Kuenstliche_Intelligenz_in_der_Energiewirtschaft.pdf

[151]: Peters, T. M., Visser, R. W. (2023). The Importance of Distrust in AI. Communications in computer and information science, 1(1), 301 - 317. https://doi.org/10.1007/978-3-031-44070-0_15

[152]: Scientific Computing World. (2024). The true cost of AI innovation. Retrieved Mar 10, 2024, from https://www.scientific-computing.com/analysis-opinion/true-cost-ai-innovation

[153]: IEA50. (2024). Electricity 2024. Retrieved Mar 10, 2024, from https://www.iea.org/reports/electricity-2024

[154]: Demertzis, M. (2023). Artificial intelligence and energy consumption. Retrieved Mar 10, 2024, from https://www.bruegel.org/comment/artificial-intelligence-and-energy-consumption#:~:text=One%20estimate%2C%20published%20recently%20in,of%20the%20world's%20electricity%20use.

[155]: Mims, C. (2023). AI Is Ravenous for Energy. Can It Be Satisfied? Retrieved Mar 10, 2024, from https://www.wsj.com/tech/ai/ai-energy-consumption-fc79d94f

[156]: World Economic Forum. (2019). A New Circular Vision for Electronics Time for a Global Reboot. Retrieved Mar 10, 2024, from https://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf

[157]: Leffer, L. (2023). The AI Boom Could Use a Shocking Amount of Electricity. Retrieved Mar 10, 2024, from https://www.scientificamerican.com/article/the-ai-boom-could-use-a-shocking-amount-of-electricity/

[158]: Calma, J. (2023). Microsoft is going nuclear to power its AI ambitions. Retrieved Mar 10, 2024, from https://www.theverge.com/2023/9/26/23889956/microsoft-next-generation-nuclear-energy-smr-job-hiring

[159]: Kanungo, A. (2024). The Green Dilemma: Can AI Fulfil Its Potential Without Harming the Environment? Retrieved Mar 10, 2024, from https://earth.org/the-green-dilemma-can-ai-fulfil-its-potential-without-harming-the-environment/

[160]: Kiel Institut für Weltwirtschaft. (2023). Potential efficiency gains from the introduction of an emissions trading system for the buildings and road transport sectors in the European Union. Retrieved Mar 18, 2024, from https://www.ifw-kiel.de/fileadmin/Dateiverwaltung/IfW-Publications/fis-import/200f22d3-1461-4366-ab70-c1a83fd7dd7f-KWP_2249.pdf

[161]: United Nations. (2023). World Investment Report 2023 Investing in sustainable energy for all. Retrieved Mar 08, 2024, from https://unctad.org/system/files/official-document/wir2023_en.pdf

[162]: InvestEU. (2024). Contribution to the Green Deal and the Just Transition Scheme. Retrieved Mar 09, 2024, from https://investeu.europa.eu/contribution-green-deal-and-just-transition-scheme_en

[163]: Bundesministerium für Wirtschaft und Klimaschutz. (2023). Smart Meter-Gesetz final beschlossen: Flächendeckender Einsatz intelligenter Stromzähler kommt. Retrieved Mar 09, 2024, from https://www.bmwk.de/Redaktion/DE/Pressemitteilung en/2023/05/20230512-smart-meter-gesetz-final-beschlossen.html

[164]: World Economic Forum. (2021). Harnessing Artificial Intelligence to Accelerate the Energy Transition. Retrieved Mar 08, 2024, from https://www3.weforum.org/docs/WEF_Harnessing_AI_to_accelerate_the_Energy_Transition_2021.pdf

[165]: European Comission. (2022). Our ambition for 2030. Retrieved Mar 18, 2024, from https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/our-ambition-2030_en

[166]: Bayer, P., Aklin, M. (2020). The European Union Emissions Trading System reduced CO2 emissions despite low prices. Proceedings of the National Academy of Sciences, 117(16), 8804-8812. https://doi.org/10.1073/pnas.1918128117

[167]: European Comission. (2022). EU Emissions Trading System (EU ETS). Retrieved Mar 18, 2024, from https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en

[168]: Osterreichs Energie. (2021). CO2-Bepreisung: Die weltweiten Modelle im Vergleich. Retrieved Mar 18, 2024, from https://oesterreichsenergie.at/aktuelles/neuigkeiten/detailseite/co2-bepreisung-die-weltweiten-modelle-im-vergleich

[169]: International Energy Agency. (2022). ETS in power sector. Retrieved Mar 18, 2024, from https://www.iea.org/reports/implementing-effective-emissions-trading-systems/ets-in-power-sector

[170]: Osterreichs Energie. (2021). CO2-Bepreisung: Die weltweiten Modelle im Vergleich. Retrieved Mar 18, 2024, from https://oesterreichsenergie.at/aktuelles/neuigkeiten/detailseite/co2-bepreisung-die-weltweiten-modelle-im-vergleich

[171]: Taubitz, P., Buhl, C. (2023). CO2-Preisentwicklung im EU ETS – was Unternehmen jetzt beachten müssen. Retrieved Mar 18, 2024, from https://www.ey.com/de_de/decarbonization/eu-ets-wie-stark-steigen-die-co-preise-bis-2030

[172]: Centre for European Reform, Cornago E. (2022). High Energy Prices Threaten the Eu Emissions Trading System. Retrieved Mar 18, 2024, from https://www.cer.eu/insights/high-energy-prices-threaten-eu-ets

[173]: European Comission. (2023). ETS 2: buildings, road transport and additional sectors. Retrieved Mar 18, 2024, from https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/ets-2-buildings-road-transport-and-additional-sectors_en

[174]: Dr. Sebastian Küppers (Mar 04, 2024). STADLER Anlagenbau

[175]: research to business energy consulting. (2021). Finanzierung der Energiewende – Aktualisierung zum VKU-Reformvorschlag der Entgelte- und Umlagesystematik. Retrieved Mar 18, 2024, from https://www.vku.de/fileadmin/user_upload/Verbandsseite/Sparten/Energiewirtschaft/Dokumente_EEE/VKU_Aktualisierung_Umlagen_Entgeltsystematik_r2b_final.pdf

[176]: Global Traceability Solutions. (2022). Lieferkettengesetz – das sollten Sie wissen. Retrieved Mar 08, 2024, from https://www.global-traceability.com/de/lieferkettengesetz/

[177]: Aldy, J. E., Bolton, P., Halem Z. M., et al. (2023). An Analysis of Corporate Climate Messaging and its Financial Impacts. Retrieved Mar 08, 2024, from https://www.lazard.com/media/nxie2y5o/show-tell-analysis-of-climate-messaging.pdf

[178]: Kerschner, S., Mulry, L., Connellan, C., et al. (2023). Eight things to know about the Taskforce on Nature-related Financial Disclosures. Retrieved Mar 09, 2024, from https://www.whitecase.com/insight-alert/eight-things-know-about-taskforce-nature-related-financial-disclosures#article-content

[179]: Arthur D. Little. (2023). ESG: Last call to take effective action

How innovation unlocks economic opportunities in a volatile world. Retrieved Mar 07, 2024, from https://www.adlittle.com/sites/default/files/reports/ADL_ESG_effective_action_2023.pdf

[180]: Acaroglu, L. (2020). Employees want climate-positive action from companies. Here's how. Retrieved Mar 07, 2024, from https://www.reutersevents.com/sustainability/employees-want-climate-positive-action-companies-heres-how-they-can-deliver#:~:text=Almost%20two%2Dthirds%20(65%25),the%20majority%20of%20the%20w-orkforce

[181]: European Comission. (2023). Corporate sustainability reporting. Retrieved Mar 08, 2024, from https://finance.ec.europa.eu/capital-markets-union-and-financial-markets/company-reporting-and-auditing/company-reporting/corporate-sustainability-reporting_en#:~:text=EU%20law%20requires%20all%20large,on%20people%20and%20the%20environment.

[182]: Buggie, M., Farbstein, E. (2024). Carbon accounting is more than a tool for fighting climate change – it's a source of competitive advantage for businesses. Retrieved Mar 07, 2024, from https://normative.io/insight/carbon-accounting-business-benefits/

[183]: Bundesverband der Energie- und Wasserwirtschaft e. V. (2023). Stellungnahme zu den Vorschlägen für EU-Standards zur Nachhaltigkeitsberichterstattung. Retrieved Mar 08, 2024, from https://www.bdew.de/media/documents/1000_BDEW-Stellungnahme_ESRS-Verbändekonsultation_2023-01-06.pdf

[184]: United Nations. (2023). World Investment Report 2023 Investing in sustainable energy for all. Retrieved Mar 07, 2024, from https://unctad.org/system/files/official-document/wir2023_en.pdf

[185]: Organisation for Economic Co-operation and Development (OECD). (2022). Green Economy Transition in Eastern Europe, the Caucasus and Central Asia: Progress and ways forward. Retrieved Mar 08, 2024, from https://unece.org/sites/default/files/2022-09/ece.nicosia.conf_.2022.inf_.8.pdf

[186]: Bank of America. (2024). What to watch: Four trends for 2024. Retrieved Mar 08, 2024, from https://institute.bankofamerica.com/content/dam/bank-of-america-institute/sustainability/four-trends-in-2024.pdf

[187]: McKinsey. (2022). The Inflation Reduction Act: Here's what's in it. Retrieved Mar 08, 2024, from https://www.mckinsey.com/industries/public-sector/our-insights/the-inflation-reduction-act-heres-whats-in-it

[188]: European Commision. (2023). The Green Deal Industrial Plan. Retrieved Mar 08, 2024, from https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/green-deal-industrial-plan_en#paragraph_33968

[189]: Onbargi, A. F., Lacobuta, G., Hermwille, L. (2022). What role should the EU green deal play in times of conflict? Retrieved Mar 07, 2024, from https://www.idos-research.de/en/the-current-column/article/what-role-should-the-eu-green-deal-play-in-times-of-conflict/

[190]: Eurazeo. (2023). Introduction to Climate Tech. Retrieved Mar 08, 2024, from https://medium.com/eurazeo/climate-tech-series-1-introduction-to-climate-tech-3d5c40bfffe4

[191]: Deloitte. (2022). IRA and the net-zero race – How EU industrial policy should respond. Retrieved Mar 08, 2024, from https://www2.deloitte.com/content/dam/Deloitte/de/Documents/about-deloitte/Deloitte-EU-Green-Industrial-Policy-Study.pdf

[192]: Jacobo, A. R., Nelivigi, N. (2022). Inflation Reduction Act Increases Funding for Energy Transition Projects in the US. Retrieved Mar 07, 2024, from https://www.whitecase.com/insight-alert/inflation-reduction-act-increases-funding-energy-transition-projects-us

[193]: Markus Drews (Mar 04, 2024). SWM | Sustainability Manager

[194]: E3G. (2023). How to make the best of the green deal industrial plan: Pragmatic recommendations for policy makers. Retrieved Mar 09, 2024, from https://www.e3g.org/wp-content/uploads/E3G-Briefing-How-to-make-the-best-of-the-Green-Deal-Industrial-Plan.pdf

[195]: IBM. (2024). What are smart meters? Retrieved Apr 02, 2024, from https://www.ibm.com/topics/smart-meter

[196]: Onwusinkwue, S., Osasona, F., Ahmad, I. A. I. (2024). Artificial intelligence (AI) in renewable energy: A review of predictive maintenance and energy optimization. World Journal of Advanced Research and Reviews, 21(1), 2487–2499. https://doi.org/10.30574/wjarr.2024.21.1.0347

[197]: European Commission. (2023). Communication From the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Retrieved Mar 08, 2024, from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2023:757:FIN

[198]: Bundesministerium für Wirtschaft und Klimaschutz. (2021). Gesetz zur Änderung des Erneuerbare-Energien-Gesetzes und weiterer energierechtlicher Vorschriften. Retrieved Mar 10, 2024, from https://www.bmwk.de/Redaktion/DE/Artikel/Service/gesetz-zur-aenderung-des-eeg-und-weiterer-energierechtlicher-vorschriften.html

[199]: European Commission. (2010). The Unbundling Regime. Retrieved Mar 11, 2024, from https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0073

[200]: Ohanu, C. P., Rufai, S. A., Oluchi, U. C. (2024). A comprehensive review of recent developments in smart grid through renewable energy resources integration. Heliyon, 10(3), e25705. https://doi.org/10.1016/j.heliyon.2024.e25705

[201]: Kua, J., Hossain, M. B., Natgunanathan, I., et al. (2023). Privacy Preservation in Smart Meters: Current Status, Challenges and Future Directions. Sensors, 23(7), 3697. https://doi.org/10.3390/s23073697

[202]: 4i-TRACTION. (2023). Germany's delayed electricity smart meter rollout and its implications on innovation, infrastructure, integration, and social acceptance. Retrieved Mar 15, 2024, from https://www.ecologic.eu/sites/default/files/publication/2023/33007-Case-Study_4-German-delayed-smartmeter-rollout.pdf

[203]: Casanovas, M., Nghiem, A. (2023). Cybersecurity – is the power system lagging behind? Retrieved Mar 09, 2024, from https://www.iea.org/commentaries/cybersecurity-is-the-power-system-lagging-behind

[204]: Cybersecurity and Infrastructure Security Agency. (2022). Cyber Incident Reporting for Critical Infrastructure Act of 2022 (CIRCIA). Retrieved Mar 09, 2024, from https://www.cisa.gov/topics/cyber-threats-and-advisories/information-sharing/cyber-incident-reporting-critical-infrastructure-act-2022-circia

[205]: European Commission. (2021). Study to support an impact assessment of regulatory requirements for Artificial Intelligence in Europe. Retrieved Mar 08, 2024, from https://doi.org/10.2759/523404

[206]: Heymann, F., Parginos, K., Bessa, R. J., et al. (2023). Operating AI systems in the electricity sector under European's AI Act – Insights on compliance costs, profitability frontiers and extraterritorial effects. Energy Reports, 10, 4538-4555. https://doi.org/10.1016/j.egyr.2023.11.020

[207]: European Commission. (2020). Cybersecurity of Artificial Intelligence in the AI Act. Retrieved Mar 08, 2024, from https://publications.jrc.ec.europa.eu/repository/handle/JRC134461

[208]: de Almeida, P. G. R., dos Santos, C. D., Farias, J. S. (2021). Artificial Intelligence Regulation: a framework for governance. Ethics and Information Technology, 23(1), 505–525. https://doi.org/10.1007/s10676-021-09593-z

[209]: Microsoft. (2022). The Convergence of IT and Operational Technology: Cyber Risks to Critical Infrastructure on the Rise. Retrieved Mar 09, 2024, from https://query.prod.cms.rt.microsoft.com/cms/api/am/binary/RE5daTD

[210]: World Economic Forum. (2023). Global Cybersecurity Outlook 2023. Retrieved Mar 09, 2024, from https://www3.weforum.org/docs/WEF_Global_Security_Outlook_Report_2023.pdf

[211]: Johan Börje (Mar 08, 2024). Stockholm Exergy

[212]: Dr. Bastian Küppers (Mar 04, 2024). STADLER Anlagenbau GmbH

[213]: Grubb, M., Jordan, N. D., Hertwich, E., et al. (2022). Carbon leakage, consumption, and trade. Retrieved Mar 11, 2024, from sato_EUI_dec2022_final.pdf

[214]: European Parliament. (2021). Carbon Leakage: Unternehmen daran hindern, Emissionsvorschriften zu umgehen. Retrieved Mar 11, 2024, from https://www.europarl.europa.eu/topics/de/article/20210303STO99110/carbon-leakage-unternehmen-daran-hindern-emissionsvorschriften-zu-umgehen

[215]: Hall, M. (2024). How Do Interest Rates Affect the Stock Market? Retrieved Mar 20, 2024, from https://www.investopedia.com/investing/how-interest-rates-affect-stock-market/

[216]: European Environment Agency. (2021). Electric vehicles and the energy sector - impacts on Europe's future emissions. Retrieved Mar 11, 2024, from https://www.eea.europa.eu/publications/electric-vehicles-and-the-energy

[217]: Hrdrogen Council. (2022). Hydrogen Insights 2022 An updated perspective on hydrogen market development and actions required to unlock hydrogen at scale. Retrieved Mar 11, 2024, from https://hydrogencouncil.com/wp-content/uploads/2022/09/Hydrogen-Insights-2022-2.pdf

[218]: European Commission. (2024). labour shortage. Retrieved Mar 12, 2024, from https://home-affairs.ec.europa.eu/networks/european-migration-network-emn/emn-asylum-and-migration-glossary/glossary/labour-shortage_en

[219]: McKinsey Digital. (2023). The economic potential of generative AI. Retrieved Mar 12, 2024, from https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/the-economic-potential-of-generative-ai-the-next-productivity-frontier

[220]: Silverblaze. (2023). What is AI, and How is it Transforming the Utility Industry? Retrieved Mar 12, 2024, from https://www.silverblaze.com/blog/what-is-ai-and-how-is-it-transforming-the-utility-industry/.

[221]: Energycentral. (2023). Revolutionizing the Utilities Industry with Generative AI: Exploring the Potential and Opportunities. Retrieved Mar 12, 2024, from https://energycentral.com/c/pip/revolutionizing-utilities-industry-generative-ai-exploring-potential-and.

[222]: Price, K. (2022). Tackling skill shortages: How AI can accompany utilities to address climate challenges. Retrieved Mar 12, 2024, from https://essmag.co.uk/tackling-skill-shortages-how-ai-can-accompany-utilities-to-address-climate-challenges/

[223]: eurostat. (2022). Three quarters of utility workers are men - Products Eurostat News. Retrieved Mar 12, 2024, from https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20200527-1#:~:text=The%20utilities%20sector%20is%20male,sector%20were%20aged%2015%2D34

[224]: Deloitte. (2022). The connected employee | The utility's most important asset. Retrieved Mar 12, 2024, from https://www2.deloitte.com/content/dam/Deloitte/es/Documents/energia/Deloitte-ES-Energia-el-empleado-concectado.pdf

[225]: McKinsey Electric Power & Natural Gas Practice. (2022). Renewable-energy development in a net-zero world: Overcoming talent gaps. Retrieved Mar 12, 2024, from https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/renewable-energy-development-in-a-net-zero-world-overcoming-talent-gaps#/

[226]: IBM. (2024). New IBM Study Data Reveals 74% of Energy & Utility Companies Surveyed Embracing AI. Retrieved Mar 12, 2024, from https://newsroom.ibm.com/2024-02-26-New-IBM-Study-Data-Reveals-74-of-Energy-Utility-Companies-Surveyed-Embracing-AI

[227]: Utilitydive. (2023). AI in the Utility Industry. Retrieved Mar 12, 2024, from https://www.utilitydive.com/news/ai-in-the-utility-industry/543876/.

[228]: European Commission. (2023). Commission report finds labour and skills shortages persist and looks at possible ways to tackle them. Retrieved Mar 12, 2024, from https://ec.europa.eu/social/main.jsp?langId=en&catId=89&furtherNews=yes&newsId=10619

[229]: Awesense. (2023). The Use of AI in Utilities. Retrieved Mar 12, 2024, from https://www.awesense.com/use-of-ai-in-utilities/.

[230]: McKinsey Global Institute. (2023). Generative AI and the future of work in America. Retrieved Mar 12, 2024, from https://www.mckinsey.com/mgi/our-research/generative-ai-and-the-future-of-work-in-america

[231]: Mörsdorf, G. (2022). A simple fix for carbon leakage? Assessing the environmental effectiveness of the EU carbon border adjustment. Energy Policy, 161, 112596. https://doi.org/10.1016/j.enpol.2021.112596

[232]: Verde, S. F. (2020). The impact of the EU emissions trading system on competitiveness and carbon leakage: the econometric evidence. Journal of Economic Surveys, 34(2), 320-343. https://doi.org/10.1111/joes.12356

[233]: Umweltbundesamt. (2021). Carbon Leakage: Klimapolitik und Investitionsverhalten. Retrieved Mar 11, 2024, from https://www.umweltbundesamt.de/themen/carbon-leakage-klimapolitik-investitionsverhalten

[234]: U.S. Bank. (2024). How do changing interest rates affect the stock market? Retrieved Mar 11, 2024, from https://www.usbank.com/investing/financial-perspectives/market-news/how-do-rising-interest-rates-affect-the-stock-market.html

[235]: Holman, J. (2023). U.S. Consumers Are Showing Signs of Stress, Retailers Say. Retrieved Mar 20, 2024, from https://www.nytimes.com/2023/08/25/business/consumer-retail-shopping.html

[236]: FX Empire. (2024). Euro Area Interest Rate 1998-2024. Retrieved Mar 07, 2024, from https://www.fxempire.com/macro/euro-area/interest-rate

[237]: Dastin, J., Nellis, S. (2023). Focus: For tech giants, AI like Bing and Bard poses billion-dollar search problem. Retrieved Mar 08, 2024, from https://www.reuters.com/technology/tech-giants-ai-like-bing-bard-poses-billion-dollar-search-problem-2023-02-22/

[238]: Vaasa ETT. (2022). Household Energy Price Index for Europe. Retrieved Mar 11, 2024, from https://www.energypriceindex.com/

[239]: Adrian, T. (2023). Higher-for-Longer Interest Rate Environment is Squeezing More Borrowers. Retrieved Mar 20, 2024, from https://www.imf.org/en/Blogs/Articles/2023/10/10/higher-for-longer-interest-rate-environment-is-squeezing-more-borrowers

[240]: Wood, J. (2021). Renewable energy is cheaper than previously thought, says a new report - and could be a gamechanger in the climate change battle. Retrieved Mar 11, 2024, from https://www.weforum.org/agenda/2021/10/how-cheap-can-renewable-energy-get/

[241]: Antweiler, W., Muesgens, F. (2021). On the long-term merit order effect of renewable energies. Energy Economics, 99, 105275. https://doi.org/10.1016/j.eneco.2021.105275

[242]: Deloitte. (2023). Financing the green energy transition. Retrieved Mar 11, 2024, from https://www2.deloitte.com/de/de/pages/sustainability1/articles/financing-the-green-energy-transition.html

[243]: Forschungsstelle für Energiewirtschaft München. (2023). The Smart Meter Rollout in Germany and Europe. Retrieved Mar 11, 2024, from https://www.ffe.de/en/publications/the-smart-meter-rollout-in-germany-and-europe/

[244]: IEA. (2019). The Future of Hydrogen. Retrieved Mar 11, 2024, from https://www.iea.org/reports/the-future-of-hydrogen

[245]: The World Bank. (2023). World Bank Proposes 10 GW Clean Hydrogen Initiative to Boost Adoption of Low-Carbon Energy. Retrieved Mar 11, 2024, from https://www.worldbank.org/en/news/press-release/2023/11/17/world-bank-proposes-10-gw-clean-hydrogen-initiative-to-boost-adoption-of-low-carbon-energy

[246]: KPMG International. (2023). Turning the tide in scaling renewables. Retrieved Mar 19, 2024, from https://assets.kpmg.com/content/dam/kpmg/xx/pdf/2023/11/ttsr-full-report.pdf

[247]: Statista. (2024). Entwicklung des Fachkräfteindex in Deutschland bis zum 3. Quartal 2023. Retrieved Mar 18, 2024, from https://de.statista.com/statistik/daten/studie/378248/umfrage/entwicklung-des-fachkraefteindex-in-deutschland/

[248]: IRENA. (2023). Renewable energy markets: GCC 2023. Retrieved Mar 18, 2024, from https://www.irena.org/Publications/2023/Dec/Renewable-energy-market-analysis-GCC

[249]: Stute J., Kühnbach M. (2023). Dynamic pricing and the flexible consumer – Investigating grid and financial implications: A case study for Germany. Energy Strategy Reviews, 45, 100987. https://doi.org/10.1016/j.esr.2022.100987

[250]: Bundesministerium für Wirtschaft & Klimaschutz. (2023). Smart Meter-Gesetz final beschlossen: Flächendeckender Einsatz intelligenter Stromzähler kommt. Retrieved Mar 09, 2024, from https://www.bmwk.de/Redaktion/DE/Pressemitteilungen/2023/05/20230512-smart-meter-gesetz-final-beschlossen.html

[251]: Deutsche Energie-Agentur. (2023). Das dezentralisierte Energiesystem im Jahr 2030. Retrieved Mar 19, 2024, from https://www.dena.de/fileadmin/dena/Publikationen/PDFs/2023/231130_dena_Das_dezentralisierte_Energiesystem_im_Jahr_2030_WEB.pdf

[252]: Dealroom. (2023). The European Deep Tech Report 2023. Retrieved Mar 18, 2024, from https://dealroom.co/reports/the-european-deep-tech-report-2023

[253]: European Environment Agency. (2022). Energy prosumers in Europe — Citizen participation in the energy transition. Retrieved Mar 19, 2024, from https://www.eea.europa.eu/publications/the-role-of-prosumers-of

[254]: European Commission. (2020). Clean Energy Transition – Technologies and Innovations. Retrieved Mar 18, 2024, from https://eur-lex.europa.eu/resource.html?uri=cellar:871975a1-0e05-11eb-bc07-01aa75ed71a1.0001.02/DOC_5&format=PDF

[255]: European Commission. (2020). Asset Study on Digital Technologies and Use Cases in the Energy Sector. Retrieved Mar 19, 2024, from https://www.apren.pt/contents/publicationsothers/eu-digital-technologies-and-use-cases-in-the-energy-sector.pdf

[256]: McKinsey. (2021). Preparing for energy transition in infrastructure. Retrieved Mar 19, 2024, from https://www.mckinsey.com/capabilities/operations/our-insights/global-infrastructure-initiative/voices/voices-on-infrastructure-preparing-for-energy-transition-in-infrastructure#/

[257]: E3 Analytics. (2021). Commercial Prosumers as Catalysts for Solar PV Adoption in Soutch East Europe. Retrieved Mar 19, 2024, from https://static.agora-energiewende.de/fileadmin/Partnerpublikationen/2021/SEE_Commercial_Prosumers_as_Catalysts/20211208_Integrated_Copy_AGORA_Commercial_Prosumers_INTEGRATED_FINAL.pdf

[258]: McKinsey. (2022). Gloabl Energy Perspective 2022. Retrieved Mar 19, 2024, from https://www.mckinsey.com/~/media/McKinsey/Industries/Oil%20and%20Gas/Our%20Insights/Global%20Energy%20Perspective%202022/Global-Energy-Perspective-2022-Executive-Summary.pdf

[259]: Next-Kraftwerke. (2023). What is a Virtual Power Plant? Retrieved Mar 18, 2024, from https://www.next-kraftwerke.com/knowledge/what-is-a-virtual-power-plant

[260]: McKinsey Operations Practice. (2023). The next frontier of customer engagement: AI-enabled customer service. Retrieved Mar 18, 2024, from https://www.mckinsey.com/capabilities/operations/our-insights/the-next-frontier-of-customer-engagement-ai-enabled-customer-service

[261]: McKinsey & Company. (2020). Simple, predictive, proactive, responsive: The future of customer operations. Retrieved Mar 18, 2024, from https://www.mckinsey.com/capabilities/operations/our-insights/simple-predictive-proactive-responsive-the-future-of-customer-operations?cid=eml-web

[262]: Bamberger, S., Clark, N., Ramachandran, S., et al. (2023). How Generative AI Is Already Transforming Customer Service. Retrieved Mar 18, 2024, from https://www.bcg.com/publications/2023/how-generative-ai-transforms-customer-service

[263]: Kumar, N. (2020). Preparing For A Zero-Touch Business Paradigm. Retrieved Mar 18, 2024, from https://www.forbes.com/sites/forbestechcouncil/2020/05/11/preparing-for-a-zero-touch-business-paradigm/

[264]: Gartner. (2023). Emerging Tech: Revenue Opportunity Projection of Conversational AI. Retrieved Mar 18, 2024, from https://www.gartner.com/en/documents/4985731

[265]: Lane, R. (2022). The 2022 Contact Center Trifecta of Pain: The Struggle to Hire (Part 1). Retrieved Mar 18, 2024, from https://www.medallia.com/blog/contact-center-trifecta-of-pain-struggle-to-hire/

[266]: Sabharwal, A. (2023). The Next Revolution In Tech: What To Know Before Implementing Conversational AI. Retrieved Mar 18, 2024, from https://www.forbes.com/sites/forbestechcouncil/2023/02/27/the-next-revolution-in-tech-what-to-know-before-implementing-conversational-ai/

[267]: McKinsey & Company. (2023). The AI-enabled utility: Rewiring to win in the energy transition. Retrieved Mar 18, 2024, from https://www.mckinsey.com/~/media/mckinsey/industries/electric%20power%20and%20natural%20gas/our%20insights/the%20ai%20enabled%20utility%20rewiring%20to%20win%20in%20the%20energy%20transition/mck_utility_compendium.pdf

[268]: McKinsey & Company. (2018). The secret to making it in the digital sales world: The human touch. Retrieved Mar 18, 2024, from https://www.mckinsey.com/capabilities/growth-marketing-and-sales/our-insights/the-secret-to-making-it-in-the-digital-sales-world

[269]: Roland Berger. (2018). Artificial Intelligence for Utilities. Retrieved Mar 18, 2024, from https://www.rolandberger.com/en/Insights/Publications/Artificial-Intelligence-for-Utilities.html

[270]: SolarPower Europe. (2023). Solar Powers Heat and EVs 2023 - Case Studies. Retrieved Mar 18, 2024, from https://www.solarpowereurope.org/insights/thematic-reports/solar-powers-heat-and-e-vs-2023-case-studies

[271]: IEA. (2022). The Future of Heat Pumps – Analysis - IEA. Retrieved Mar 18, 2024, from https://www.iea.org/reports/the-future-of-heat-pumps

[272]: IEA. (2024). Renewables 2023 - Analysis. Retrieved Mar 18, 2024, from https://www.iea.org/reports/renewables-2023

[273]: IEA. (2023). Solar PV. Retrieved Mar 18, 2024, from https://www.iea.org/energy-system/renewables/solar-pv#

[274]: IEA. (2022). Installation of about 600 million heat pumps covering 20% of buildings heating needs required by 2030. Retrieved Mar 18, 2024, from https://www.iea.org/reports/installation-of-about-600-million-heat-pumps-covering-20-of-buildings-heating-needs-required-by-2030

[275]: Conway, A. (2023). How can green technology adapt and thrive in the energy transition. Retrieved Mar 18, 2024, from https://delta.lcp.com/whitepaper/can-tech-manufacturers-adapt-and-thrive-in-the-energy-transition/

[276]: Timperley, N. (2023). The dawn of a customer centric transition. Retrieved Mar 18, 2024, from https://delta.lcp.com/whitepaper/the-dawn-of-a-customer-centric-transition/

[277]: IRENA. (2021). World Energy Transitions Outlook: 1.5°C Pathway. Retrieved Mar 18, 2024, from https://www.irena.org/publications/2021/Jun/World-Energy-Transitions-Outlook

[278]: European Commission. (2020). Digital Technologies and Use Cases in the Energy Sector. Retrieved Mar 18, 2024, from https://doi.org/10.2833/006724

[279]: McKinsey. (2022). Navigating the energy transition: Electric power and natural gas 2022. Retrieved Mar 18, 2024, from https://www.mckinsey.com/~/media/mckinsey/industries/electric%20power%20and%20natural%20gas/our%20insights/energy%20and%20renewable%20insights/energy-and-renewable-insights.pdf

[280]: Agora Energiewende. (2021). Commercial Prosumers as Catalysts for Solar PV Adoption in South East Europe. Retrieved Mar 18, 2024, from https://static.agora-energiewende.de/fileadmin/Partnerpublikationen/2021/SEE_Commercial_Prosumers_as_Catalysts/20211208_Integrated_Copy_AGORA_Commercial_Prosumers_INTEGRATED_FINAL.pdf

[281]: UNDP. (2022). Linking Global Finance to Small-Scale Clean Energy | United Nations Development Programme. Retrieved Mar 18, 2024, from https://www.undp.org/publications/linking-global-finance-small-scale-clean-energy

[282]: KPMG. (2023). Turning The Tide In Scaling Renewables. Retrieved Mar 18, 2024, from https://kpmg.com/xx/en/home/insights/2023/09/energy-transition/turning-the-tide-in-scaling-renewables.html#:~:text=The%20renewable%20energy%20industry%20has,grew%20by%20double%20digits%20worldwide.&text=However%2C%20only%2014%20percent%20of,currently%20comes%20from%20renewable%20sources.

Trend

Exploration

Ideation

[283]: Roland Berger GmbH. (2018). Artificial Intelligence: A smart move for utilities. Retrieved Mar 11, 2024, from https://www.rolandberger.com/publications/publication_pdf/roland_berger_artificial_intelligence_utilities_en.pdf

[284]: Zhao, X., Gao, W., Qian, F., et al. (2021). Electricity cost comparison of dynamic pricing model based on load forecasting in home energy management system. Energy , 229, 120538. https://doi.org/10.1016/j.energy.2021.120538

[285]: Imöhl, S. (2024). Geld sparen und die Energiewende fördern? Wann sich ein dynamischer Stromvertrag lohnt. Retrieved Mar 11, 2024, from https://www.wiwo.de/finanzen/immobilien/dynamischer-stromtarif-geld-sparen-und-die-energiewende-foerdern-wann-sich-ein-dynamischer-stromvertrag-lohnt/29642854.html

[286]: Neubauer, L. (2023). Dynamische Stromtarife lohnen sich für die meisten Haushalte noch nicht. Retrieved Mar 10, 2024, from https://www.verivox.de/strom/nachrichten/dynamische-stromtarife-lohnen-sich-fuer-die-meisten-haushalte-noch-nicht-1120424/

[287]: gridX. (2023). Dynamische Strompreisgestaltung. Retrieved Mar 11, 2024, from https://de.gridx.ai/wissen/dynamische-strompreise

[288]: Nechet, K. (2023). Dynamic Energy Contracts to Harness Price Volatility and Get Loyal Customers. Retrieved Mar 10, 2024, from https://maxbill.com/blog/dynamic-contracts-in-energy-and-utility-for-sustainability/

[289]: Arthur D. Little. (2018). The Future of Urban Mobility. Retrieved Mar 11, 2024, from https://www.adlittle.com/sites/default/files/viewpoints/adl_the_future_of_urban_mobility_report.pdf

[290]: Willing, C., Brandt, T., Neumann, D. (2017). Intermodal Mobility. Business & Information Systems Engineering, 59(3), 173-179. https://doi.org/10.1007/s12599-017-0471-7

[291]: McKinsey Center for Future Mobility. (2023). Shared mobility: Sustainable cities, shared destinies. Retrieved Mar 12, 2024, from https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/shared-mobility-sustainable-cities-shared-destinies

[292]: Alessandretti, L., Natera Orozco, L. G., Saberi, M., et al. (2022). Multimodal urban mobility and multilayer transport networks. Environment and Planning B: Urban Analytics and City Science, 50(8), 2038-2070. https://doi.org/10.1177/23998083221108190

[293]: EIT Urban Mobility. (2021). Urban Mobility Next #5: Costs and benefits of the sustainable urban mobility transition. Retrieved Mar 12, 2024, from https://www.eiturbanmobility.eu/wp-content/uploads/2021/11/UrbanMobilityNext5_Final-1.pdf

[294]: Statista. (2024). Prognose der Nachfrage nach urbanen Mobilitätsleistungen weltweit bis 2050. Retrieved Mar 12, 2024, from https://de.statista.com/statistik/daten/studie/1084696/umfrage/prognose-der-nachfrage-nach-urbanen-mobilitaetsleistungen-weltweit/

[295]: Bolt. (2022). Bolt Shift Mode Analysis Research. Retrieved Mar 12, 2024, from https://drive.google.com/file/d/1SZE5SuJu89MAXm0MJG2bGWaxN-nR3x2p/view

[296]: European Commission. (2021). Transport and the Green Deal. Retrieved Mar 11, 2024, from https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/transport-and-green-deal_en

[297]: McKinsey. (2023). The big picture: Worldwide mobility in 2035. Retrieved Mar 11, 2024, from https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/The-future-of-mobility-global-implications

[298]: Sophia Bildstein, Andreas Steinbeisser (Mar 06, 2024). SWM | Strategy Manager Mobility & Leiter Innovationsentwicklung

[299]: McKinsey. (2019). The future of mobility is at our doorstep. Retrieved Mar 11, 2024, from https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-future-of-mobility-is-at-our-doorstep

[300]: Statista. (2024). Einfluss autonomer Taxis auf den Autokauf in Ländern weltweit 2019. Retrieved Mar 12, 2024, from https://de.statista.com/statistik/daten/studie/785931/umfrage/einfluss-autonomer-taxis-auf-den-autokauf-in-laendern-weltweit/

[301]: McKinsey & Company. (2023). The future of mobility. Retrieved Mar 11, 2024, from https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-future-of-mobility-mobility-evolves

[302]: Harvard Business Review Analytic Services. (2021). Improving the Customer Experience in the Utilities Industry. Retrieved Mar 21, 2024, from https://hbr.org/resources/pdfs/comm/salesforce/ImprovingtheCustomerExperienceintheUtilitiesIndustry.pdf

[303]: Monitor Deloitte. (2017). Kundenerlebnis@EVU - Kundenerwartungen als Werthebel für Energieversorger. Retrieved Mar 21, 2024, from https://www2.deloitte.com/content/dam/Deloitte/de/Documents/energy-resources/Deloitte_Customer-Experience_EVU_12-2017.pdf

[304]: Hughes, J. (2022). What does the current energy crisis mean for the energy transition? Retrieved Mar 21, 2024, from https://delta.lcp.com/whitepaper/whitepaper-what-does-the-current-energy-crisis-mean-for-the-energy-transition/

[305]: Dullweber, A. (2020). Why customer loyalty matters to utilities. Retrieved Mar 21, 2024, from https://www.bain.com/insights/why-customer-loyalty-matters-to-utilities/

[306]: Bhattacharya, A., Morgan, N. A., Rego, L. L. (2020). Customer Satisfaction and Firm Profits in Monopolies: A Study of Utilities. Journal of Marketing Research, 58(1), 202 - 222. https://doi.org/10.1177/0022243720962405

[307]: Massachusetts Institute of Technology Energy Initiative. (2016). UTILITY OF THE FUTURE An MIT Energy Initiative response to an industry in transition. Retrieved Mar 21, 2024, from https://energy.mit.edu/wp-content/uploads/2016/12/Utility-of-the-Future-Full-Report.pdf

[308]: Timperley, N. (2023). The Dawn of a Customer-Centric Transition. Retrieved Mar 21, 2024, from https://delta.lcp.com/whitepaper/the-dawn-of-a-customer-centric-transition/

[309]: Guthridge, G. (2022). When energy hits home, will providers be left out in the cold? Retrieved Mar 21, 2024, from https://www.ey.com/en_gl/insights/energy-resources/when-energy-hits-home-will-providers-be-left-out-in-the-cold

[310]: Li, W., Pomegbe, W. W. K., Dogbe, C. S. K., et al. (2019). Employees' customer orientation and customer satisfaction in the public utility sector: The mediating role of service quality. African Journal of Economic and Management Studies, 10(4), 408-423. https://doi.org/10.1108/AJEMS-10-2018-0314

[311]: Moritz von Klot (Mar 20, 2024). earlybird | Investment Team

[312]: Dr. Oliver Schoppe (Mar 20, 2024). UVC Partners | Principal

[313]: Hutchins, J. (2024). Transforming Customer Satisfaction in the Utilities Industry. Retrieved Mar 22, 2024, from https://energydigital.com/articles/transforming-customer-satisfaction-in-the-utilities-industry

[314]: Kearney Energy Transition Institute. (2024). Solar photovoltaic (PV): toward commoditization. Retrieved Mar 20, 2024, from https://www.energy-transition-institute.com/documents/17779499/300572190/Energy+Transition+Institute_SolarPV+Executive+Summary_2024.pdf/4ab8da01-54a0-0ed9-24d4-6c2b3bf83a06?t=

[315]: LCP Delta. (2023). How can green technology manufacturers adapt and thrive in the energy transition? Retrieved Mar 21, 2024, from https://delta.lcp.com/wp-content/uploads/2023/12/lcp-delta-oems-in-the-energy-transition-whitepaper-2023-1.pdf

[316]: Arthur D. Little. (2022). Disruption is now. Retrieved Mar 21, 2024, from https://www.adlittle.com/en/insights/report/disruption-now

[317]: EY. (2022). When energy hits home, will providers be left out in the cold? Retrieved Mar 21, 2024, from https://www.ey.com/content/dam/ey-unified-site/ey-com/en-gl/insights/energy-resources/documents/ey-energy-transition-consumer-insights-final.pdf

[318]: Ofgem Ipsos. (2021). Ofgem Consumer Survey 2021. Retrieved Mar 21, 2024, from https://www.ofgem.gov.uk/sites/default/files/2023-07/Consumer%20Survey%202021%20-%20Engagement%20report.pdf

[319]: Danish Energy Agency, K2 Management. (2019). Analysis of the Potential for Corporate Power Purchasing Agreements for Renewable Energy Production in Denmark. Retrieved Mar 21, 2024, from https://ens.dk/sites/ens.dk/files/Analyser/corporate_ppa_report_june_2019.pdf

[320]: Biegel, B., Hansen, L. H., Stoustrup, J., et al. (2014). Value of flexible consumption in the electricity markets. Energy, 66, 354-362. https://doi.org/10.1016/j.energy.2013.12.041

[321]: Dr. Oliver Schoppe (Mar 20, 2024). UVC Partners | Principal

[322]: McKinsey & Company. (2016). The digital utility: New opportunities and challenges. Retrieved Mar 21, 2024, from https://ipu.msu.edu/wp-content/uploads/2018/03/McKinsey-Digital-Utility-2016.pdf

[323]: McKinsey Electric Power and Natural Gas. (2021). Transforming customer experience in utilities. Retrieved Mar 21, 2024, from https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/transforming-customer-experience-in-utilities

[324]: PolyAI. (2024). Utilities 2024: Navigating changes for a customer-led future. Retrieved Mar 21, 2024, from https://poly.ai/resources/blog/utilities-2024-navigating-changes-for-a-customer-led-future/

[325]: Mclelland, J. (2024). The Utilities Industry Is At The Center Of A Massive Global Shift. Retrieved Mar 21, 2024, from https://www.forbes.com/sites/sap/2021/06/23/the-utilities-industry-is-at-the-center-of-a-massive-global-shift/

[326]: MIT Energy Initiative. (2011). The Future of the Electric Grid. Retrieved Apr 04, 2024, from https://energy.mit.edu/wp-content/uploads/2011/12/MITEI-The-Future-of-the-Electric-Grid.pdf

[327]: McKinsey. (2022). Navigating the energy transition: Electric power and natural gas 2022. Retrieved Apr 04, 2024, from https://www.mckinsey.com/~/media/mckinsey/industries/electric%20power%20and%20natural%20gas/our%20insights/energy%20and%20renewable%20insights/energy-and-renewable-insights.pdf

[328]: Amelang, S. (2024). 80 percent of German utilities expect worsening of skills shortage - survey. Retrieved Apr 04, 2024, from https://www.cleanenergywire.org/news/80-percent-german-utilities-expect-worsening-skills-shortage-survey

[329]: Gilliland, G., Sackey, E., Liu, C., et. al. (2023). Finding the Business Value in Augmented Reality. Retrieved Apr 04, 2024, from https://www.bcg.com/publications/2023/finding-the-business-value-in-ar

[330]: Molavi, N. (2019). Powering up the energy, utilities and resources workforce: Upskilling initiatives can help companies address the skills gap. Retrieved Apr 04, 2024, from https://www.pwc.com/gx/en/industries/energy-utilities-resources/publications/powering-up-the-energy--utilities-and-resources-workforce.html

[331]: Ilanes, P., Lund, S., Mourshed, M., et. al. (2018). Retraining and reskilling workers in the age of automation. Retrieved Apr 04, 2024, from https://www.mckinsey.com/featured-insights/future-of-work/retraining-and-reskilling-workers-in-the-age-of-automation

[332]: Thomson, J., Hardin, K., Sanborn, S. (2024). 2024 power and utilities industry outlook. Retrieved Apr 04, 2024, from https://www2.deloitte.com/us/en/insights/industry/power-and-utilities/power-and-utilities-industry-outlook.html

[333]: McKinsey Electric Power & Natural Gas. (2022). Renewable-energy development in a net-zero world. Retrieved Apr 04, 2024, from https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/renewable-energy-development-in-a-net-zero-world

[334]: Home Builders Institute. (2023). Construction Labor Market Report Spring 2023. Retrieved Apr 04, 2024, from https://hbi.org/wp-content/uploads/2023/06/Spring-2023-construction-labor-market-report_final-PDF.pdf

[335]: Ahmed, M., Bailey, A. (2023). How Companies Can Support Blue-collar Women. Retrieved Apr 04, 2024, from https://www.oliverwymanforum.com/global-consumer-sentiment/2023/aug/how-companies-can-support-blue-collar-women--.html

[336]: Black Hills Corporation. (2023). Black Hills Corporation 2022 Annual Report. Retrieved Apr 04, 2024, from https://ir.blackhillscorp.com/static-files/3272995a-705c-4ad5-a27b-a549970e6a5f

[337]: Harnoss, J., Kugel, J., Kleissl, K., et. al. (2022). Migration Matters: A Human Cause with a $20 Trillion Business Case. Retrieved Apr 04, 2024, from https://www.bcg.com/publications/2022/global-talent-migration-the-business-opportunity

[338]: Alexander Worbs (Mar 20, 2024). Picus Capital | Investor

[339]: World Economic Forum. (2022). The Good Work Framework: A new business agenda for the future of work. Retrieved Apr 04, 2024, from https://www.weforum.org/publications/the-good-work-framework-a-new-business-agenda-for-the-future-of-work/

[340]: European Commission. Joint Research Centre. (2023). Clean Energy Technology Observatory: Overall Strategic Analysis of Clean Energy Technology in the European Union - 2023 Status Report. Retrieved Apr 04, 2024, from https://dx.doi.org/10.2760/150096

[341]: Woetzel, J,.Seong, J., Leung, N., et. al. (2021). Reskilling China. Retrieved Apr 04, 2024, from https://www.mckinsey.com/~/media/mckinsey/featured%20insights/china/reskilling%20china%20transforming%20the%20worlds%20largest%20workforce%20into%20lifelong%20learners/reskilling-china-transforming-the-worlds-largest-workforce-into-lifelong-learners-full-report-f.pdf

[342]: Boston Consulting Group. (2023). Ten Paths to Value. Using Augmented Reality. Retrieved Apr 04, 2024, from https://web-assets.bcg.com/28/eb/f34306fa465784ee419818e289f6/10-paths-to-value-using-augmented-reality-slideshow-oct-2023.pdf

[343]: World Economic Forum. (2023). Jobs of Tomorrow: Large Language Models and Jobs – A Business Toolkit. Retrieved Apr 04, 2024, from https://www3.weforum.org/docs/WEF_Jobs_of_Tomorrow_Large_Language_Models_and_Jobs_2023.pdf

[344]: Hoteit, L., Mérey, T., Bobier, J. F. (2022). Creating a New Reality: The Metaverse in MENAT. Retrieved Apr 04, 2024, from https://www.bcg.com/publications/2022/seizing-the-potential-of-the-metaverse-in-menat

[345]: EY. (2021). If tech powers the future, who powers the tech? Retrieved Apr 04, 2024, from https://assets.ey.com/content/dam/ey-sites/ey-com/en_us/topics/power-and-utilities/ey-power-and-digital-survey.pdf

[346]: International Energy Agency. (2019). Energy efficiency and digitalisation. Retrieved Apr 04, 2024, from https://www.iea.org/articles/energy-efficiency-and-digitalisation

[347]: Parag, Y., Sovacool, B. K. (2016). Electricity market design for the prosumer era. nature Energy, 1(16032), 45444. https://doi.org/10.1038/nenergy.2016.32

[348]: International Energy Agency. (2017). Digitalisation and Energy. Retrieved Apr 04, 2024, from https://www.iea.org/reports/digitalisation-and-energy

[349]: Manyika, J., Chui, M., Miremadi, M., et al. (2017). Harnessing automation for a future that works. Retrieved Apr 04, 2024, from https://www.mckinsey.com/featured-insights/digital-disruption/harnessing-automation-for-a-future-that-works

[350]: European Commission. (2022). Smart cities. Retrieved Mar 21, 2024, from https://commission.europa.eu/eu-regional-and-urban-development/topics/cities-and-urban-development/city-initiatives/smart-cities_en

[351]: Repsol. (2023). Smart cities are already a reality. Retrieved Mar 21, 2024, from https://www.repsol.com/en/energy-and-the-future/technology-and-innovation/smart-cities/index.cshtml

[352]: World Economic Forum. (2023). Data for the City of Tomorrow: Developing the Capabilities and Capacity to Guide Better Urban Futures. Retrieved Mar 22, 2024, from https://www.weforum.org/publications/data-for-the-city-of-tomorrow-developing-the-capabilities-and-capacity-to-guide-better-urban-futures/

[353]: Henzelmann, T. (2019). Smart Cities: A big opportunity for utilities. Retrieved Mar 21, 2024, from https://www.rolandberger.com/en/Insights/Publications/Smart-Cities-A-big-opportunity-for-utilities.html

[354]: MSG Advisors. (2022). Smart City Setup and development of data infrastructures. Retrieved Mar 21, 2024, from https://advisors.msg.group/en/smart-cities

[355]: EAS Enterprise Estonia. (2023). Smart cities. Retrieved Mar 21, 2024, from https://investinestonia.com/business-opportunities/smart-cities/

[356]: EAS Enterprise Estonia. (2023). Infrastructure. Retrieved Mar 21, 2024, from https://investinestonia.com/business-in-estonia/infrastructure-and-premises/utilities/

[357]: European Commission. Directorate General for Energy. & Guidehouse. (2021). Digital technologies and use cases in the energy sector. Retrieved Mar 21, 2024, from https://doi.org/10.2833/006724

[358]: IEA. (2021). Empowering Cities for a Net Zero Future. Retrieved Mar 21, 2024, from https://doi.org/10.1787/7a222c8b-en

[359]: Nunes, P., Santos, J., Rocha, E. (2023). Challenges in predictive maintenance – A review. CIRP Journal of Manufacturing Science and Technology, 40, 53-67. https://doi.org/10.1016/j.cirpj.2022.11.004

[360]: European Environment Agency. (2021). Water resources across Europe — confronting water stress: an updated assessment. Retrieved Mar 21, 2024, from https://www.eea.europa.eu/publications/water-resources-across-europe-confronting

[361]: Eparu, C. N., Neacsa, A., Stoica, D. B. (2023). Gas Losses in the Distribution Networks: An Interdisciplinary Analysis. Energies, 16(1), 196. https://doi.org/10.3390/en16010196

[362]: Alexander Worbs (Mar 20, 2024). Picus Capital | Investor

[363]: Rodriguez, J., McConachie, N., Doshi, P., et al. (2023). A Digital Approach to Rolling Stock Maintenance. Retrieved Mar 21, 2024, from https://www.bcg.com/publications/2023/a-digital-approach-to-rolling-stock-maintenance

[364]: International Energy Agency. (2021). Empowering Cities for a Net Zero Future. Retrieved Mar 21, 2024, from https://iea.blob.core.windows.net/assets/4d5c939d-9c37-490b-bb53-2c0d23f2cf3d/G20EmpoweringCitiesforaNetZeroFuture.pdf

[365]: G20 Empower. (2023). G20 EMPOWER Best Practices Playbook 2023. Retrieved Mar 21, 2024, from https://g20empower-india.org/event/Playbook_India%20G20%20Empower%20Book.pdf

[366]: Hernandez, E., Azaola, M. (2017). Smart Cities - overcoming the integration barrier. Retrieved Mar 21, 2024, from https://www2.softtek.com/hubfs/insights/SmartCities.pdf

[367]: Dr. Oliver Schoppe (Mar 20, 2024). UVC Partners | Principal

[368]: Frick, K. T., Abre, G. M., Malkin, N., et al. (2021). The Cybersecurity Risks of Smart City Technologies. Retrieved Mar 20, 2024, from https://cltc.berkeley.edu/wp-content/uploads/2021/03/Smart_City_Cybersecurity.pdf

[369]: Casanovas, M., Nghiem, A. (2023). Cybersecurity – is the power system lagging behind? Retrieved Mar 20, 2024, from https://www.iea.org/commentaries/cybersecurity-is-the-power-system-lagging-behind

[370]: EAS Enterprise Estonia. (2021). Cyber security - Secure Data Sharing. Retrieved Mar 20, 2024, from https://e-estonia.com/solutions/cyber-security/secure-data-sharing/

[371]: Cybersecurity & Infrastructure Security Agency. (2023). Cybersecurity Best Practices for Smart Cities. Retrieved Mar 20, 2024, from https://www.cisa.gov/sites/default/files/2023-04/cybersecurity-best-practices-for-smart-cities_508.pdf

[372]: Cybersecurity & Infrastructure Security Agency. (2020). TRUST IN SMART CITY SYSTEMS Characteristics and Key Considerations. Retrieved Mar 20, 2024, from https://www.cisa.gov/sites/default/files/publications/Trust%20in%20Smart%20City%20Systems%20Report_0.pdf

[373]: S&P Global. (2023). The State of Edge Security Report. Retrieved Mar 20, 2024, from https://www.redhat.com/rhdc/managed-files/cl-sp-state-edge-security-report-analyst-material-329450-202305-en.pdf

[374]: International Energy Agency. (2023). Managing Seasonal and Interannual Variability of Renewables. Retrieved Mar 22, 2024, from https://www.iea.org/reports/managing-seasonal-and-interannual-variability-of-renewables

[375]: SolarPower Europe. (2023). Global Market Outlook For Solar Power 2023 - 2027. Retrieved Mar 22, 2024, from https://www.solarpowereurope.org/insights/outlooks/global-market-outlook-for-solar-power-2023-2027/detail#gw-scale-markets-6.-germany

[376]: Robinson, D. (2022). Current Energy Crises, the Energy Transition and the Design of Electricity Markets. Retrieved Mar 22, 2024, from https://www.oxfordenergy.org/publications/current-energy-crises-the-energy-transition-and-the-design-of-electricity-markets/

[377]: Die Bundesregierung. (2022). "We're tripling the speed of the expansion of renewable energies". Retrieved Mar 22, 2024, from https://www.bundesregierung.de/breg-de/schwerpunkte/klimaschutz/amendment-of-the-renewables-act-2060448#:~:text=The%20EEG%202023%20is%20the,least%2080%20percent%20by%202030.

[378]: Die Bundesregierung. (2023). Mehr Energie aus erneuerbaren Quellen. Retrieved Mar 22, 2024, from https://www.bundesregierung.de/breg-de/schwerpunkte/klimaschutz/energiewende-beschleunigen-2040310

[379]: Hyundai. (2022). Die Vehicle to Grid (V2G)-Technologie unterstützt Nutzung von Strom aus erneuerbaren Energiequellen. Retrieved Mar 22, 2024, from https://www.hyundai.news/de/articles/press-releases/v2g-technologie-unterstuetzt-nutzung-von-strom-aus-erneuerbaren-energiequellen.html

[380]: DESTATIS. (2024). Photovoltaik: Deutschland größter Erzeuger in der EU. Retrieved Mar 22, 2024, from https://www.destatis.de/Europa/DE/Thema/Umwelt-Energie/Photovoltaik.html#:~:text=Die%20EU%2Dweite%20Stromerzeugungskapazit%C3%A4t%20durch,sowie%20Spanien%20mit%2014%20Gigawatt

[381]: Bundesministerium für Wirtschaft und Klimaschutz. (2024). Neue Photovoltaik-Anlage installieren und von Förderung profitieren. Retrieved Mar 22, 2024, from https://www.energiewechsel.de/KAENEF/Redaktion/DE/Standardartikel/solarstromanlagen-umsatzsteuer-sparen.html

[382]: Bundesnetzagentur. (2024). EEG-Förderung und -Fördersätze. Retrieved Mar 22, 2024, from https://www.bundesnetzagentur.de/DE/Fachthemen/ElektrizitaetundGas/ErneuerbareEnergien/EEG_Foerderung/start.html

[383]: Électricité de France. (2019). EDF acquires e2m and strengthen its position in the field of decentralised energy management in Europe. Retrieved Mar 22, 2024, from https://www.edf.fr/en/the-edf-group/dedicated-sections/journalists/all-press-releases/edf-acquires-e2m-and-strengthen-its-position-in-the-field-of-decentralised-energy-management-in-europe

[384]: International Energy Agency. (2024). Solar PV. Retrieved Mar 22, 2024, from https://www.iea.org/energy-system/renewables/solar-pv

[385]: Sophia Escheu (Mar 20, 2024). SpeedInvest | Associate

[386]: Hyundai. (2022). Die Vehicle to Grid (V2G)-Technologie unterstützt Nutzung von Strom aus erneuerbaren Energiequellen. Retrieved Mar 21, 2024, from https://www.hyundai.news/de/articles/press-releases/v2g-technologie-unterstuetzt-nutzung-von-strom-aus-erneuerbaren-energiequellen.html

[387]: Abnett, K. (2020). EU to target 30 million electric cars by 2030. Retrieved Mar 21, 2024, from https://www.reuters.com/article/idUSKBN28E2KL/

[388]: Hyundai. (2022). Die Vehicle to Grid (V2G)-Technologie unterstützt Nutzung von Strom aus erneuerbaren Energiequellen. Retrieved Mar 21, 2024, from https://www.hyundai.news/de/articles/press-releases/v2g-technologie-unterstuetzt-nutzung-von-strom-aus-erneuerbaren-energiequellen.html

[389]: Cenex. (2022). EV-elocity Final Report. Retrieved Mar 21, 2024, from https://www.cenex.co.uk/app/uploads/2022/06/EV-elocity-Final-Report.pdf

[390]: Hyundai. (2022). Die Vehicle to Grid (V2G)-Technologie unterstützt Nutzung von Strom aus erneuerbaren Energiequellen. Retrieved Mar 21, 2024, from https://www.hyundai.news/de/articles/press-releases/v2g-technologie-unterstuetzt-nutzung-von-strom-aus-erneuerbaren-energiequellen.html#:~:text=13.12.2022%20Pressemeldung-,Die%20Vehicle%20to%20Grid%20(V2G)%2DTechnologie%20unterst%C3%BCtzt,von%20Strom%20aus%20erneuerbaren%20Energiequellen&text=Nach%20einer%20aktuellen%20Einsch%C3%A4tzung%20der,%C3%BCber%20einen%20vollelektrischen%20Antrieb%20verf%C3%BCgen.

[391]: Kempton, W., Tomić, J. (2005). Vehicle-to-grid power fundamentals: Calculating capacity and net revenue. Journal of Power Sources, 144(1), 268-279. https://doi.org/10.1016/j.jpowsour.2004.12.025

[392]: Tomić, J., Kempton, W. (2007). Using fleets of electric-drive vehicles for grid support. Journal of Power Sources, 168(2), 459-468. http://dx.doi.org/10.1016/j.jpowsour.2007.03.010

[393]: Zimmerman, L. (2022). Reversing the charge; Battery power from electric vehicles to the grid could open a fast lane to a net-zero future. Retrieved Mar 21, 2024, from https://news.mit.edu/2022/reversing-charge-electric-vehicles-1128

[394]: RACE for 2030. (2021). N1 Opportunity Assessment; Electric vehicles and the grid. Retrieved Mar 21, 2024, from https://www.racefor2030.com.au/wp-content/uploads/2021/11/N1-EV-Opportunity-Assessement-Report-FINAL_05112021.pdf

[395]: Coban, H., Lewicki, W., Sendek-Matysiak, E., et al. (2022). Electric Vehicles and Vehicle–Grid Interaction in the Turkish Electricity System. Energies, 15(21), 8218. https://doi.org/10.3390/en15218218

[396]: RACE for 2030. (2021). N1 Opportunity Assessment; Electric vehicles and the grid. Retrieved Mar 21, 2024, from https://www.racefor2030.com.au/wp-content/uploads/2021/11/N1-EV-Opportunity-Assessement-Report-FINAL_05112021.pdf

[397]: Coban, H., Lewicki, W., Sendek-Matysiak, E., et al. (2022). Electric Vehicles and Vehicle–Grid Interaction in the Turkish Electricity System. Energies, 15(21), 8218. https://doi.org/10.3390/en15218218

[398]: European Commission, Directorate-General for Energy, Torres Vega, P., Beaussant, O., De Vita, A. et al.,. (2023). Technical support for RES policy development and implementation: Delivering on an increased ambition through energy system integration. Retrieved Mar 21, 2024, from https://data.europa.eu/doi/10.2833/86135

[399]: Fahmy, S. (2023). Who powers whom? – The benefits of bidirectional charging. Retrieved Mar 21, 2024, from https://www.siemens.com/global/en/company/stories/infrastructure/2023/the-benefits-of-bidirectional-charging-v2g-v2h.html

[400]: Bland, R., Gao, W., Noffsinger, J., et. al. (2020). Charging electric-vehicle fleets: How to seize the emerging opportunity. Retrieved Mar 22, 2024, from https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Sustainability/Our%20Insights/Charging%20electric%20vehicle%20fleets%20How%20to%20seize%20the%20emerging%20opportunity/Charging-electric-vehicle-fleets-how-to-seize-the-emerging-opportunity-FINAL.pdf

[401]: Future Lab Energy. (2023). The decentralized energy system in 2030. Retrieved Mar 21, 2024, from https://future-energy-lab.de/news/das-dezentralisierte-energiesystem-im-jahr-2030/

[402]: IEA. (2017). Cities lead the way on clean and decentralized energy solutions. Retrieved Mar 22, 2024, from https://www.iea.org/news/cities-lead-the-way-on-clean-and-decentralized-energy-solutions

[403]: European Environment Agency. (2022). Energy prosumers in EuropeCitizen participation in the energy transition. Retrieved Mar 23, 2024, from https://www.eea.europa.eu/publications/the-role-of-prosumers-of

[404]: Fuentes, R., Fattouh, B. (2023). The implications of digitalization on future electricity market design. Retrieved Mar 24, 2024, from https://www.oxfordenergy.org/publications/the-implications-of-digitalization-on-future-electricity-market-design/

[405]: Hove, A., Meidan ,M., Andrews-Speed, P. (2021). Software versus hardware: how China's institutional setting helps and hinders the clean energy transition. Retrieved Mar 25, 2024, from https://www.oxfordenergy.org/publications/software-versus-hardware-how-chinas-institutional-setting-helps-and-hinders-the-clean-energy-transition/

[406]: European Commission, Directorate-General for Energy, Antretter, M., Klobasa, M., Kühnbach, M. et al. (2022). Digitalisation of energy flexibility, Publications Office of the European Union. Retrieved Mar 26, 2024, from https://data.europa.eu/doi/10.2833/113770

[407]: Dr. Oliver Schoppe (Mar 20, 2024). UVC Partners | Principal

[408]: Exro. (2023). Load Shifting: What Is It and How Does It Work? Retrieved Mar 20, 2024, from https://www.exro.com/industry-insights/load-shifting#:~:text=Load%20shifting%20is%20an%20electricity%20load%20management%20technique%20in%20which,but%20total%20consumption%20remains%20constant

[409]: Bazhinov, A. (2023). Automating Energy Load Shifting During Peak Times. Retrieved Mar 20, 2024, from https://www.luminsmart.com/blog/load-shifting

[410]: Dr. Oliver Schoppe (Mar 20, 2024). UVC Partners | Principal

[411]: Alexander Worbs (Mar 20, 2024). Picus Capital | Investor

[412]: Bene, C., Ellerbeck, A., Dedecca, J. G. (2023). Solving the energy storage problem for a clean energy system. Retrieved Mar 20, 2024, from https://sdg-action.org/solving-the-energy-storage-problem-for-a-clean-energy-system/

[413]: Araner Group. (2024). Challenges of energy storage: TES global prospects. Retrieved Mar 20, 2024, from https://www.araner.com/blog/challenges-of-energy-storage

[414]: Alexander Worbs (Mar 20, 2024). Picus Capital | Investor

[415]: Dr. Oliver Schoppe (Mar 20, 2024). UVC Partners | Principal

[416]: International Energy Agency. (2021). Renewable electricity growth is accelerating faster than ever worldwide, supporting the emergence of the new global energy economy. Retrieved Mar 20, 2024, from https://www.iea.org/news/renewable-electricity-growth-is-accelerating-faster-than-ever-worldwide-supporting-the-emergence-of-the-new-global-energy-economy

[417]: McGovan, J. (2023). Germany's electricity storage strategy to fall short of industry expectations. Retrieved Mar 20, 2024, from https://www.cleanenergywire.org/news/germanys-electricity-storage-strategy-fall-short-industry-expectations-media

[418]: Fraunhofer ISI. (2020). Energy Storage in Germany – Present Developments and Applicability in China. Retrieved Mar 20, 2024, from https://www.isi.fraunhofer.de/content/dam/isi/dokumente/ccx/2020/Energy_Storage_in_Germany_EN_Final-1.pdf

[419]: Fioravanti R., Kumar K., Nakata S., et. al. (2020). Predictive-Maintenance Practices For Operational Safety of Battery Energy Storage Systems. Retrieved Mar 20, 2024, from https://www.sandia.gov/ess-ssl/wp-content/uploads/2020/10/Predictive-Maintenance-IEEE-Draft-Paper-Final-RA.pdf

[420]: Olabi, A. G., Wilberforce, T., Ramadan, M., et al. (2021). Compressed air energy storage systems: Components and operating parameters – A review. Journal of Energy Storage, 34, 102000. https://doi.org/10.1016/j.est.2020.102000

[421]: Dr. Oliver Schoppe (Mar 20, 2024). UVC Partners | Principal

[422]: Sophia Escheu (Mar 20, 2024). SpeedInvest | Associate

[423]: Harmony Energy. (2024). Battery. Retrieved Mar 20, 2024, from https://harmonyenergy.co.uk/services/battery/

[424]: Hunt, J., Zakeri, B., Jurasz, J., et al. (2023). Underground Gravity Energy Storage: A Solution for Long-Term Energy Storage. Energies, 16(2), 825. https://doi.org/10.3390/en16020825

[425]: PwC GmbH. (2020). Marktstudie ERP Systeme in der Energiewirtschaft. Retrieved Mar 28, 2024, from https://www.pwc.de/de/energiewirtschaft/marktstudie-erp-systeme-in-der-energiewirtschaft.pdf

[426]: Timperley, N. (2023). The Dawn of a Customer-Centric Transition. Retrieved Mar 28, 2024, from https://delta.lcp.com/whitepaper/the-dawn-of-a-customer-centric-transition/

[427]: Haller, T., Kaesser, M., Trukenmueller, M. (2023). Smart Meter Rollout: Wie Verbraucher und Energieversorger vom neuen Gesetz zu dynamischen Stromtarifen profitieren können. Retrieved Mar 28, 2024, from https://www.simon-kucher.com/de/insights/smart-meter-rollout-wie-verbraucher-und-energieversorger-vom-neuen-gesetz-profitieren-koennen

[428]: European Commission, Directorate-General for Energy, Boeve, S., Cherkasky, J., Bons, M. et al. (2021). ASSET study on dynamic retail electricity prices. Retrieved Mar 28, 2024, from https://data.europa.eu/doi/10.2833/87875

[429]: GfK UK Social Research. (2018). Consumer Engagement in the Energy Market 2018. Retrieved Mar 28, 2024, from https://www.ofgem.gov.uk/sites/default/files/docs/2018/10/consumer_engagement_survey_2018_technical_report_0.pdf

[430]: Presse- und Informationsamt der Bundesregierung. (2023). Neustart für die digitale Energiewende. Retrieved Mar 28, 2024, from https://www.bundesregierung.de/breg-de/schwerpunkte/klimaschutz/digitale-energiewende-2157184

[431]: Edelmann, H., Kaniut, M. (2019). Der System- und Plattformgedanke des GDEW als Treiber der digitalen Transformation. Realisierung Utility 4.0 Band 1, 63-78. https://doi.org/10.1007/978-3-658-25332-5_2

[432]: Bundesministerium für Wirtschaft und Klimaschutz. (2020). Smart Meter: Fragen & Antworten. Retrieved Mar 28, 2024, from https://www.bmwk-energiewende.de/EWD/Redaktion/Newsletter/2020/03/Meldung/News1.html

[433]: SAP Deutschland SE & Co. KG. (2024). SAP Intelligent Metering for German Energy Utilities. Retrieved Mar 28, 2024, from https://help.sap.com/docs/SAP_INTELL_METER_GER_ENRGY/3e88baa8ca4e4863a6203e00deb32df2/e4ead854d2cfed05e10000000a4450e5.html

[434]: SAP Deutschland SE & Co. KG. (2021). SAP S/4HANA Utilities: Echtzeitdaten für Versorger. Retrieved Mar 28, 2024, from https://news.sap.com/germany/2021/11/versorgungswirtschaft-utility-nachfolge-loesung-produkt/

[435]: Uniserv GmbH. (2023). The replacement of IS-U is just around the corner. Retrieved Mar 28, 2024, from https://www.uniserv.com/en/knowledge/magazine/article/replacement-is-u-migration-sap-s4hana/

[436]: SAP Deutschland SE & Co. KG. (2020). Zweite Generation der SAP Utilities-Lösung: Freiräume für Innovationen schaffen. Retrieved Mar 28, 2024, from https://news.sap.com/germany/2020/12/utilities-cloud-innovation-zukunft/

[437]: Statistisches Bundesamt. (2020). Material and energy flows Energy consumption. Retrieved Mar 28, 2024, from https://www.destatis.de/EN/Themes/Society-Environment/Environment/Material-Energy-Flows/Tables/electricity-consumption-households.html

[438]: Verivox GmbH. (2024). Aktuelle Strompreise für Neukunden. Retrieved Mar 28, 2024, from https://www.verivox.de/strom/strompreisentwicklung/#:~:text=Die%20Strompreise%20f%C3%BCr%20Neukunden%20liegen,Stand%3A%2031.03.2024).

[439]: eurostat. (2023). Electricity markets - generation and installed capacity. Retrieved Mar 28, 2024, from https://ec.europa.eu/eurostat/statistics-explained/index.php

[440]: BDEW. (2023). Anzahl der Unternehmen am Energiemarkt in Deutschland nach Bereichen im Jahr 2022. Retrieved Mar 28, 2024, from https://de.statista.com/statistik/daten/studie/173884/umfrage/zahl-der-unternehmen-in-den-einzelnen-marktbereichen-des-energiemarktes/

[441]: Kilian Egger (Mar 26, 2024). SWM | Strategy und Corporate Management

[442]: Capgemini Invent. (2020). Die Abkündigung von SAP IS-U – ein Impuls für die IT-Architekturen der Energiewirtschaft. Retrieved Mar 28, 2024, from https://www.capgemini.com/de-de/insights/blog/die-abkundigung-von-sap-is-u-ein-impuls-fur-die-it-architekturen-der-energiewirtschaft/

[443]: octopus energy. (2024). Wo startet deine Energiewende? Retrieved Mar 28, 2024, from https://octopusenergy.de/

[444]: SWM. (2024). Tarifvertrag Versorgungsbetriebe. Retrieved Apr 04, 2024, from https://www.swm.de/dam/doc/karriere/tv-v.pdf

[445]: Kaiser, R., Schatsky, D. (2017). Augmented and virtual reality in the enterprise. Retrieved Apr 03, 2024, from https://www2.deloitte.com/us/en/insights/focus/signals-for-strategists/augmented-and-virtual-reality-enterprise-applications.html

[446]: Eurostat. (2020). Three quarters of utility workers are men. Retrieved Apr 04, 2024, from https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20200527-1

[447]: Statista. (2023). AR & VR - Worldwide. Retrieved Apr 04, 2024, from https://www.statista.com/outlook/amo/ar-vr/worldwide#:~:text=This%20market%20is%20expected%20to

[448]: bdew. (2024). Personalbedarf in der Energiewirtschaft wird weiter zunehmen. Retrieved Apr 04, 2024, from https://www.bdew.de/presse/presseinformationen/personalbedarf-in-der-energiewirtschaft-wird-weiter-zunehmen/

[449]: Aleksandrova, A. (2023). Why most training programmes are doomed to fail. Retrieved Apr 04, 2024, from https://www.thehrdirector.com/features/learning-development/training-programmes-doomed-fail/

[450]: Deutsche Rentenversicherung. (2024). In den nächsten zehn Jahren gehen sieben Millionen Beschäftigte in Rente. Retrieved Apr 04, 2024, from https://rvaktuell.de/02-2022/in-den-naechsten-zehn-jahren-gehen-sieben-millionen-beschaeftigte-in-rente/

[451]: International Energy Agency. (2019). Overview – World Energy Employment – Analysis. Retrieved Apr 04, 2024, from https://www.iea.org/reports/world-energy-employment/overview

[452]: Capgemini. (2018). Immersive technology has arrived: AR and VR set to become mainstream in business operations in the next 3 years. Retrieved Apr 04, 2024, from https://www.capgemini.com/news/press-releases/immersive-technology-has-arrived-ar-and-vr-set-to-become-mainstream-in-business-operations-in-the-next-3-years/

[453]: Molavi, N. (2019). Powering up the energy, utilities and resources workforce: Upskilling initiatives can help companies address the skills gap. Retrieved Apr 04, 2024, from https://www.pwc.com/gx/en/industries/energy-utilities-resources/publications/powering-up-the-energy--utilities-and-resources-workforce.html

[454]: EY. (2021). If tech powers the future, who powers the tech? Retrieved Apr 04, 2024, from https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/power-and-utilities/power-and-utilities-pdf/ey-power-utilities-digital-survey-final.pdf

[455]: Santamaria, J. (2024). In lieu of recruitment, energy companies turn to upskilling to produce gen AI talent. Retrieved Apr 04, 2024, from https://www.smart-energy.com/industry-sectors/new-technology/in-lieu-of-recruitment-energy-companies-turn-to-upskilling-to-produce-gen-ai-talent/

[456]: iGrowStaff. (2024). Empowering Your Utilities Workforce: Strategies for Skill Enhancement. Retrieved Apr 04, 2024, from https://igrowstaff.com/empowering-your-utilities-workforce-strategies-for-skill-enhancement/

[457]: Montamo. (2024). Wir lösen den Fachkräftemangel im Handwerk. Retrieved Apr 04, 2024, from https://montamo.com/

[458]: Smalt. (2024). We increase talent supply and productivity in the climate trades. Retrieved Apr 04, 2024, from https://www.smalt.eu/

[459]: Knowron. (2024). Complex questions, instant answers. Retrieved Apr 04, 2024, from https://www.knowron.com/

[460]: Hall, S., Takahashi, R. (2017). Augmented and virtual reality: The promise and peril of immersive technologies. Retrieved Apr 03, 2024, from https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/augmented-and-virtual-reality-the-promise-and-peril-of-immersive-technologies

[461]: Yusuf, Z., Lukic, V., Heppelmann, J. (2020). Unleashing the Power of Data with IoT and Augmented Reality. Retrieved Apr 03, 2024, from https://www.bcg.com/publications/2020/unleashing-the-power-of-data-with-iot-and-augmented-reality

[462]: The Federal Government of Germany. (2023). Driving Progress with Data. Retrieved Mar 28, 2024, from https://bmdv.bund.de/SharedDocs/DE/Anlage/K/driving-progress-with-data.pdf?__blob=publicationFile

[463]: Kilian Egger (Mar 21, 2024). SWM | Strategy und Corporate Management

[464]: Research & Development Hub. (2024). Enterprise Data Management Market Size. Retrieved Mar 28, 2024, from https://www.linkedin.com/pulse/enterprise-data-management-market-size-103-pages-peapf/

[465]: Inkwood Research. (2022). Europe business intelligence market forecast. Retrieved Mar 28, 2024, from https://inkwoodresearch.com/reports/europe-business-intelligence-market/

[466]: Capgemini Research Institute. (2021). Data Sharing Masters. Retrieved Mar 28, 2024, from https://www.capgemini.com/wp-content/uploads/2021/09/Data-Ecosystems_Infographic_V6.pdf

[467]: Tonic.ai. (2024). Achieve developer-friendly compliance. Retrieved Mar 29, 2024, from https://www.tonic.ai/

[468]: atlan. (2024). Governance, without the governing. Retrieved Mar 29, 2024, from https://atlan.com/ai/

[469]: TIBCO. (2024). Get to your data faster. Retrieved Mar 29, 2024, from https://www.tibco.com/platform/data-virtualization

[470]: IBM. (2024). Harness the power of data science. Retrieved Mar 29, 2024, from https://www.ibm.com/data-science

[471]: Mostly.ai. (2024). Gen AI for tabular data. Retrieved Apr 03, 2024, from https://mostly.ai/

[472]: Garbe Industrial Real Estate. (2023). The PV capacity of roof surfaces in Germany. Retrieved Apr 02, 2024, from https://www.garbe-industrial.de/en/covering-the-building-and-the-electric-bill-the-pv-capacity-of-roof-surfaces-in-germany-harbours-enormous-potential/#:~:text=Equipping%20all%20of%20these%20roof,36%20average%20nuclear%20power%20plants

[473]: European Commission. (2023). Commission welcomes political agreement on new rules to boost energy performance of buildings across the EU. Retrieved Apr 02, 2024, from https://ec.europa.eu/commission/presscorner/detail/en/IP_23_6423

[474]: The Federal Government of Germany. (2024). What is the German government doing for the climate? Retrieved Apr 04, 2024, from https://www.bundesregierung.de/breg-en/issues/climate-action/government-climate-policy-1779414#:~:text=Under%20the%20Climate%20Action%20Programme,coal%20to%20generate%20electric%20power.

[475]: Fraunhofer Institute for Solar Energy Systems, ISE. (2023). Photovoltaics Report. Retrieved Apr 04, 2024, from https://www.ise.fraunhofer.de/content/dam/ise/de/documents/publications/studies/Photovoltaics-Report.pdf

[476]: Die Bundesregierung. (2022). Nicht weniger fortbewegen, sondern anders. Retrieved Apr 02, 2024, from https://www.bundesregierung.de/breg-de/schwerpunkte/klimaschutz/nachhaltige-mobilitaet-2044132

[477]: Rozite, V., Miller, J., Oh, S. (2023). Why AI and energy are the new power couple. Retrieved Apr 02, 2024, from https://www.iea.org/commentaries/why-ai-and-energy-are-the-new-power-couple

[478]: Yang, Z. (2024). Why China's EV ambitions need virtual power plants. Retrieved Apr 02, 2024, from https://www.technologyreview.com/2024/02/21/1088748/virtual-power-plant-electric-vehicle/

[479]: Die Bundesregierung. (2023). Mehr Energie aus erneuerbaren Quellen. Retrieved Apr 02, 2024, from https://www.bundesregierung.de/breg-de/schwerpunkte/klimaschutz/energiewende-beschleunigen-2040310

[480]: Bundesnetzagentur. (2024). Zubau Erneuerbarer Energien 2023. Retrieved Apr 02, 2024, from https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/DE/2024/20240105_EEGZubau.html#:~:text=Am%20Jahresende%202023%20betrug%20die,betriebenen%20Geb%C3%A4udeanlagen%20umfasst%20einen%20Speicher.

[481]: Bundesministerium für Wirtschaft und Klimaschutz. (2024). Mehr Energie aus erneuerbaren Quellen. Retrieved Apr 02, 2024, from https://www.energiewechsel.de/KAENEF/Redaktion/DE/Standardartikel/energieeffizienzgesetz.html

[482]: Stein, Z. (2024). Gigawatt-Hour (GWh). Retrieved Apr 03, 2024, from https://www.carboncollective.co/sustainable-investing/gigawatt-hour-gwh

[483]: Wehrmann, B. (2024). Solar power in Germany – output, business & perspectives. Retrieved Mar 28, 2024, from https://www.cleanenergywire.org/factsheets/solar-power-germany-output-business-perspectives

[484]: Willuhn, M. (2022). Germany raises feed-in tariffs for solar up to 750 kW. Retrieved Mar 29, 2024, from https://www.pv-magazine.com/2022/07/07/germany-raises-feed-in-tariffs-for-solar-up-to-750-kw/

[485]: PitchBook. (2024). Carbon & Emissions Tech Report. Retrieved Apr 03, 2024, from https://pitchbook.com/news/reports/q2-2023-carbon-emissions-tech-report

[486]: Next Kraftwerke. (2024). PV Direktvermarktung. Retrieved Apr 03, 2024, from https://www.next-kraftwerke.de/virtuelles-kraftwerk/solar

[487]: gridX. (2024). Home-Energy-Management-System. Retrieved Apr 03, 2024, from https://de.gridx.ai/use-cases/home-energy-management-system

[488]: Energy Land Lease. (2024). Photovoltaic feed-in tariff 2024: Current rates and changes at a glance. Retrieved Apr 03, 2024, from https://www.enlapa.de/blog/Einspeiseverg%C3%BCtung_2024_f%C3%BCr_PV-Anlagen

[489]: Mitali, J., Dhinakaran, S., Mohamad, A. A. (2022). Energy storage systems: a review. Energy Storage and Saving, 1(3), 166-216. https://doi.org/10.1016/j.enss.2022.07.002

[490]: International Energy Agency. (2024). Germany. Retrieved Apr 02, 2024, from https://www.iea.org/countries/germany

[491]: Cosgrove, P., Roulstone, T., Zachary, S. (2023). Intermittency and periodicity in net-zero renewable energy systems with storage. Renewable Energy, 212, 299-307. https://doi.org/10.1016/j.renene.2023.04.135

[492]: Kilian Egger (Mar 26, 2024). Strategy und Corporate management at SWM

[493]: Ritchie, H., Roser, M., Rosado, P. (2020). Renewable Energy. Retrieved Apr 02, 2024, from https://ourworldindata.org/renewable-energy

[494]: Bundesnetzagentur. (2024). Eckpunkte zur Verteilung von Netzkosten. Retrieved Apr 02, 2024, from https://www.bundesnetzagentur.de/993236

[495]: Bundesnetzagentur. (2024). Strommarktdaten für Deutschland. Retrieved Apr 02, 2024, from https://www.smard.de/page/home/marktdaten/78

[496]: Kyon Energy. (2023). For a world with a clean and sustainable energy supply. Retrieved Apr 02, 2024, from https://en.kyon-energy.de/uber-uns

[497]: Octave Energy. (2024). Power Your Business with Sustainable Energy Storage. Retrieved Apr 02, 2024, from https://octave.energy/en/

[498]: Neoom. (2023). Your independent energy supply. Retrieved Apr 02, 2024, from https://neoom.com/en/

Publisher Center for Digital Technology and Management
Arcisstr. 21
80333 Munich, Germany

E-Mail: info@cdtm.de
www.cdtm.de

Editors Vera Eger, Felix Dörpmund

Team Heads Valentin Gölz (Editing)
Elisabeth Goebel, Johann Stürken (QA)
Amy Chao (Pictures)
Niko Pallas (Layouting)
Thomas Kaar (Sources & Abbreviations)
Het Dave, Marcelo Rohn (Marketing & Communication)
With support from the entire Class Spring 2024 :)

Printed Copies 100

Printing Company printworld.com GmbH
Weststraße 60
09603 Großschirma

Photos https://www.istockphoto.com/
https://openai.com/dall-e-2
https://www.pexels.com/

Year of Publication 2024

THE FUTURE OF UTILITIES IN THE ERA OF AI

The utility sector accelerates the transition towards a net-zero future, playing a pivotal role as the principal architect of large-scale infrastructure projects. The integration of AI drives this transformation among utility providers. It mirrors the global shift towards sustainability and green energy production as grid operators must navigate the complexities of modern energy demands, environmental responsibilities, and the ever-changing landscape of consumer expectations. Serving as the backbone of societal infrastructure, the sector's adoption of AI is essential for improving public services, optimizing resource management, and achieving carbon neutrality objectives. This report examines the challenges and opportunities of this green transition, highlighting the role of AI in reshaping the utility industry amidst global efforts to combat climate change and promote sustainable growth.

By embracing AI, utility providers gain advantages in predictive maintenance, demand forecasting, and attaining carbon neutrality, emphasizing the economic move towards sustainable energy solutions. Meeting regulatory requirements for innovation and equitable access necessitates joint efforts to tackle challenges related to the privacy of citizens' data, protection of critical infrastructure, and ethical application of AI. As utility providers adapt to technological advancements and consumer expectations, they face obstacles like cybersecurity and investment requirements.

Emerging technologies, increased data accessibility, and novel business models offer potential solutions and long-term benefits for the utility sector. This report focuses on the current critical challenges and provides an outlook on adopting AI in the utility sector by 2030. It is structured into three main sections: Trends, Exploration, and Ideation.

The opening section presents trends across technical, societal, environmental, regulatory, economic, and business model opportunities, examining their future influence on the industry. Following this, the report clusters and explores significant challenges and opportunities by analyzing actions from existing market leaders and innovators. The concluding part presents the findings of five distinct business concepts, spanning diverse fields from data governance solutions to energy storage systems, dynamic pricing platforms, virtual power plants, and AR-based upskilling software.

CDTM

The Center for Digital Technology and Management (CDTM) is a joint interdisciplinary institution of education, research, and entrepreneurship of the Ludwig Maximilians University (LMU) and the Technical University of Munich (TUM).

CDTM offers the interdisciplinary add-on study program "Technology Management", which is part of the Elite Network of Bavaria. Students from various study backgrounds with creative ideas, great motivation and an entrepreneurial mindset are offered the tools to put their ideas into practice. As a research institution, CDTM closely cooperates with the industry, startups and the public sector concentrating on topics at the intersection of technology, innovation, and entrepreneurship.

E-mail info@cdtm.de
Website www.cdtm.de

Vera Eger, Felix Dörpmund

9 783982 634005