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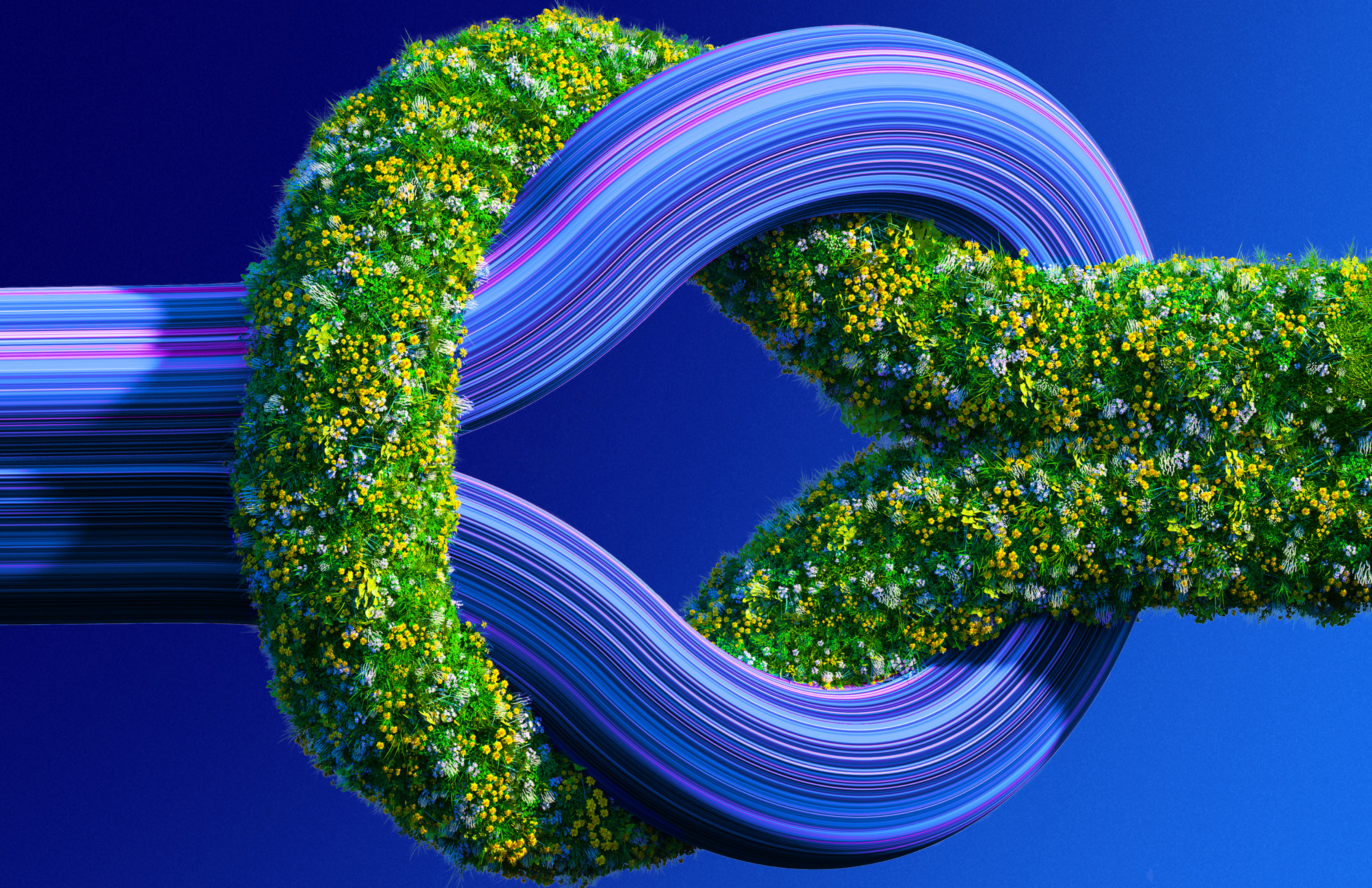
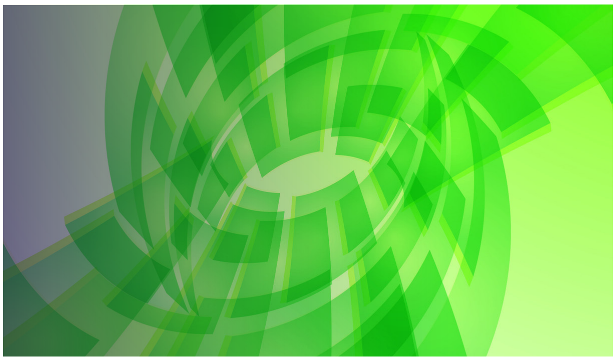
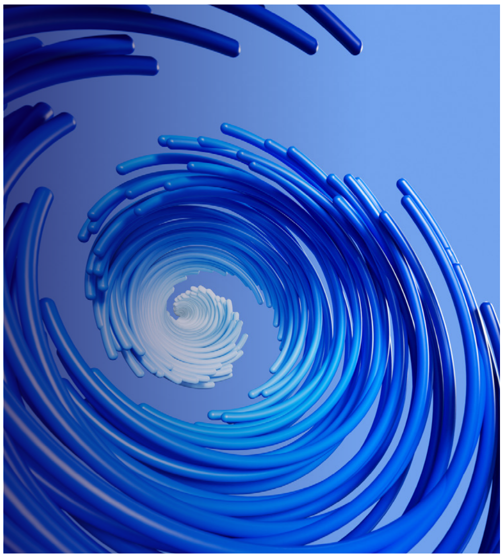


The Twin Transition: Digital Innovation & Climate Action

CONTENT





THE TWIN TRANSITION: DIGITAL INNOVATION & CLIMATE ACTION

BY LUKAS FALCKE, GUEST EDITOR

While the world is undergoing widespread digital and AI transformation, it is also facing the urgent challenge of climate change, which threatens the foundations of a functioning economy. Economic activities from industrial processes and increasingly energy-intensive data centers produce greenhouse gases that raise global temperatures.

To avoid the worst consequences of climate change, the Paris Agreement lays out a commitment to limit the increase of global surface temperature to 1.5 degrees Celsius. Although governments and companies are increasingly setting targets to achieve net zero emissions by 2050, progress has been extremely limited.

With the exponential development of digital innovations such as AI, blockchain, and the Metaverse, new opportunities arise to turn climate ambition into climate action. However, policymakers and managers alike seem to struggle with both their digital and their net zero transition. Given digital innovation's potential to significantly facilitate or hinder progress in the fight against climate change, it seems imperative to combine digital and climate efforts, focusing on a "twin transition." Yet so far, neither research nor practice provide much guidance for managing this transition.

In a recent article for the *Academy of Management Perspectives*, my colleagues Ann-Kristin Zobel, Youngjin Yoo, Christopher Tucci, and I began laying out digital sustainability strategies that challenge managers and policymakers to think about digital sustainability as an opportunity to innovate, rather than a way to comply with regulations.[1] We challenged digital sustainability researchers and practitioners to go beyond mitigation and reduction to consider carbon removal and nature regeneration. Importantly, we introduced digitally enabled and digital-first innovation as pathways to implement governmental and corporate net zero strategies.

At the same time, recent work by René Bohnsack, Christina Bidmon, and Jonatan Pinkse (all contributors to this issue of *Amplify*) highlight that digital sustainability can lead to unintended consequences.[2] Recent examples include the staggering emissions from blockchain mining and the data centers powering AI applications.

Given the potential for digital innovation to facilitate progress on the global economy's net zero transition and the vast risks of a digital sustainability approach, we need clear, actionable advice for managers and policymakers.

This issue of *Amplify*, Part I in a two-part series, offers a set of insightful articles from leading researchers and practitioners working on digital innovation for climate action. They share a common message: **digital innovation can be the key to accelerated climate action if managed correctly**. Of course, it will lead us directly to climate disaster if used irresponsibly. Applying the carefully crafted frameworks presented in this issue can help us avoid the latter and enable the former.

IN THIS ISSUE

We start with a fascinating overview of priorities for the twin transition presented by the special interest group Digitalization & AI for Sustainability (DAISY) at the Copernicus Institute for Sustainability Development at Utrecht University, the Netherlands. Christina Bidmon, Laura Piscicelli, and Iryna Susha, along with Devin Diran, Francesca Ciulli, and Albert Meijer provide four core messages. First, that a successful twin transition requires rigorous conceptual and empirical research that provides us with the tools and insights to help navigate the complexities of the transition. Remarkably, the second core message entails a warning to stay clear of tech optimism, which speaks directly to issues related to unintended consequences. Digital innovation can be the key to sustainability but will not solve all our problems — often, other approaches and nature-based solutions should be prioritized. Third, Bidmon et al. highlight the need to understand the factors that facilitate or prevent collaboration for digital sustainability. Finally, the authors point out that neither policies nor businesses can achieve the twin transition alone; rather, comprehensive policies are needed to provide smart incentives for businesses to engage responsibly.

> **DIGITAL INNOVATION CAN BE THE KEY TO SUSTAINABILITY BUT WILL NOT SOLVE ALL OUR PROBLEMS**

Our second piece highlights an insightful example of such a policy from a high-profile team of researchers at the KIN Center for Digital Innovation at Vrije Universiteit Amsterdam, the Netherlands. Damla Diriker and Amanda J. Porter teamed up with Ilse Hellemans from the Netherlands Organization for Applied Scientific Research (TNO). Their article shows how we can use digital innovation for mission-oriented innovation policies. Based on several years of research and practice, they present crowdsourcing as a vehicle for mission-oriented policies. The ability of digital innovation to leverage the "wisdom of the crowd" facilitates policy agenda-setting because it allows initial broad exploration and refinement into sub-challenges. It also promotes solution development through targeted experimentation and broadens the scope of experimentation. Finally, it facilitates policy implementation by collecting local insights on planned interventions and testing and gathering feedback on implementing interventions.

Next, two digital sustainability champions present insights on digital innovation's potential in the electricity and mobility industry based on their experience in leading climate tech start-ups and scale-ups.

First, Jannis Jehmlich, a senior product manager from 1KOMMA5, the German unicorn that set out to digitally transform the energy industry, provides a deep dive into the load management problem that comes with the integration of renewable energy sources into our energy systems. Because large-scale integration of renewables is probably the most important challenge for emission reductions, digital innovation can play a huge role. Jehmlich walks us through the complex supply and demand dynamics in Germany's energy systems and introduces the idea of a digital power economy driven by real-time data and a dynamic electricity tariff that can solve the load management problem. However, this envisioned digital power economy depends on comprehensive data gathering through smart meters, enhanced data processing capabilities, and synchronous regulation and process changes in a heavily regulated industry.

Second, Pieter Waller, cofounder and previous chief commercial officer of Chargetrip, a leading start-up in the smart electric vehicle routing space, takes us on a journey to scale e-mobility through digital solutions. Focusing on the electrification of commercial fleets, he unpacks the multitude of constraints that complicate e-mobility scaling. Waller then provides clear managerial guidance on how to manage these constraints. Similar to the challenge in the general electricity system, the task of matching supply and demand through data must be the guiding mantra. Furthermore, companies must design a technology stack that is open to integration and allows for the coordination of multiple actors through APIs. Finally, Waller explains that given the differences in regulations and local conditions across countries and locations, a flexible and bottom-up approach to piloting and scaling smart-charging and routing applications is the key to success.

UNLOCKING THE BENEFITS OF DIGITAL SUSTAINABILITY & MANAGING ITS UNINTENDED CONSEQUENCES REQUIRES THE RIGHT DIGITAL TALENT

Together, Jehmlich's and Waller's articles give us a clear picture of how digital innovation can be the solution to some of the most pressing and crucial sustainability problems if managed correctly. That brings us to our final two articles, which present frameworks for wisely managing AI and digital transformations.

In a thought-provoking article on the butterfly effect of AI, Jonatan Pinkse, professor of sustainable business and director of the Centre for Sustainable Business at King's College London, teamed up with René Bohnsack, professor at Católica Lisbon School of Business & Economics, Portugal, where she also heads the Digital+Sustainable Innovation Lab. Since "seemingly harmless" AI applications can have adverse effects on the environment and society at large, they present a comprehensive framework for wisely managing AI for sustainability. Managers must control AI's training data, the optimization drivers and parameters in AI algorithms, and the decisions taken based on training data and algorithms with potential biases. The authors demonstrate that successfully managing unintended consequences requires continually monitoring, measuring, modeling, and managing AI applications for sustainability.

Finally, Aspen Institute Fellow Alessia Falsarone sheds light on an often-overlooked aspect of digital sustainability: the digital talent needed to manage digital sustainability solutions. Unlocking the benefits of digital sustainability and managing its unintended consequences requires the right digital talent. Falsarone's best practices for growing the talent pool for digital climate transformations include: (1) identifying climate-resilience skills and capabilities, (2) leveraging collaborative tools and research for learning, and (3) embracing AI and feedback for advancement. Finally, going beyond the perspective of a single firm, she presents best practices for building and leveraging stakeholder networks for digital talent: leveraging living laboratories, fostering diverse networks, and championing collaborative initiatives.

Part I of this two-part series of *Amplify* presents six articles that advance our understanding of digital innovation for climate action. From priorities and smart policymaking to successful business applications and frameworks for managing AI and digital talent, this issue provides clear insights for managers and policymakers on how to make the twin transition a success.

Part II will dive deeper into mission-driven policies, provide more case studies and success stories on digital sustainability from various industries, and shed light on approaches for managing the increasing energy cost of AI and data centers.

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4 PRIORITIES FOR ADVANCING THE TWIN TRANSITION

Authors

Christina Bidmon, Laura Piscicelli, and Iryna Susha, with Devin Diran, Francesca Ciulli, and Albert Meijer

The importance of linking the green and digital transitions is undisputed. However, while both will transform our societies and economies, they are very different in nature and dynamics. This requires understanding the "twin transition" as a new phenomenon.

The European Commission has shown clear strategic direction and ambitious leadership by acknowledging that these two trends will shape Europe and its future. But the simultaneous pursuit of digital and green transitions raises questions for industry and government institutions alike. How can we steer the twin transition in the desired direction while avoiding recognized risks? How can we ensure that digital and green initiatives support and enhance each other rather than working against one another? What policies can simultaneously promote digital innovation and environmental sustainability?

One thing is certain: a just transition is crucial for widespread acceptance of green-digital solutions.[1] Ensuring that the twin transition proceeds in a fair, equitable manner hinges on a holistic understanding of its dynamics, including opportunities, pitfalls, and remaining uncertainties.

In this article, we propose four priority areas that managers and policymakers should consider as they work to understand and advance the twin transition. Our ideas are based on a joint session with researchers, policymakers, and practitioners at the first annual symposium of the Special Interest Group on Digitalization and AI for Sustainability (DAISY), hosted by the Copernicus Institute of Sustainable Development, Utrecht University, the Netherlands.

During the session, we had a unique opportunity to explore the interplay between the green and digital transitions, discuss drivers and concerns, and gather expert advice on how it may be possible to align the transitions. Based on this, we identified four priority areas for better understanding and advancing the twin transition (see Figure 1):

1. **Conducting systematic empirical research** to inform data standardization efforts and overcome the problems associated with data fragmentation (e.g., operational inefficiencies and security risks)
2. **Steering clear of "tech solutionism"** and exploring areas where little or no technology use can be beneficial
3. **Developing a comprehensive understanding of the relational factors at play** in the twin transition (e.g., power imbalances, fairness)
4. **Combining government regulation with smart incentives** for business in a well-rounded twin transition policy

> **ONE THING IS CERTAIN: A JUST TRANSITION IS CRUCIAL FOR WIDESPREAD ACCEPTANCE OF GREEN-DIGITAL SOLUTIONS**

These four areas are in line with the EU's call for a proactive and integrated management of social, technological, environmental, economic, and political domains in twin transition.[2] We believe the connections between "hard" and "soft" aspects, such as funding research on new technologies while considering alternatives to tech solutionism and fostering social innovation, are especially important. By combining hard and soft aspects,

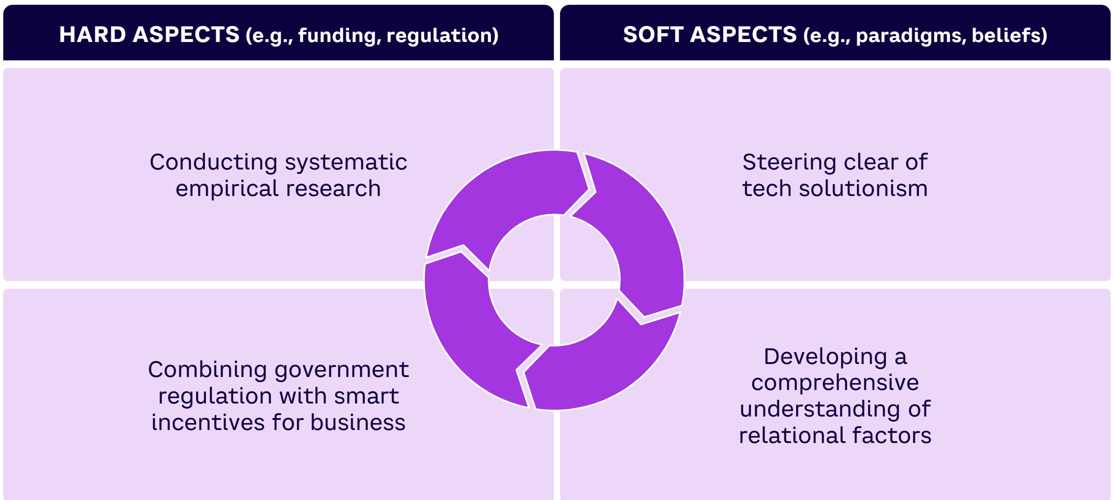

Figure 1. Four priority areas for understanding and advancing the twin transition

managers and policymakers (as well as researchers and civil society) can champion a comprehensive, multidimensional approach that leverages the strengths of various stakeholders and helps the twin transition proceed in a fair and equitable way.

THE INTRICACIES OF THE TWIN TRANSITION

"We should harness this transformative power of the twin digital and climate transition to strengthen our own industrial base and innovation potential," announced European Commission President Ursula von der Leyen at the advent of the European Green Deal.[3]

It is undisputed that the digital transformation has the potential to be a powerful tool in the fight against climate change and the move toward a more sustainable future. In fact, in an era where we are transgressing planetary boundaries, achieving climate goals is virtually impossible without digital technology.[4,5] Still, even though policymakers talk about a win-win and express confidence in their ability to govern and control the development of the twin transition, there are problems.[6]

The green and digital transitions can reinforce each other in many areas, but they do not necessarily align. Digital technology deployment can have unintended consequences, including rebound effects nullifying net emission reduction achieved or concerns about social aspects like data security and privacy.[7] The fact that it's impossible to fully forecast these effects and the difficulty in ensuring collaboration between the many sectors involved in managing these effects poses an enormous challenge for governing the twin transition.

The academic debate on unintended consequences and the crossover of multiple transitions is just beginning, and problems are already popping up in practice. What infrastructure investments should be made to support the twin transition? Which digital technologies are most critical for achieving sustainability objectives? How should we allocate funding? "There is no time to waste," states a recent report by the European Commission.[8] Indeed, the twin transition is already taking place and requires decisions.

CONDUCTING SYSTEMATIC EMPIRICAL RESEARCH

To make informed decisions, managers and policymakers need a reliable evidence base. Empirical research is crucial for identifying replicable best practices and uncovering potential risks (e.g., job displacement and digital divides). Unfortunately, current research often overlooks the negative social, economic, and environmental impacts of the twin transition and lacks empirical data.[9] When numbers and figures are available (e.g., measured carbon emissions), they tend to be difficult to compare and translate into data-driven insights designed to guide policymakers and businesses.

We need large-scale projects that allow for consensus building on definitions, standards, and which data to collect and share. A good example is CIRPASS, a collaborative initiative funded by the European Commission to prepare for the gradual piloting and deployment of a standards-based Digital Product Passport (DPP).[10] Consisting of 31 partners in 15 countries, CIRPASS aims to build stakeholder consensus on key data for circularity, define vocabulary standards to be included in the DPP, develop a cross-sectoral product data model, and propose an open DPP data-exchange protocol.

Researchers must leverage insights from such projects to create use cases and evidence-based roadmaps for the twin transition in different sectors. New approaches, such as the decentralized data reuse proposed by the Open Science in Qualitative Management Research (OPEN-QUAL) initiative, can help researchers compare qualitative case studies and datasets for a better understanding of the dynamics of the twin transition.[11]

Managers and policymakers can take a leading role in supporting and funding research initiatives that deliver the type of empirical, reliable, and comparable data essential for monitoring the progress and success of the twin transition over time.

STEERING CLEAR OF TECH SOLUTIONISM

Twin transition policy discussions tend to portray technology as a solution to environmental challenges, with less emphasis on how technology can contribute to the problem. This could lead to technology becoming a pacifier that prevents us from tackling the structural causes of sustainability problems. For instance, it is often presumed that as net zero technologies become widely available (e.g., clean energy for air travel, net zero data centers), our consumption patterns can continue as usual. Instead, technology should contribute to deep sustainability transformations.[12]

Government support for clean air travel in the Netherlands is an example of the reliance on technology as a solution.[13] The country's goal is to reduce CO_2 emissions by 35% by 2030 thanks to the development of "clean" airplanes and sustainable fuels. However, the number of flights is set to increase by 40% and the number of passengers by 60%.[14]

Relying on new technologies for sustainable air travel is an appealing promise for airlines, travel agencies, and consumers as they offer a way to maintain air travel without drastic cuts, but there is a real risk that these technologies will not be developed fast enough and will reinforce the belief that fundamental changes to the way we use air travel are not required.

Excessive reliance on digital technologies as a solution for sustainability can hinder essential structural changes. We call on managers and policymakers to discuss and investigate whether technology is the best solution to a given sustainability problem, whether low-tech solutions can be employed, and whether nonuse of technology can contribute to developing a better solution. We must let go of the idea that if we are not using the latest technology, the solution is old-fashioned.

Additionally, we call on researchers to support decision makers with evidence about circumstances in which low-tech solutions or technology nonuse create better outcomes.

DEVELOPING A COMPREHENSIVE UNDERSTANDING OF RELATIONAL FACTORS

The twin transition requires the coordinated efforts of a wide range of stakeholders, including governments, businesses, civil society, and international organizations. It is often assumed that these stakeholders will collaborate for the sake of sustainability and that solutions that are technically possible will be implemented. This assumption is problematic because relevant stakeholders lack connection, trust, and shared values, leading to power imbalances.

Take food-waste-recovery platforms like Too Good To Go, Olio, and MyFoody. These platforms, designed to transform traditional supply chains into circular ones, have emerged to address issues such as the lack of connection between relevant stakeholders. By leveraging digital technologies, these circularity brokers connect previously disconnected actors and facilitate their interaction.[15]

The underlying technology is rather simple, but these platforms face challenges related to relational factors. For instance, using digital platforms increases visibility, but this may worry suppliers who prefer not to disclose the amount of waste they produce. Some managers of donating firms are uncertain about legal risks and potential damage to their business reputation. There are also concerns around data sharing and which firm gets to be customer-facing.

It is essential to anticipate these issues and conduct a power analysis up front.[16] What is being proposed? Who gains from it? Who is potentially harmed or marginalized? Ignoring these relational factors jeopardizes the success of promising technological solutions.

COMBINING REGULATION WITH SMART INCENTIVES

A successful twin transition requires coordinated efforts from a variety of stakeholders, with businesses and industries playing a key role. An effective policy must strike a balance between regulation and incentives to drive business action. Relying only on regulatory pressure is not sufficient to motivate the private sector to take ambitious steps and can result in digital greenwashing. Moreover, policies in the digital domain are often perceived as vague, reactive, and lagging.

We urge policymakers to expand the use of smart incentives for businesses and citizen initiatives, alongside regulation, to stimulate private sector engagement and deliver win-win outcomes. This balance between regulation and smart incentives represents a measured approach, one that acknowledges the potential of technology solutionism to address societal challenges while recognizing there may be unintended consequences.

Policymakers should also develop a clear vision of both the desired and undesired roles and impacts of digital technologies in the short and long term, using a participatory and inclusive approach that involves all sectors of society. Explorative scenario analysis is a valuable tool for gathering this knowledge.

A notable example of this type of effort is the National Coalition for Sustainable Digitalization in the Netherlands, which engages in agenda-setting for policymakers from an industry perspective. Although the initiative still lacks crucial input from citizens, it serves as a building block toward a balanced approach to regulation and incentives.

Another prime example is the French government, which has been at the forefront of integrating ecological considerations into IT while balancing regulation and incentives.[17] Key legislation includes the 2020 Anti-Waste and Circular Economy Law (AGEC) and the 2021 Reducing the Environmental Footprint of the Digital Sector (REEN) Law. AGEC aims to inform consumers about the environmental impact of their digital consumption, and REEN focuses on increasing awareness, promoting reuse and recycling, implementing sustainable digital practices, and supporting energy-efficient data centers. Both incentivize companies to reduce the ecological footprint of digital technologies.

MOVING FORWARD

To successfully navigate the twin transition, a holistic approach is essential: one that recognizes the complexity of both technological and societal transformations. As the transition progresses, it will require a robust, multidimensional strategy that integrates technological innovation with sustainability principles, ensuring that the environmental and social dimensions are equally prioritized.

Among the most critical elements in understanding and advancing the twin transition lies in addressing both its hard and soft aspects. On the one hand, governments and industries need to continue investing in technologies, infrastructures, and regulatory frameworks: the "hard" elements. On the other hand, there is a growing need to challenge established paradigms, rethink consumption patterns, and engage in transparent and inclusive social dialogues: the "soft" factors that will underpin the cultural and behavioral shifts required for a just transition.

The four priority areas can be categorized into needs and opportunities based on their urgency and potential to unlock new advancements.

"Conducting systematic empirical research" and a "comprehensive understanding of relational factors" are needs; these are essential areas that must be addressed to ensure the success and smooth governance of the twin transition. Without these, the transition could stall or cause unintended harm.

"Steering clear of tech solutionism" and "combining government regulation with smart incentives" are opportunities; these are areas that present potential for innovation, better practices, and a deeper alignment between green and digital transitions.

By devising actions from the four priorities (see Figure 2), policymakers, the business community, researchers, and civil society can ensure the twin transition proceeds in a fair, inclusive, sustainable way. Ultimately, the success of the twin transition will depend not just on technological advances, but on a shared commitment to rethink societal norms, challenge entrenched power structures, and foster more equitable economic and social development models.

Going forward, continuous reflection and adaptability will be crucial. We must remain open to questioning the directionality and efficacy of digital solutions, especially when low-tech alternatives offer more sustainable and equitable paths.[18] The digital and green transitions should not only coexist, they should actively reinforce one another, creating a future where technological progress and environmental sustainability are mutually supportive. Meanwhile, the research and practitioner community must further expand the debate on what constitutes a deep sustainability transition and a deep digital transition.[19,20]

Conducting systematic empirical research	Establish, support & fund research initiatives that deliver the type of empirical, reliable, comparable data essential for monitoring progress & success of twin transition.
Steering clear of tech solutionism	Investigate whether technology is the best solution to a given sustainability problem; check whether low-tech solutions can be employed & whether nonuse of technology can contribute to better solutions.
Developing comprehensive understanding of relational factors	Anticipate relational issues & conduct a power analysis up front. What is being proposed? Who gains from it? Who is potentially harmed or marginalized?
Combining government regulation with smart incentives for business	Ensure the right balance between regulation & incentives; explore places where use of smart incentives for businesses can be expanded.

Figure 2. Actions to address the four priorities

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USING COLLABORATIVE CROWDSOURCING TO ADVANCE MISSION-ORIENTED INNOVATION POLICY

Authors

Damla Diriker, Amanda J. Porter, and Ilse Hellemans

We face an era where climate change is one of the most pressing challenges for businesses and society. The scale of the crisis — ranging from extreme weather events and rising sea levels to the devastating loss of biodiversity — demands bold, innovative solutions. Yet the pace of change has been alarmingly slow.

Unlike traditional approaches that focus on incremental improvements in specific policy areas, mission-oriented innovation policy (MOIP) takes aim at large, complex societal challenges like climate change by setting bold, overarching goals — often referred to as "missions."[1,2]

Although missions hold significant promise for driving radical change across sectors, MOIP orchestrators face a range of trade-offs as they design and implement mission interventions.[3] Failing to manage these trade-offs can result in fragmented efforts, misaligned priorities across sectors, and, ultimately, an inability to achieve the transformative impact the mission was designed to deliver.

Collaborative crowdsourcing can help policy orchestrators balance and navigate the trade-offs inherent in managing the missions aimed at climate change mitigation. Once viewed as a tool for generating ideas, crowdsourcing is now recognized as a beneficial method for engaging large, diverse groups of actors to collaboratively tackle systemic problems.[4]

Unlike tournament-based crowdsourcing, where members of the crowd compete to solve a problem, collaborative crowdsourcing platforms engage the crowd to leverage their collective intelligence, skills, and resources to address the problem.[5] By lowering the threshold for participation and offering visibility into a wide range of concerns and suggestions, collaborative crowdsourcing helps orchestrators design more effective governance structures and processes.

In this article, we discuss how MOIP orchestrators can use collaborative crowdsourcing platforms to manage the intricate trade-offs inherent in MOIP: balancing intentionality with emergence in agenda setting, managing monodisciplinary and multidisciplinary experimentation in solution development, and navigating the simplicity and complexity of mission implementation. We also suggest practical implementation steps and actionable tips for policy orchestrators who wish to add crowdsourcing to their innovation toolkit.

> **COLLABORATIVE CROWDSOURCING PLATFORMS ENGAGE THE CROWD TO LEVERAGE THEIR COLLECTIVE INTELLIGENCE, SKILLS & RESOURCES TO ADDRESS THE PROBLEM**

COLLABORATIVE CROWDSOURCING: VEHICLE FOR MOIP

Missions are designed to address complex, multifaceted issues like climate change by cutting across sectors and disciplines to encourage collaboration among government, knowledge institutes, industry, academia, and civil society — each with its own interests, priorities, and agendas.[6] Because the problem spans multiple sectors (energy, agriculture, transportation, and more), solutions often have ripple effects, leading to unexpected outcomes. The impacts of problems like climate change are felt across industries, geographies, and ecosystems, making it challenging to pinpoint clear boundaries for action. These interconnected issues and uncertain outcomes make it difficult to predict the full impact of any given intervention.[7]

As a result, MOIP orchestrators must continually navigate trade-offs.[8,9] What is highly desirable in achieving one goal (e.g., aligning action across stakeholder groups) may require compromises on another (e.g., relaxing initial goals to respond to emerging issues), forcing policy orchestrators into a delicate balancing act.

Collaborative crowdsourcing can play an important role here, helping orchestrators: (1) create governance structures that foster collaboration without compromising individual stakeholder needs, (2) facilitate iteration and course correction as knowledge or needs emerge, and (3) employ flexible yet focused strategies to adapt to shifting circumstances while maintaining clear objectives. Figure 1 provides an overview of the trade-offs in the various phases of MOIP and shows how a collaborative crowdsourcing process can be used to manage them.

TRADE-OFF 1: BALANCING INTENTIONALITY & EMERGENCE IN AGENDA-SETTING

The first task for MOIP is defining the boundaries and key goals of the mission.[10] For example, one of the missions identified in a Dutch MOIP in 2019 was to create a fully CO2-free electricity system by 2050, focusing on solar and wind energy.[11]

Leaning on incumbents (experienced actors in knowledge and innovation) to draft the missions and programs facilitated the development of

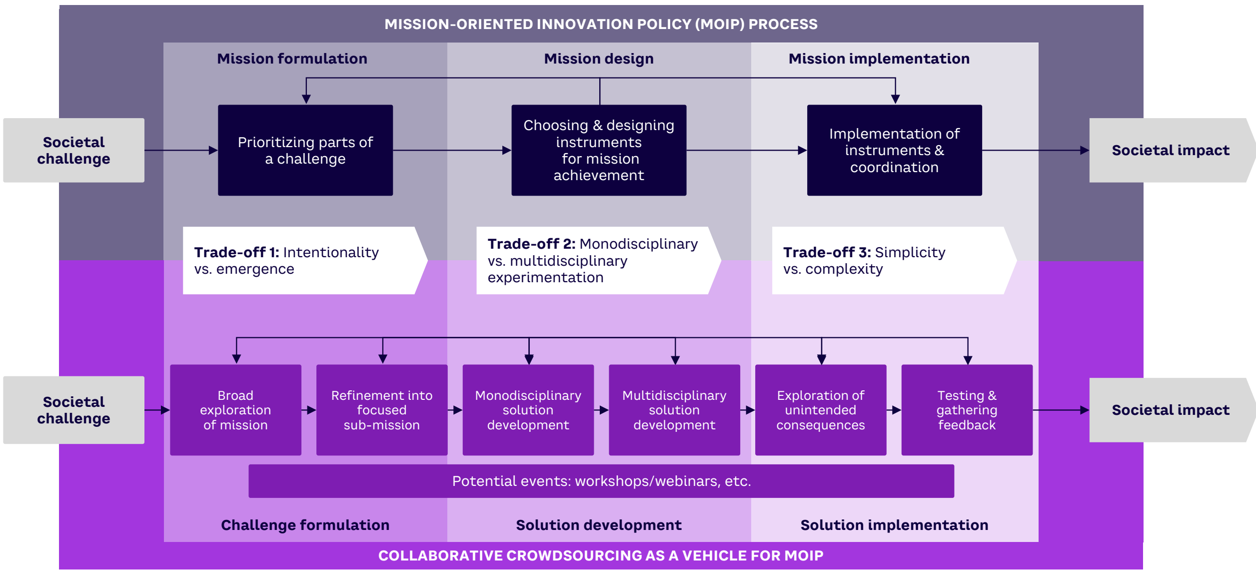

Figure 1. The MOIP process

specific programs and initiatives aimed at scaling these technologies.[12] This intentionality ensured that efforts were aligned, resources were used efficiently, and progress was measurable.

However, after investments in the original mission, incumbents became aware of new technologies and unforeseen challenges. Developments in hydrogen technology, raw materials, and circularity emerged as more important themes than originally thought, and increased tightness in the labor market began posing major challenges for the energy sector.[13] Defining the scope of a mission is a complex task that requires an iterative, flexible approach aligned with design thinking, as climate change is not a static issue.

Using crowdsourcing for the agenda-setting phase of MOIP widens the pool of participants to include those that may not fit well in established strategic agendas. For instance, diverse stakeholders (e.g., energy research centers/universities, environmental/sustainability nongovernmental organizations [NGOs], labor unions, and workforce development agencies) can be invited to offer valuable insights about challenges related to raw material shortages or labor constraints before sunken investments have created path dependency for a mission definition.

These contributions can be made visible in real time through the collaborative crowdsourcing platform, signaling to policy orchestrators early on which missions should gain more attention and which require a shift in focus or scope to address emerging concerns. The ability to course correct a mission's definition as knowledge or needs emerge helps missions stay on track as the world changes.

TRADE-OFF 2: BALANCING MONODISCIPLINARY & MULTIDISCIPLINARY EXPERIMENTATION IN SOLUTION DEVELOPMENT

The next task is choosing and designing the mission's innovation instruments.[14] These often focus on specific themes or solutions within a single field. Focusing on themes within broader missions enabled the Dutch MOIP to achieve targeted, accelerated innovation.

For example, the Unmanned Surface Vessel project focuses on developing autonomous vessels for offshore wind farms while Recycling for Lead-Free Solar Panels aims to create circular, sustainable solar panels.[15]

Both solutions fall under the broader mission of achieving a CO2-free electricity system by 2050, with the involvement of select technical organizations: Fugro, which specializes in geotechnical and geospatial services, and Sea-Kit, an expert in autonomous marine vessels, are collaborating on the unmanned surface vessels. TNO, a Dutch organization for applied scientific research, works with solar specialists to develop circular solar panels.

Focused experimentation within their respective fields enables rapid development and testing because stakeholder groups can concentrate on well-defined challenges without extensive coordination across sectors. However, monodisciplinary experimentation for too long will inevitably fall short of achieving systemic change. For instance, the broader mission of transforming the built environment requires that innovations in construction align with goals for energy efficiency, biodiversity, urban sustainability, and more, necessitating collaboration between city planners, environmental agencies, architects, construction companies, and energy suppliers.

Collaborative crowdsourcing lets policy orchestrators transition from monodisciplinary to multidisciplinary solution development by facilitating the integration of diverse perspectives across disciplines in incremental steps. In the case of the Unmanned Surface Vessel project, orchestrators can expand participation beyond a few preselected organizations by asking marine engineers, roboticists, and environmental scientists to contribute ideas or propose design improvements through the crowdsourcing platform.

Each discipline-specific contribution adds to the larger pool of knowledge being shared on the platform, helping stakeholders from different disciplines see the breadth of concerns and issues of the broader mission.

Importantly, crowdsourcing platforms allow participants to "like" or "upvote," which highlights the most relevant contributions and enables a multi-disciplinary community to surface critical insights that span disciplines.[16] For example, if a proposed solution from an architect is seen as highly compatible with energy-efficient designs and sustainable materials, engineers or environmentalists can vote to elevate that solution. Such insights can be fed back into the broader mission, ensuring that targeted innovations contribute to a comprehensive, systemic solution.

By making key insights more visible, orchestrators can guide the conversation toward solutions that best address the problem's complexity.

TRADE-OFF 3: BALANCING SIMPLICITY & COMPLEXITY IN MISSION IMPLEMENTATION

During the implementation phase, MOIP orchestrators often prioritize simple, scalable interventions for immediate, measurable results. However, focusing on simple interventions can lead to overlooking systemic complexities. For instance, in the Dutch MOIP's expansion of offshore wind energy, interventions are designed to deploy wind turbines rapidly and cost-effectively, contributing to immediate energy goals.[17] These interventions may overlook second-order effects (e.g., construction noise disrupting marine life) and third-order effects (e.g., declining fish populations impacting local fishing economies).[18]

Conversely, complex interventions that address these deeper issues can appear overly ambitious or impractical, leading to implementation difficulties. Striking a balance between simplicity and complexity during implementation is crucial to ensure that interventions both deliver quick wins and address broader systemic impacts.

Local stakeholders can visualize the immediate and broader impacts of potential interventions, and crowdsourcing platforms help orchestrators tap into that expertise. For instance, crowdsourcing can involve marine biologists, fishermen, energy companies, environmental NGOs, and coastal communities to provide input on expanding offshore wind farms. Fishermen can describe how construction noise affects fish populations, marine biologists can provide insights into potential impacts on marine biodiversity, and coastal community members can posit changes to tourism or the local economy.

Participants can critically reflect and comment on each other's contributions on the platform, and this dialogue highlights potential issues from multiple angles. The visibility of contributions to the platform lets orchestrators see the full range of concerns and suggestions, which they can use to iteratively refine interventions. For example, if feedback reveals concerns about construction noise or environmental impacts, orchestrators might implement quieter construction techniques or establish marine conservation areas.

IMPLEMENTING COLLABORATIVE CROWDSOURCING TO ENABLE MOIP

This section describes steps for using collaborative crowdsourcing at each phase of the MOIP process (agenda setting, solution development, and mission implementation) and offers practical tips to ensure its effectiveness. Table 1 provides an overview of steps, tips, and key questions to guide MOIP orchestrators in using collaborative crowdsourcing.

TRADE-OFF	GUIDING QUESTIONS	IMPLEMENTATION STEPS	TIPS FOR EFFECTIVE IMPLEMENTATION
Intentionality vs. emergence	• For the mission at hand, what assumptions do key stakeholders have about how intentional or emergent the agenda should be? • Can the mission be dissected into sub-missions, where different approaches to intentionality or emergence are required? • Historically, how did past efforts (non-crowdsourced) handle intentionality vs. emergence, and is a different approach now beneficial?	**Step 1:** Initial broad exploration **Step 2:** Refinement into sub-challenges	Manage large volumes of input with (1) advanced data analytics & (2) crowdsourced voting mechanisms
Monodisciplinary vs. multidisciplinary experimentation	• Are there sub-problem areas, where a specific discipline can provide building blocks (e.g., engineering solutions for energy renovation) that can later be integrated with other disciplines for system-wide impact? • How do monodisciplinary experiments contribute to the broader mission? Are there bottlenecks that require input from other disciplines?	**Step 1:** Target monodisciplinary experiments **Step 2:** Broaden scope for multidisciplinary integration	Facilitate knowledge integration across thematic areas with (1) dedicated moderators/facilitators, (2) labeling systems & (3) in-person workshops
Simplicity vs. complexity	• Are implementation experts actively involved in the crowdsourcing challenge? If not, how can they be brought in to refine and validate interventions? • How are potential unintended consequences of the proposed interventions considered?	**Step 1:** Collect local insights on planned interventions **Step 2:** Test & gather feedback on interventions	Ensure continued participation/engagement by (1) conducting sentiment analysis, (2) incentivizing engagement & (3) maintaining transparency

Table 1. Overview of guiding questions, implementation steps, and tips

PHASE 1: AGENDA-SETTING

Step 1: Initial broad exploration. Start by conducting a broad exploration of the mission to gather perspectives from a wide range of stakeholders. In this phase, crowdsourcing platforms help orchestrators tap into the collective intelligence of industry experts, academics, civil society members, and the public. The goal is to understand the full scope of the mission while identifying emergent themes and sub-problems in real time — things that traditional policy approaches (relying on a narrow set of preselected experts) might miss or reveal too late.

Step 2: Refinement into sub-challenges. The next step is to refine the inputs into sub-challenges. Leverage crowdsourcing platforms to highlight recurring themes, draw attention to the most pressing issues, and focus attention on areas with the highest potential. For example, general feedback on renewable energy can lead to sub-challenges like grid modernization, offshore wind feasibility, or energy-storage innovations. Shifting from broad exploration to sub-challenges enables focused contributions that clarify the sub-missions within the broader mission.

Challenge: Managing large volumes of input. One challenge during this phase is the volume of input. Crowdsourcing gathers feedback from a large, diverse crowd, and orchestrators may find themselves overwhelmed by the number of contributions. To ensure that emergent perspectives don't overwhelm the core mission and valuable insights aren't missed, use tools to filter and prioritize relevant contributions:

- **Leverage advanced data analytics.** Using AI-driven tools, orchestrators can more effectively manage large volumes of data on a crowdsourcing platform. These tools can automatically cluster similar ideas, track trends, and filter contributions based on predefined criteria such as alignment with mission goals, potential impact, and feasibility. Machine learning algorithms can help orchestrators sift through contributions to detect emergent themes or patterns. Using text mining to analyze contributions can reveal frequently mentioned aspects of the problem or recurring concerns to help orchestrators understand the key issues driving the conversation.
- **Use crowdsourced voting mechanisms.** Voting and rating systems enable participants to upvote or rate the most relevant contributions, reducing the burden on orchestrators and allowing the crowd to refine the mission's direction.

PHASE 2: SOLUTION DEVELOPMENT

Step 1: Target monodisciplinary experiments. Start by focusing on thematic areas that align with the broader mission, such as the sub-challenges identified in agenda setting. This encourages targeted experimentation on specific challenges, directing participants' attention to certain issues (e.g., energy efficiency in wind turbines) or key sectors (e.g., the maritime industry). This lets orchestrators extract insights from stakeholders with expertise in these topics, making it easier to generate early-stage experiments that can feed into broader efforts.

Step 2: Broaden scope for multidisciplinary integration. Once initial contributions have been collected from sub-challenges, orchestrators should broaden the scope, gradually introducing multidisciplinary collaboration. This involves integrating perspectives from across contributions and sub-challenges, such as combining technical innovations from engineers with the social or ecological concerns of environmental scientists, economists, and civil society.

Challenge: Facilitating knowledge integration. Solution development relies on how effectively different perspectives and knowledge are integrated. Without clear strategies for integrating knowledge, contributions risk becoming fragmented. Below are some tips for facilitating effective knowledge integration when using crowdsourcing in the solution development phase:

- **Assign dedicated moderators and facilitators.** Moderators or facilitators can guide discussions, tag/connect the right experts to specific conversations, and ensure that conversations remain focused and constructive. Moderators can also help bridge knowledge gaps between participants from different disciplines, facilitating knowledge integration.
- **Label and categorize contributions.** Use labeling systems to categorize contributions by theme, discipline, or relevance. This makes it easier for participants to navigate and engage with content and for orchestrators to track contributions that cut across multiple sectors or knowledge areas.
- **Host knowledge-integration workshops.** By hosting periodic workshops (virtual or in-person), participants from different disciplines can come together to integrate their insights. These workshops can help crystallize ideas and identify synergies that may not emerge in asynchronous online interactions.

PHASE 3: POLICY IMPLEMENTATION

Step 1: Collect local insights on planned interventions. Actively involve local stakeholders early in the process (community members, regional experts, business owners, and other affected groups). Use the platform to identify potential second-order effects (e.g., environmental impacts like habitat disruption) and third-order effects (e.g., socioeconomic consequences such as changes in local employment patterns) of planned interventions. By collecting and integrating these insights early on, orchestrators can develop a comprehensive understanding of the local context and tailor interventions to address specific needs and concerns.

Step 2: Test and gather feedback on implemented interventions. Once pilot projects are rolled out, orchestrators should use the platform to monitor their outcomes, collecting data on effectiveness, challenges, and unintended consequences.

Challenge: Ensuring participation and engagement. Maintaining active participation and engagement throughout the crowdsourcing process can be challenging, especially as interest wanes. Below are some tips for initiating and sustaining engagement when using crowdsourcing in the policy implementation phase:

- **Conduct sentiment analysis for deeper insights.** Orchestrators can use sentiment analysis to analyze the tone and emotional content of comments, helping them gauge the overall sentiment about specific interventions. This deeper layer of understanding helps orchestrators respond more sensitively to the public's concerns and better adjust policies. Orchestrators can use text mining tools in combination with sentiment analysis to identify patterns, trends, and emerging concerns from contributions shared by the crowd.

> **RESPONSIBLE INNOVATION MUST BE A KEY CONSIDERATION WHEN USING CROWDSOURCING FOR MOIP**

- **Incentivize engagement.** To encourage participation, create incentives or opportunities in the form of small grants, public acknowledgment, or the opportunity to directly influence policy outcomes.
- **Maintain transparency.** Maintain communication channels with participants throughout the process, letting them see how their contributions are being used and encouraging continuous engagement. Be sure to update participants on progress, acknowledge contributions, and celebrate milestones.

CONCLUSION

Collaborative crowdsourcing has the potential to accelerate MOIP, helping policymakers navigate complex trade-offs in agenda setting, solution development, and implementation. However, there are challenges to this approach, including dealing with large volumes of input, integrating diverse stakeholder perspectives, and maintaining ongoing participation. For crowdsourcing to be effective, it must be thoughtfully designed and actively managed throughout.

Responsible innovation must be a key consideration when using crowdsourcing for MOIP. Ensuring social inclusion is critical — every stakeholder must have the opportunity to contribute, and diverse perspectives should be actively encouraged to avoid marginalizing voices that are often left out. Platform design should adhere to the principle of "digital sufficiency," ensuring that digital solutions are lean and sustainable.

When used responsibly, crowdsourcing can be a powerful tool for accelerating innovation and advancing environmental goals, making it an ideal solution for organizations and governments committed to the twin transition of digitalization and sustainability.

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A SELF-REGULATING POWER GRID:

GERMANY'S DIGITAL TRANSFORMATION

Author

Jannis Jehmlich

The German power sector is undergoing a profound transformation that is fundamentally changing the way we generate, consume, and manage power. Historically, power systems have been governed by complex, highly regulated mechanisms, designed to ensure that supply meets demand while maintaining grid stability. With the rapid advancement of digital technologies, the industry is moving away from this centralized approach toward a more efficient, self-regulating system. This shift represents a significant evolution in how power is managed and consumed, and it promises to close the feedback loop between power consumption and creation, bringing substantial benefits to consumers, the energy transition, the grid, and society at large.

The convergence of power systems and digitalization is unlocking new levels of efficiency, transparency, and sustainability. Through advancements such as real-time data collection, smart meters, and dynamic pricing, power markets are being reshaped. This shift is essential for improving system efficiency and critical for the successful integration of renewable power sources, which are inherently variable. Digitalization provides the necessary tools to manage this variability, ensuring that power is available when needed while maintaining the balance of the grid.

This article explores how the German power economy is transitioning from a highly regulated, manual system to one driven by digital innovation. We examine the challenges of the pre-digital power economy, the transition to a digital model, and the numerous advantages this transformation offers for consumers, the power grid, and society.

> **THE CONVERGENCE OF POWER SYSTEMS & DIGITALIZATION IS UNLOCKING NEW LEVELS OF EFFICIENCY, TRANSPARENCY & SUSTAINABILITY**

OVERARCHING FRAMEWORK: THE GERMAN POWER ECONOMY

To understand the scale and significance of the changes taking place within the German power economy, it is useful to view the system through an abstraction of its key players and activities, both in its current form and the target state. The complete power economy is, of course, a lot more complex, and the players have many more roles than the ones discussed here.

The framework in Figure 1 focuses on two interdependent processes (consumption and generation) that have an influence on a shared resource (system load) and are kept in balance by a central element (the balancing mechanism).

As in many developed nations, the German power economy has long relied on analog systems that offer limited visibility into real-time consumption and generation patterns. Most readers probably still have an analog power meter with a spinning disc in their cellar. In 2023, about 99% of the power economy was still in this pre-digital state in which neither time, place, nor the amount of power consumption was available in real time.[1] This lack of transparency leads to several challenges.

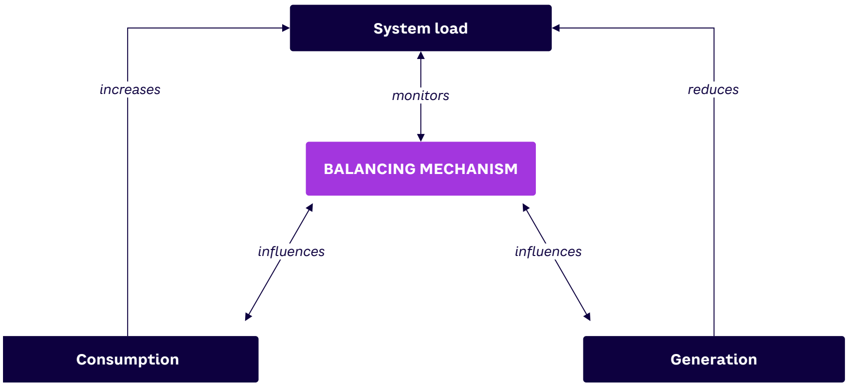


Figure 1. An abstract view of the German power industry

The most pressing is the need for a central regulated monopoly, in this case, the Transmission System Operator (TSO), to ensure that generation meets consumption at all times. As we can't store significant amounts of power, electricity must be consumed the moment it is generated, making balancing the grid especially difficult.

Because the grid lacks real-time data, the involved parties rely on average consumption patterns across all consumers based on single historical studies to ensure that enough supply is available. These patterns are called "standard load profiles." This leads to inefficiencies, as the TSO must maintain large reserves of backup capacity to compensate for over- and under-supply at any given time.

This one-size-fits-all approach to consumption estimation and grid management means that differences between consumption and production are often balanced by having extensive backup power sources, such as gas power plants or pumped-storage facilities, which is costly and inefficient.[2]

The lack of real-time data also means that electricity pricing is disconnected from market conditions. Consumers typically pay a fixed rate for electricity, regardless of when or how much they use, which removes any incentive to shift consumption to times when power is less expensive or more abundant and leaves supply struggling to match demand.

Figure 2 shows the framework adapted to the current situation. Consumption and supply capacity need to be balanced for the system load not to tilt in one direction. In the middle sits the TSO as the regulated monopoly that monitors the system load (frequency of the grid) and uses workarounds like standard load profiles to estimate consumption and ensure enough supply is available for a balanced system. This is primarily done by having enough supply planned for the expected demand and dispatching fallback supply capacities as needed to compensate for estimation errors.

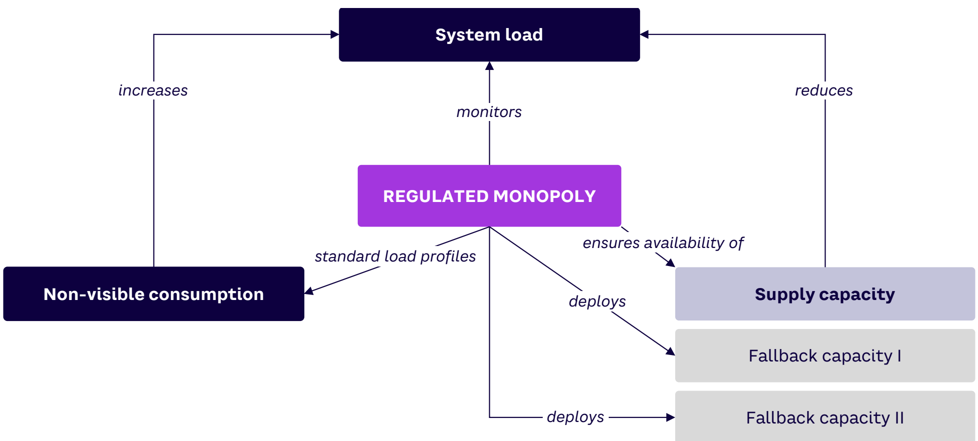


Figure 2. Workarounds to balance consumption against supply

TRANSITIONING TO A DIGITAL POWER ECONOMY

The key to overcoming these challenges lies in digitalizing the power economy. At the heart of this transformation are smart meters, which provide real-time data on time, place, and amount of power consumption. These devices record how much power is consumed at 15-minute intervals and transmit this information to both the consumer and the power provider.

This seemingly simple change has profound implications. With real-time data on consumption, power providers can accurately bill customers based on actual usage, rather than relying on estimates. Moreover, the data supports the introduction of dynamic tariffs, in which the price of electricity fluctuates based on market conditions.

During times of high demand or low supply, prices increase, encouraging consumers to reduce or shift their consumption. Conversely, when renewable power is abundant, prices drop, incenting consumers to use more electricity or shift consumption to these periods.

Dynamic pricing closes the feedback loop between power consumption and generation, letting consumers actively manage their power use in response to real-time pricing. This setup not only makes the system more efficient, it helps integrate more renewable power into the grid, as consumers are encouraged to shift their consumption to times when renewable power generation is high.

For example, electric vehicle (EV) owners can charge their vehicles overnight when electricity is less expensive due to low demand or when wind power is abundant.

Looking at Figure 3, we see many new connections between the now-visible consumption and the supply capacity, leading to a largely self-regulating system. The regulated monopoly in the middle is absent in this diagram, as the price signal takes over the role that this article focuses on (of course, it is still needed but to a lesser extent and for other roles).

DYNAMIC PRICING CLOSES THE FEEDBACK LOOP BETWEEN POWER CONSUMPTION & GENERATION

The diagram demonstrates how the feedback loop between consumption and supply has been effectively closed through dynamic price signals. For instance, when supply capacity is high (such as on a sunny day with abundant solar energy from photovoltaic panels) prices drop, encouraging consumers to shift their energy use to lower-cost periods.

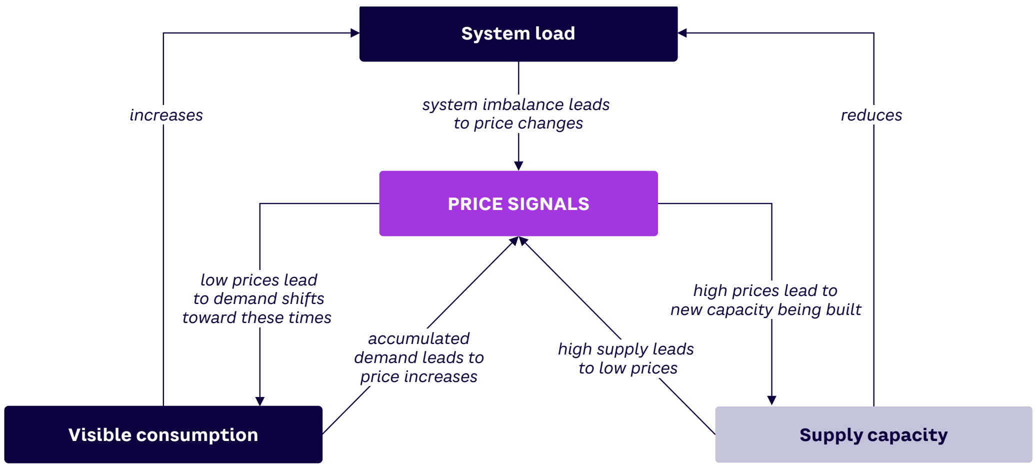
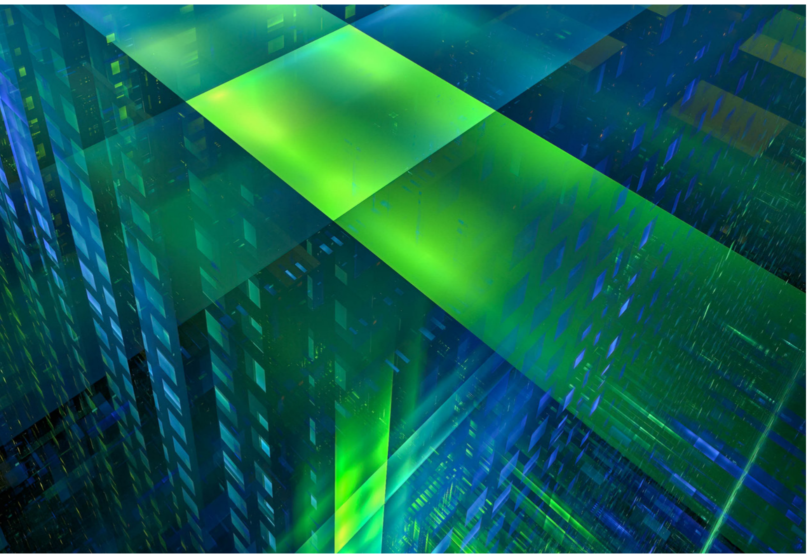


Figure 3. Self-regulating consumption and supply through price signals

As demand accumulates during these hours, prices naturally rise again, balancing the system. The increase in demand during periods of high renewable generation further incents investment in additional renewable capacity, such as solar and wind. As more renewable energy infrastructure is developed, the cycle repeats, accelerating the transition to a carbon-free energy supply and creating a virtuous loop that drives the system toward greater sustainability.



ADVANTAGES OF A DIGITAL POWER ECONOMY

The digitalization of the power economy offers numerous advantages for consumers and society. These benefits can be grouped into three categories: for consumers, for the energy transition, and for the grid.

FOR CONSUMERS

One of the most immediate benefits is the potential for reduced energy costs. By shifting their consumption to times when electricity is less expensive, consumers can take advantage of dynamic pricing to lower their bills.[3]

For example, homeowners with heat pumps can schedule them to run during periods of low-cost power, reducing their power bill. For consumers who have installed home batteries, the benefits are even greater, as they can store inexpensive power for use during more expensive peak times.

Companies are already offering integrated home energy management solutions that connect to all high-consumption household appliances and steer them based on the price signals of a dynamic tariff, allowing the customer to relax and enjoy inexpensive, sustainable power.

Additionally, real-time data on power consumption gives consumers greater visibility into their usage patterns, helping them make more informed decisions about how and when they use electricity.

This level of transparency and low electricity prices make it easier for consumers to electrify other areas of their household, such as transportation and heating. As the cost of electricity decreases and becomes more predictable, the economic case for switching to EVs and heat pumps becomes more compelling.

FOR THE ENERGY TRANSITION

Renewable power sources like wind and solar are at the heart of reducing carbon emissions and combating climate change. However, their variability poses a challenge to grid stability if the supply is not matched by demand. By passing real-time price signals onto consumers, the digital power economy helps customers follow the rhythm of sun and wind. When renewable power is abundant, prices drop, encouraging consumers to increase consumption. This makes it easier to integrate renewable energy into the grid and reduces the need for backup generation from fossil fuels.

The more consumers can align their power use with renewable energy generation, the more attractive it becomes to invest in renewable energy infrastructure. As demand for clean energy grows, so will financial incentives for developing additional renewable capacity. This virtuous cycle helps accelerate the transition to a low-carbon economy.

FOR THE GRID

The availability of real-time consumption data dramatically improves grid management. In the pre-digital world, grid operators had to rely on estimates and historical data to predict consumption patterns. Now, consumption forecasts can be adjusted depending on the real-time consumption of users.[4] With real-time data, grid operators can make more accurate predictions about demand, reducing the need for expensive reserves.

Moreover, as consumers shift their power use to off-peak times in response to dynamic pricing, the overall demand on the grid becomes more balanced.[5] This reduces strain on the infrastructure, allowing the grid to operate more efficiently and transport more power without the need for costly infrastructure investments.

In this way, digitalization helps optimize the use of existing grid infrastructure, reducing both operational costs and the need for additional investment, reducing the grid costs consumers must pay.[6]

A META VIEW OF THE POWER SECTOR'S TRANSFORMATION

The transition from a pre-digital to a digital power economy can be viewed as the closing of a crucial feedback loop between two interdependent processes: power consumption and generation. In the analog world, these processes operated largely independently, necessitating a regulating party in the middle to maintain balance. This is achieved by manual intervention and costly workarounds. In the power economy, the grid operators take on that role.

By introducing real-time data and a signal that connects the processes, digitalization allows the system to regulate itself. Consumption and supply are directly linked through a signal, which provides the feedback necessary for consumers and generators to adjust their behavior in real time. This system reduces the need for manual intervention, lowering operational costs and improving overall efficiency.

The key factors driving the transition are the availability of real-time data and the presence of a central signal (in this case, price) that both consumers and producers respond to. By aligning these two processes, a more balanced, efficient, and sustainable system is created.

PUBLIC TRANSPORT CASE STUDY

The concept of a closed feedback loop is not limited to the energy sector. A similar situation exists in public transportation (and many other industries where the system operates in an open loop). The number of buses and trains deployed is based on historical data and fixed schedules, with no real-time feedback about demand (see Figure 4). This leads to inefficiencies, as vehicles may run empty during off-peak hours or become overcrowded during peak times. Identifying some peak times is easy (e.g., children on their way to school), but other peaks and valleys are unpredictable: a cold wave that leads to many office workers staying home or a popular event that leads to an overload of a single connection.

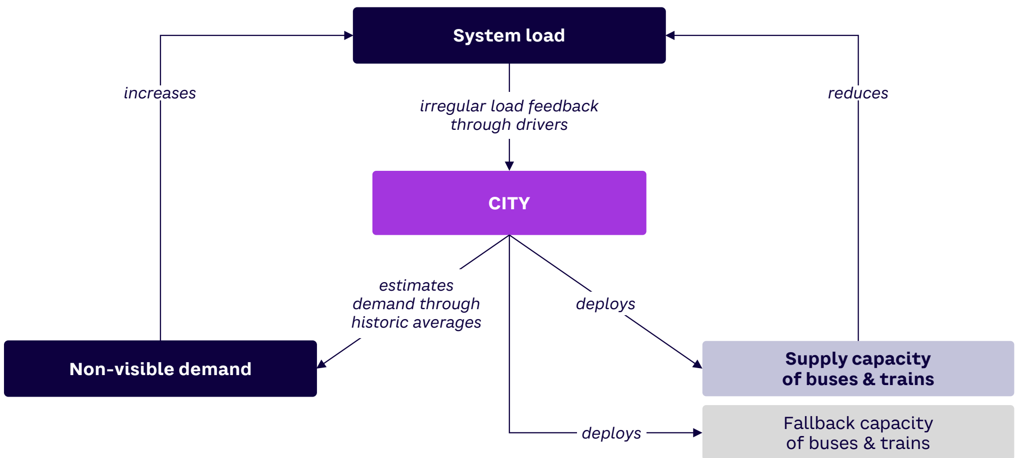


Figure 4. Case study of an open feedback loop in public transport

By integrating real-time data on passenger movement (potentially collected via telecommunications networks) and implementing dynamic pricing, the feedback loop in public transport can be closed. Off-peak discounts incent passengers to travel during quieter times, reducing strain on the system and improving efficiency. Or the city could shift capacities from one connection to another based on the live data. This would prevent overcrowding and dissatisfaction.

LESSONS FROM GERMANY'S DIGITAL POWER TRANSITION

Germany's transition to a digital power economy offers several lessons that can be applied across industries:

- **Data gathering.** The importance of starting early with data collection cannot be overstated. Without accurate, real-time data, digital initiatives will fail to reflect the true state of processes, leading to inefficiencies and missed opportunities. In Germany, delays in rolling out smart meters have hindered the transition to a fully digitalized power economy. The lesson here is to prioritize data collection and focus on building a solid foundation before layering on complexity.[7]
- **Data processing capabilities.** Access to real-time data is only valuable if it can be effectively processed and acted on. In Germany, grid operators have struggled to adapt to modern data processing practices, slowing the adoption of digital solutions.[8] Early build-out of robust data processing capabilities, both technology and human expertise, is essential to making full use of the data collected.
- **Synchronous regulation and process changes.** As digital systems take over many tasks that are managed manually, regulatory frameworks and processes must evolve in parallel. In Germany, the static nature of grid costs has deterred consumers from shifting their power use, limiting the effectiveness of dynamic pricing.[9] Introducing dynamic grid pricing, which reflects the actual strain on infrastructure, would further incent consumers to adjust their behavior and help optimize the system.

FINAL REMARKS

The digitalization of Germany's power economy demonstrates the immense potential of self-regulating systems to improve efficiency, reduce costs, and support the transition to a low-carbon economy. By leveraging real-time data and dynamic pricing, power consumption can be aligned with supply, creating a more balanced and sustainable system. As industries around the world undergo digital transformations, the lessons learned from Germany's power sector provide a valuable blueprint for harnessing the power of self-regulation to unlock new levels of efficiency and sustainability.

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DIGITAL SOLUTIONS ARE CRUCIAL TO SCALING E-MOBILITY

Author

Pieter Waller

This article explores how digital innovation can be used to transition to and operate large-scale electrified commercial vehicle fleets. It builds on prior research on digital sustainability, industry experience, and empirical illustrations.[1,2]

THE PROBLEM

The large-scale electrification of commercial vehicles is urgently needed. In the Netherlands in 2022, light and heavy commercial vehicles accounted for nearly 41% of CO2 emissions from road traffic while representing only 10% of all road vehicles.[3,4]

Between 2019 and 2022, CO2 emissions from these vehicles increased by 4% and 5.2%, respectively, mainly due to increased kilometers driven. In contrast, bus and coach CO2 emissions fell by 31.2% in the same period, largely due to government-mandated rapid electrification of city buses, with 27% of all city buses being electric by the end of 2022.[5,6]

THE OBVIOUS SOLUTION

The logical conclusion is that the electrification of commercial vehicle fleets needs to be scaled up quickly. Replacing all vans and trucks with battery-electric equivalents and electrifying depots seems like a straightforward solution to reduce emissions and air pollution. Awesome, let's go!

(Still need convincing that electric vehicles [EVs] are less damaging to the environment versus internal combustion engine [ICE] equivalents? I am happy to point you to the amazing work of Auke Hoekstra, program director at NEON research at Eindhoven University of Technology.[7])

UNFORTUNATELY ...

Although necessary, the electrification of commercial vehicle fleets is not that simple. When not done right, it becomes expensive, complex, and ineffective. It is so new to the world that it makes AI hallucinate. When prompted to create "a depot for electric delivery vans with chargers and packages," AI makes up some bizarre stuff (see Figure 1). It simply has no training data to make such an image.

> **THE LOGICAL CONCLUSION IS THAT THE ELECTRIFICATION OF COMMERCIAL VEHICLE FLEETS NEEDS TO BE SCALED UP QUICKLY**

Figure 1. Four images created with Adobe Firefly based on the same prompt, none representing a realistic solution.

Compared to city buses or passenger vehicles, commercial vehicle fleets encounter more constraints that affect their electrification and efficient operations. The constraints arise from factors such as electricity generation, storage, and access; EVs and charging infrastructure; and logistical and fleet operations.

To address these challenges, it's essential to understand the implications these constraints have on operations, recognize the trade-offs and optimization points they introduce, and acknowledge that a suite of intelligent software solutions can help manage the trade-offs while capitalizing on opportunities for optimization. With this understanding, it's possible to scale e-mobility operations to reduce the total cost of operation of a commercial fleet, accelerating the EV transition and sustainability impact.

UNPACKING THE CONSTRAINTS

ELECTRICITY

Electrifying commercial vehicles at scale involves more than replacing a propulsion system and energy source. There's a fundamental difference between using energy from fossil fuels and using electricity for mobility operations.

The energy transition impacts both the supply and demand sides of the electricity system, challenging the grid's balance. Renewable energy sources are increasing on the supply side; on the demand side, processes previously powered by fossil fuels are being electrified.

Hydropower and biomass offer stable renewable energy but face geographical limitations and scalability issues, respectively. Solar and wind power, although scalable and cost-effective, present challenges due to their production volatility.

This volatility makes grid balancing from the supply side more difficult, increasing the importance of using dynamic electricity pricing to incentivize demand at appropriate times. Consequently, electricity prices have become more volatile, with variations of up to 1,000% in a day in the Netherlands. Negative prices are also possible, with 105 instances of hourly negative prices in 2023, up from 70 in 2021.[8]

On the demand side, the electrification of various activities (heating, cooking, production processes, mobility) is changing the predictability of electricity needs. For instance, any location with electricity can become a charging point, creating a totally new source of electricity demand.

These changes make it challenging for grid operators to maintain balance. The transition requires new strategies for managing supply volatility and unpredictable demand patterns, emphasizing the need for flexible, responsive electricity systems.

IMPLICATIONS FOR E-MOBILITY AT SCALE

Using electricity to scale commercial vehicle mobility operations has several important implications. First, demand for electricity must be balanced with supply in terms of quantity, location, and timing. The ability to predict in advance how much energy will be needed, as well as where and when it will be required, simplifies the process of securing the necessary supply, especially since a fleet will not have access to unlimited electric energy. Additionally, increasing access to electric energy is not a quick process; in some cases, it will not be feasible. Ideally, EV fleets will be able to take advantage of fluctuating electricity prices. Furthermore, charging can occur at a wider range of locations compared to traditional fueling stations.

EVs & CHARGING

The second set of constraints impacting efficient fleet electrification comes from EVs and charging. To understand these challenges, it's useful to contrast them with the ICE ecosystem.

THE ICE AGE

Over the past century, the ICE vehicle ecosystem has been refined and optimized. There is universal compatibility between vehicles and fuel pumps, ensuring that fueling is consistent across stations. Fueling speeds are uniform, and widely accepted payment options are available at all stations. The extensive distribution of fuel stations significantly reduces the risk of running out of fuel, and price variations between stations are relatively small, typically 0% to 5%. Decades of fleet operator experience have led to predictable outcomes in terms of fuel consumption, maintenance, vehicle capabilities, operating costs, and residual values.

EV VARIABLES

With battery EVs, established norms and standardized practices are evolving. We are just beginning to adopt this technology and need to invent, create, and optimize its ecosystems. In doing so, many variables have an operational impact on EVs. We must take these on board and design for them.

The electrification of commercial fleets introduces several complexities related to charging infrastructure, starting with plug types. Multiple incompatible plug types exist (e.g., Combined Charging System [CCS], CHAdeMO [charge for moving], Type 2, North American Charging Standard [NACS], and Megawatt Charging System [MCS]). Although there has been some regional convergence, it's essential to know which chargers are compatible with your fleet to ensure successful charging.

Charge power also varies across chargers, directly impacting charge times. To avoid unnecessary time and financial costs, it is crucial to identify in advance the optimal chargers for each vehicle. Although charging takes longer than refueling, it can be done wherever electricity is available, enabling an "always charging" approach. Charging is most efficient when combined with other activities to minimize downtime.

Another challenge is availability: busy periods can lead to bottlenecks at charging stations. Access to reliable, predictive availability data helps drivers and fleet operators avoid wasting time waiting for chargers. Payment methods also vary across charging stations, and not all charge cards are universally accepted. Understanding which chargers support which payment methods is key to a smooth charging process.

Unlike traditional fueling, where prices are relatively stable, charging costs are highly volatile, making it important for fleet managers to carefully select charging locations to balance time and cost. Finally, an EV's range is not fixed. It depends on factors such as vehicle specifications, driving conditions, environmental factors, auxiliary systems, and battery type.

IMPLICATIONS FOR E-MOBILITY AT SCALE

These variables introduce complex considerations around charging infrastructure, vehicle capabilities, investments, and operational planning. Key areas to focus on include:

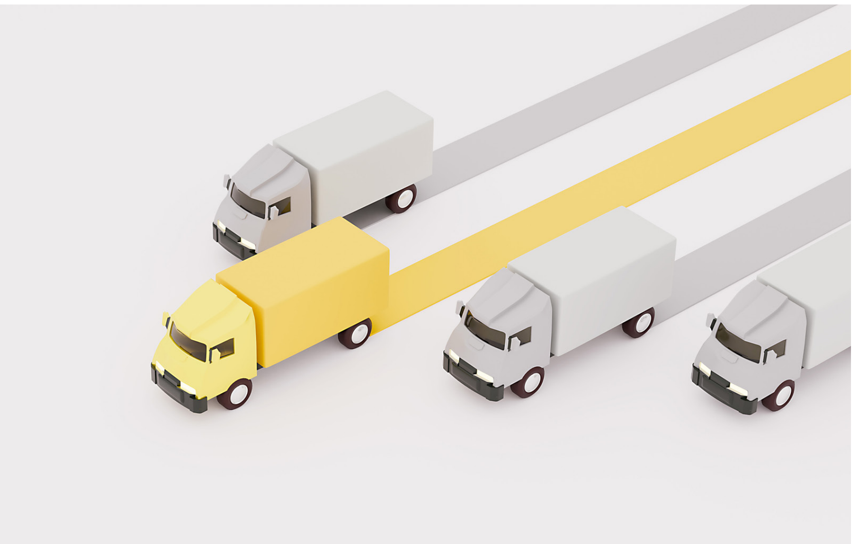
- **Compatibility** — ensuring vehicles and charging stations have matching plug types and power capabilities
- **Charging strategy** — balancing slow and fast charging options to optimize time and cost-efficiency
- **Payment and pricing** — navigating the complex landscape of electricity pricing, charge providers, payment methods, and pricing structures
- **Range management** — accounting for various factors affecting EV range to plan charging and routes effectively
- **Fleet optimization** — considering vehicle specifications, charging infrastructure, and operational needs to maximize efficiency and minimize total cost of ownership

By addressing these aspects, fleet operators can successfully transition to EVs while maintaining operational efficiency and cost-effectiveness.

LOGISTICS & FLEET OPERATIONS

The logistics, distribution, and supply chain ecosystem aims to move goods from manufacturers to consumers. It is highly intertwined and operates at low margins, leaving little room for errors or costly experiments during the transition to electrified fleets.

The logistics ecosystem is generally divided into three key stages: (1) the *first mile*, which involves collecting goods from producers or manufacturers; (2) the *middle mile*, which focuses on transporting goods between local hubs and regional distribution centers; and (3) the *last mile*, which entails delivering goods to the end consumer.



Each stage has unique challenges. In the first mile, ensuring physical accuracy in product selection and packaging, maintaining precise data and documentation, and having adequate infrastructure and technology are critical. The middle mile faces challenges related to long-distance international coordination and managing unforeseen disruptions.

The last mile is particularly complex. It involves meeting customer expectations for fast (and often free) shipping while managing high costs, which can account for up to 53% of total shipping expenses.[9] Other challenges include navigating urban congestion, optimizing delivery routes, handling returns and failed deliveries, providing flexible delivery options, and addressing sustainability concerns.

FRAGMENTATION

The last-mile delivery industry is highly fragmented, particularly in the Netherlands.[10,11] Although there are well-known brand names, most deliveries are handled by networks of subcontractors and sub-subcontractors. Most fleet operators have relatively few vehicles (10-40). The first- and mid-mile sectors are even more fragmented, with 90% of companies operating fewer than 10 trucks and only 1% operating more than 50.[12]

Service fleets, such as those used by construction workers, plumbers, and electricians, also rely on commercial vehicles. These drivers often take vehicles home, using hubs primarily for restocking equipment and onboarding crews.

Last-mile delivery and service fleets face the most pressure to electrify due to their urban presence. These fleets primarily use light- and medium-duty vehicles, for which many electric options are available. First- and mid-mile operations, which rely on trucks, are seeing slower adoption of electric variants as megawatt charging infrastructure develops.

Charging strategies vary based on operational needs. Last-mile delivery vehicles are typically parked overnight at logistical hubs or depots; service fleet vehicles are often taken home by drivers. For trucks, key considerations include daily travel distances and whether vehicles park overnight at depots or truck stops for long-distance operations.

These factors significantly influence charging requirements, vehicle ranges, available charging time slots, and resulting electric power needs. The fragmentation in the market makes change complicated. Small players lack the resources (financial and technical) to coordinate, develop, and introduce new processes and technology that require integration with other parts of an ecosystem.

The transition to e-mobility in logistics and fleet operations presents unique challenges for each segment. Successful electrification strategies must consider the specific operational needs, infrastructure requirements, and charging patterns of various fleet types while addressing the broader issues of fragmentation and sustainability in the industry.

THE WORKING SOLUTION

How do we get to seamless, scalable, and cost-effective commercial EV operations? We do it by: (1) accepting that the requirements, constraints, and dynamics mentioned above are (like your fleet) part of a new charge-drive-logistics ecosystem; (2) understanding that transitioning to and operating in this new ecosystem has different optimization points that must be designed for; and (3) realizing that simplistic, like-for-like hardware replacement of ICE vehicles with EVs and chargers won't cut it.

We need intelligent, flexible digital solutions to bridge the gaps between electricity, EVs, and logistics. These solutions consist of building blocks that must be integrated with one another, the chargers, and EVs. The aim of the hardware/software combination is to optimize the two primary states of a fleet: being driven (on a mobility mission) and being on downtime.

In a moment, we'll examine the software building blocks and describe their functions. We'll also discuss the most important implementation strategies, allowing you to efficiently scale and future-proof an electrified fleet. But first, we need to take a step back and discuss the most important design mantra for any fleet electrification — the principle that overarches all.

THE MANTRA: MATCH SUPPLY & DEMAND

As is the case with anything you want to scale in "electricity land," you must match supply and demand. In the case of e-mobility at scale, you must match charge supply with charge demand. Charge supply is a fleet's access to actual charge and battery capacity. Charge demand is the amount of energy a fleet needs for its operations.

THE TYPICAL EV PILOT

Most fleets don't follow this mantra. They order a small number of EVs as pilots, often with large battery packs, install a charger for each vehicle, and charge them fully overnight. These vehicles are then deployed on short, predictable runs.

The issue is that this approach doesn't scale. A like-for-like replacement results in overinvestment, potentially leading to higher total cost of ownership and loss of competitive position.

A BALANCED ELECTRIFICATION STRATEGY

The goal should be to efficiently grow an electrified fleet while balancing charge demand with supply. This involves having the right number of chargers with high utilization, understanding and managing grid connection limitations, and optimizing charging based on fluctuating electricity prices. It also requires investing in vehicles and battery capacities that are fit for purpose: electrifying all routes, operating at a lower total cost of ownership, and leveraging electrification as a competitive advantage.

BALANCING CHARGE DEMAND & SUPPLY IN OPERATION

A fleet's charge demand refers to the electricity required for all operations, considering each route's start and stop points, cargo, road conditions, year-round weather (e.g., extreme temperatures), peak operational moments, and the need for on-route charging on longer routes.

Charge supply includes the available charge power and capacity from the fleet's own charge locations, secondary sites with excess capacity, frequently visited stops and destinations, and public charging networks. To effectively integrate these options into a fleet's charge strategy, it is essential to know each option's predicted, dynamic pricing and access windows.

APPLICATION: DELIVERY FLEET OPERATING FROM A DEPOT

Applying this to a delivery fleet means you need to be able to predict the energy needed for each route for each vehicle, translate that into the required charge level, and calculate the optimal charge strategy based on the fleet's charge window and predicted electricity prices. This approach results in a lean charge strategy that avoids overcharging, allows vehicles to share chargers, and optimizes cost based on dynamic electricity pricing. But the journey doesn't end there.

As your electric fleet evolves, new challenges emerge. Longer routes require strategic on-route charging, necessitating sophisticated charge point recommendations. Fleet expansion demands rigorous simulations using historical data to determine the optimal mix of vehicle types, battery configurations, and charging infrastructure to avoid overinvestments.

At some point, many organizations will face grid limitations, presenting significant hurdles. Solutions range from upgrading existing connections to decentralizing charge locations — or even generating power independently and creating a local shared grid. Each option has trade-offs between operational flexibility, energy-supply reliability, CAPEX, operating costs, and revenue growth.

It doesn't matter the type of commercial vehicle fleet or what phase you are in with electrifying it; your ability to balance your charge demand and charge supply will determine your operational costs.

Keep in mind that accounting for a disbalance drives up costs and complexity: it results in overinvestment and stacking safety buffer on safety buffer. So the optimization points for running a lean, mean commercial EV fleet are found in that balance. That's why we call it a "mantra."

A TECHNOLOGY STACK OPEN TO INTEGRATION

A fleet's ability to match supply and demand depends on its capability to predict its charge supply and demand. This requires integrating various technologies, including:

- Logistics and operations
- Transportation management
- Energy management
- Depot charge management
- Predictive energy consumption
- On-route charge station recommendations
- Real-time vehicle data
- Charge-pricing data

No single company can provide all these solutions. Integration of multiple providers' technologies is key to creating a fleet-specific predictive stack.

THE CHARGING & DRIVING PROCESS

Figure 2 shows the technologies needed for charging and driving commercial vehicles from a depot, on longer routes, and when unexpected situations require dynamic rerouting. It also outlines all the steps and interactions between the various technologies:

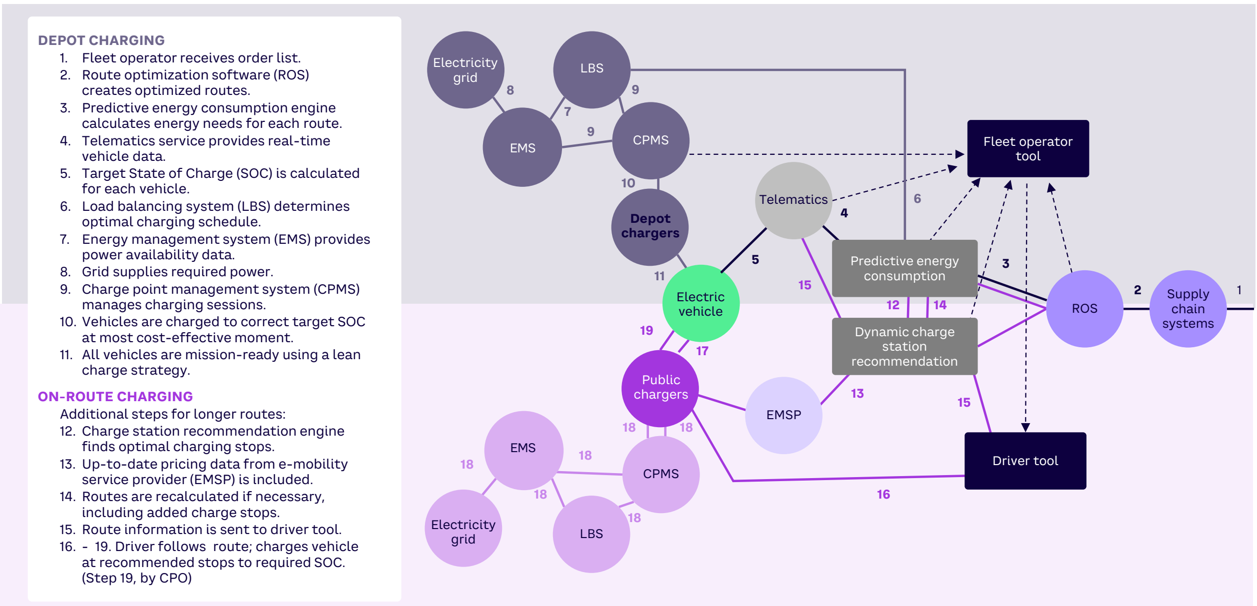


Figure 2. EV fleet technology stack

- **Depot charging a delivery fleet.** The process starts with charging all vehicles at the depot.
- **Driving long routes with on-route charging.** Steps 1 to 5 remain the same. Steps 12 to 20 are added, whereas Step 19 is done by the charge point operator (CPO) and is beyond the control of the fleet or driver.
- **Dynamic rerouting a delivery fleet.** The combination of real-time telemetry, a predictive energy-consumption engine, and a charge station recommendation engine enable dynamic rerouting of an EV. The use case for this is offering drivers a seamless contingency plan should anything not go according to plan on a route, such as an unexpected detour.
- **Fleet operator and driver tool.** Dashed arrows indicate the technologies "feeding" the apps that the fleet operator uses to orchestrate/monitor the fleet and that the driver uses to execute the mission.

FUTURE-PROOFING A FLEET'S TECH STACK

The ICE ecosystem has matured over a century, but the (commercial) EV and charging landscape is in its infancy. Today's EV operations require integrating various technologies to achieve efficiency.

Creating an adaptable, integration-ready technology foundation is the key to future-proofing fleet operations. This strategy allows for the seamless addition of functionalities or upgrades to existing systems as advancements occur, ensuring long-term operational efficiency and competitive advantage.

ONE SIZE WON'T FIT ALL

Energy supply varies by location, and fleets differ in purpose, size, and operating context. This reality demands a flexible, bottom-up approach to electrification. Success lies in:

- Leveraging historical fleet data for accurate simulation
- Incorporating site-specific electricity supply information
- Customizing hardware configurations for each fleet and location

Although a core technology stack (including route optimization, consumption prediction, station recommendation, telematics, and charge management systems) can be shared across fleet segments, it's crucial to maintain flexibility. An agnostic, integration-friendly approach prevents vendor lock-in and allows seamless incorporation of new technologies.

INTEGRATION STRATEGY

Fleet electrification parallels digital transformation in other industries. Three typical approaches are:

1. **Best in class** — integrating and combining top solutions for each function
2. **Single vendor** — opting for a ready-made, all-in-one solution
3. **Integrator** — employing a third party to blend various vendor solutions

Each strategy has benefits in terms of flexibility, control, and resource requirements. The optimal choice depends on an organization's needs, capabilities, and long-term vision.

CONCLUSION

The large-scale electrification of commercial vehicles presents significant challenges due to the highly optimized, low-margin nature of logistics and distribution systems. The fundamental difference between using fossil fuels and electricity for operations lies in energy storage and availability.

Fossil fuels allow for easy storage of large amounts of energy; electricity storage is limited and expensive. This means electric fleets must rely on the local grid's capacity and availability, which can vary.

To overcome these challenges and make electrification efficient, intelligent and flexible digital solutions are needed. These guiding principles are crucial for scaling and future-proofing an electrified fleet:

- **Match supply and demand.** Balance charge supply (access to charging and battery capacity) with charge demand (energy needed for operations).

- **Develop an open technology stack.** Integrate a variety of technologies to predict charge supply and demand, including supply chain, energy system, depot charging, vehicle, predictive range, on-route charging, and transportation management systems.
- **Adopt a flexible approach.** Recognize that one size doesn't fit all due to varying energy supply conditions at different locations. A bottom-up approach to electrification is necessary for efficiency.

By adhering to these principles and leveraging digital solutions, companies can take advantage of electricity's benefits, including lower costs, less environmental impact, improved user experience, reduced pollution, and new operating models.

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Pieter Waller is an independent e-mobility consultant, a scale-up advisor, and a user-centric innovator. He's deeply interested in understanding people's needs and behaviors and uncovering how these can be tied to sustainable business objectives that deliver real-world impact. Mr. Waller cofounded Chargetrip and successfully expanded it into a global e-mobility intelligence API. Chargetrip supports myriad companies, including Shell Recharge, Porsche, Fleetcor/Plugsurfing, Engie, Volvo Trucks, EnBW, Repsol, WEX, Norsk Elbilforening, FLO, Livewire, and Hertz, assisting them in developing new solutions for electric vehicles and fleets. With experience operating at the intersection of e-mobility service providers, charge point operators, fleets, and logistics providers, he has gained valuable insights into efficiently scaling electrified fleets and e-mobility services, playing a key role in future-proofing these services across Europe and North America. Prior to Chargetrip, he created successful fintech, video on demand, and B2B e-commerce platforms while also leading marketing teams at Bacardi and Louis Vuitton. Mr. Waller earned a master of science degree in economics from Erasmus University Rotterdam, the Netherlands. He can be reached at pieter.waller@lapinconsult.com.

HARNESSING AI BUTTERFLY EFFECT FOR SUSTAINABILITY:

DIGITAL BOOST OR RECIPE FOR DISASTER?

Authors

Jonatan Pinkse and René Bohnsack

The hype around the twin transitions paints a seductive picture of the power of AI to provide solutions for countless sustainability challenges. AI's boost in computing power helps firms identify opportunities and address the risks of sustainable innovations. The AI revolution has immense power to generate new solutions and transform business models, making them less wasteful, more energy-efficient, and more socially responsible. The potential to use AI to reimagine business and develop sustainable models for long-term value creation seems boundless. Recent research shows, for example, that firms using AI for decarbonization purposes gain more financial benefits by reducing operational costs through improved energy efficiency and waste-reduction initiatives.[1]

However, there is considerable concern about AI spinning out of control when used in an irresponsible and disorderly fashion. The global AI race could involve tech firms cutting corners while downplaying the risks. Firms using AI to improve their sustainability performance must be aware of the social responsibility hazards that come with it.

AI's fast-increasing carbon impact from soaring energy consumption is a serious concern.[2] Big Tech is receiving heavy criticism about the exponential growth in AI-driven data center energy consumption.[3] AI risks following in the footsteps of blockchain and cryptocurrency, both of which suffered significant reputational damage due to excessive energy consumption.[4]

Given that AI leads to data-driven decision-making, there is worry about the potential consequences for people's privacy, data security, and exposure to bias and discrimination. Scandals stemming from algorithms leading to ethnic profiling and discrimination abound.[5]

How can firms strike a balance between relying on AI for sustainable solutions and not creating social and environmental problems?

We propose a framework to help managers harness the seemingly uncontrollable elements. Using the analogy of the butterfly effect, our framework shows how managers can use AI for sustainability while putting simple guardrails in place to harness opportunities responsibly and prudently curtail risks (see Figure 1).

> **AI'S FAST-INCREASING CARBON IMPACT FROM SOARING ENERGY CONSUMPTION IS A SERIOUS CONCERN**

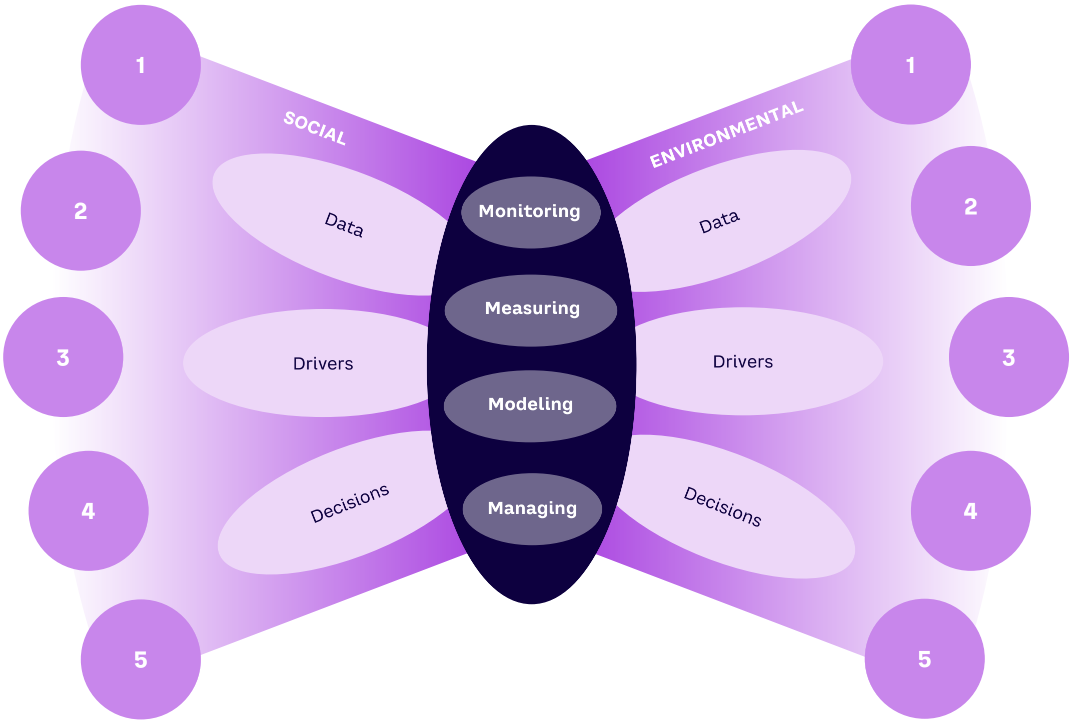

Figure 1. AI Butterfly Effect framework

The framework demonstrates how managers can leverage AI's unique attributes to perform the tasks of monitoring, measuring, modeling, and managing to improve sustainable business practices while keeping undesirable consequences stemming from reliance on data-driven decision-making based on algorithms at bay. By highlighting AI's positive and negative impacts across social and environmental dimensions, we explain how using AI for sustainability can create complex decision-making scenarios that need careful thought before taking action.

USING AI FOR SUSTAINABILITY

AI has the potential to become a general-purpose technology, as its applications are numerous and far-reaching.[6] Typical features include processing vast amounts of data, using neural networks to train and learn from previous tasks to adapt and improve, and speeding up decision-making processes. Intuitively, these features should help firms accelerate their transition to net zero, operate in a circular way/close resource loops, and become resilient to external shocks.

AI is useful in the context of sustainability because social and environmental issues confront managers with ambiguous data that cannot easily be translated into business-relevant information. For example, what is the value of protecting biodiversity or ending modern slavery? How will sustainability initiatives help a firm improve its financial bottom line or regulatory compliance? AI should prove pivotal in unlocking the value of sustainability-related data because it can process vast amounts of complex data at high speed that can be integrated into strategic decision-making processes.

Take Octopus Energy, which was founded in 2015 and is already the fifth-largest energy supplier in the UK. Much of its success comes from harnessing AI and data analytics. Its digital skills allow Octopus to get the most value out of renewables like wind and solar power.

Recognizing that customers are increasingly buying electric vehicles (EVs), heat pumps, and solar panels, Octopus offers a range of smart tariffs that best fit each technology's energy needs. In return for handing over some control over their appliances, Octopus customers can use them when electricity tariffs are at their lowest point. Using AI, Octopus improved its value proposition and began offering novel product-service combinations. The firm no longer sells energy alone; it gives customers the opportunity to buy heat pumps, home batteries, and solar panels.

Managing intermittent renewable energy flows is just one example of AI underpinning a business model that creates long-term value while advancing sustainability. However, being a sustainable business goes beyond offering renewable energy. Sustainability comprises many social, environmental, and economic issues, each posing unique challenges:

- **How can firms deliver on their promise that products like garments or chocolate have been produced without any form of modern slavery?** AI can assist firms in monitoring the firms involved in their supply chains and what practices they are using.
- **How do firms know whether their deforestation policies are having the intended impact of protecting primary forests across the globe?** AI can use remote sensing based on satellite data to help firms monitor remote areas they are trying to protect from further deforestation.
- **How do chemical firms know whether new chemicals contain toxic substances?** Based on information about materials, AI can help firms estimate whether these chemicals could be hazardous without having to test each one individually.

AI can broaden the scope of sustainability issues that firms can manage by facilitating more insight and control over what is happening in their global supply chains. With advanced estimation techniques that can handle vast amounts of data, firms can roll out sustainability initiatives more quickly.

At the same time, it is not always obvious how AI can help drive a firm's sustainability strategy. Which advanced tasks will AI perform, and how will improving these tasks drive social and environmental performance? Once the use case of AI for sustainability is clear, how can managers ensure their digital solutions are, on balance, improving sustainability performance rather than creating social responsibility hazards?

HARNESSING AI BUTTERFLY EFFECT

Using AI for sustainability can induce a butterfly effect, whereby seemingly harmless AI applications generate adverse social and environmental impacts that quickly spin out of control. Even if AI is used with the best of intentions, butterfly effects can occur because it is difficult to foresee how digital solutions will change sustainable business practices over time or in remote places.

AI relies on algorithms, so the way it shapes sustainable business practices can easily change when the algorithms are reprogrammed to fulfill a different purpose. Our framework is built on two elements that together give rise to potential unintended social and environmental impacts.

> **BUTTERFLY EFFECTS CAN OCCUR BECAUSE IT IS DIFFICULT TO FORESEE HOW DIGITAL SOLUTIONS WILL CHANGE SUSTAINABLE BUSINESS PRACTICES**

As mentioned, the first element consists of four tasks (monitoring, measuring, modeling, and managing) through which AI can improve sustainability performance. These tasks are on a continuum from identifying problems to formulating solutions.[7]

The second element consists of three parts of a data-driven decision-making process (data, drivers, and decisions) with algorithms as the foundation. The way AI for sustainability can lead to unintended impacts depends on: (1) the data involved in training and applying AI tools, (2) the drivers emerging from how algorithms optimize the data analysis, and (3) the decisions made using data or drivers containing errors or biases.

Whether social responsibility hazards occur depends on the specific task for which AI is used and the potential flaws in decision-making due to errors or biases in data, drivers, or decisions. As these hazards can be manifold, our framework does not specify them. Rather, the framework is a mapping tool for business leaders to list potential social and environmental hazards (up to five each). In the end, a firm's specific context determines which potential unintended impacts emerge and how they can best be managed.

MONITORING

A key part of managing sustainability is understanding a firm's impact on society and the environment. The potential social and environmental issues that might be material for a firm can be endless. Business leaders want to make sure they don't neglect an issue that could make them a target of social activists, shareholders, or the media. AI can vastly expand how much data is collected and analyzed, so it helps firms keep abreast of a large number of issues.

For example, managing biodiversity in the agri-food sector seems like an insurmountable task. But today, agri-food firms can use sensors to measure precipitation, temperature, soil quality, and more to keep an eye on the health of the natural systems on which they rely. AI also helps these firms uncover potential social and environmental issues. For example, remote sensing using satellite data helps them detect deforestation and modern slavery practices. Satellite imagery can detect sites like mines or quarries that are prone to using modern slavery and show how widespread such sites are.[8]

However, collecting vast amounts of data for AI adds to the need for more energy-consuming data centers. Managers must start weighing the benefits of that data against the burden of soaring energy consumption. Currently, data is considered a low-priced commodity, which does not fit with the potential hidden environmental costs.

There are social costs, too. Monitoring people working in remote places involves ethical considerations. The better the satellite-imagery resolution, the more remote sensing can lead to privacy violations, and exposing modern slavery practices can harm the vulnerable people who are victim to this.[9] Having more data broadens the scope for firms to better monitor their social and environmental impacts; managers must anticipate how the data could be used by someone without good intentions.

MEASURING

Measuring sustainability is akin to trying to measure the immeasurable.[10] Although there have been many attempts to measure social and environmental impact (e.g., social return on investment), each methodology comes with limitations. AI is not a panacea for this problem, but it lets firms capture and analyze many more data sources to reach a more reliable estimate of their sustainability impact.

Recently, machine learning has been used to estimate to what extent utilities around the world are investing in renewables and fossil fuels. Renewables are gaining ground, but the analysis showed that the vast majority continue to invest in fossil fuels.[11]

One key application for AI is in measuring a firm's carbon footprint. A firm can estimate direct emissions (Scope 1) from its fuel mix, but measuring indirect (Scope 3) emissions relies on assumptions about how goods are produced and consumed along its supply chains. AI can vastly improve estimation of indirect emissions because of its learning potential. For example, it can detect anomalies in the greenhouse gas emissions reports from a firm's suppliers.

Measurement's main social responsibility hazards occur due to AI's connection to the role of data and drivers in the decision-making process. Measurement relies on data availability, and AI can create better estimates for sustainability issues for which there's abundant data. A lack of data quality can seriously harm the reliability of decisions because AI starts filling in missing data without necessarily disclosing how.

As what is measured tends to be managed, the way AI algorithms measure social or environmental impact affects what managers will consider relevant for their decision-making. An algorithm's objective function determines how sustainability data is analyzed, and optimal solutions are found. Changing the objective function will affect how various social and environmental factors are traded against one another in the process of measuring a firm's sustainability impact.

A lack of transparency in how algorithms work and optimize data can lead to bias in drivers of a firm's sustainability performance. Managers should take care not to become totally dependent on algorithms in their decision-making without knowing the criteria used to measure social and environmental factors and their relation to overall sustainability.

MODELING

Better measurements help firms detect which social and environmental problems are material to their business. However, only when AI-improved measures become part of modeling exercises does their relevance become clear. Modeling reveals how urgent the problems are and which solutions best address these problems.

AI excels in identifying patterns and trends, leading to improved forecasting and modeling. Modeling is central to managing sustainability because firms need to know which trajectory they are on and whether their emissions are decreasing fast enough to stay within a safe operating space (preventing catastrophic climate change and ecological degradation).

Modeling is also essential to estimating which solutions are most appropriate to improve social and environmental performance. Firms need to know the potential impact of investing in specific solutions, such as green hydrogen for long-term carbon emissions, in part to convince potential investors.

As with measuring, the main hazard related to social responsibility is in how modeling affects which drivers managers consider important in their decision-making. Modeling exercises can provide insight into potential futures, but they are not necessarily based on real-world practices. Models use AI to uncover the most cost-efficient or fastest way to reduce emissions by plugging in green technologies that help achieve such objectives.

However, using algorithms to predict which green technologies can lead to the least expensive or fastest emission reductions can lead to an optimism bias that sustainability challenges can be solved quickly. For example, a green technology's success within a model might start driving investment decisions without data on whether the market is keen to adopt it.

Using historical data to train models to predict future trends can be risky because technology adoption curves are nonlinear, with growth often slowing. For example, sustainable solutions like hydrogen and electric cars tend to get caught up in a hype cycle. Exponential growth in one period might mean their success goes from boom to bust rather than growing further along the same trajectory.

Solving sustainability issues using models is no guarantee that there won't be any unforeseen problems in practice. Using AI for modeling can lead to managers forgetting about the difference between the model and the real world. They must be careful to avoid straying too far from what is technically possible and commercially viable in the near term and be cautious with letting modeling-based outcomes be the drivers of their decision-making.[12]

MANAGING

Although improved monitoring, measuring, and modeling can give a firm insight into how it is doing regarding sustainability, these are mainly diagnostic tools. They do not necessarily motivate managers to address issues by taking decisive action. Using AI to manage sustainability issues is solution-driven and potentially more impactful.

As argued, managing sustainability is all about managing and optimizing complex data. For example, integrating renewables that involve intermittency (solar and wind) will be nearly impossible without AI-based optimization processes. Similarly, any attempt to create a circular economy relies on managing complex material flows across organizational boundaries and optimizing who should do what to be practical and cost-efficient.

There is so much complexity involved in knowing what each intermediate product contains and whether a firm should reduce, reuse, or recycle it to optimize its sustainability performance that such decisions can only be made at scale using AI. Getting consumers on board also depends on AI because green technologies such as EVs, solar panels, and heat pumps rely on optimizing their integration into a home's energy system. People must be able to use green products without sacrificing too much of their current lifestyle; otherwise, they will not embrace them.[13]

The main social responsibility hazard related to managing sustainability with AI relates to which decisions AI will be used for. Although AI's potential to optimize processes and smooth new technology integration seems endless, firms might not be motivated to use AI for sustainability as their main priority.

It remains to be seen whether firms will use AI to optimize decision-making predominantly for sustainability or for other purposes (like operations) that could augment AI's negative consequences. Recently, Microsoft was accused of hypocrisy for selling both AI solutions to develop climate solutions and those designed to help oil and gas companies find more fossil fuel reserves.[14]

AI can help firms obtain financial benefits when managing sustainability, but the financial returns of applying it to other parts of the business (or highlighting other parts of their value offering, such as improving people's comfort) can be tempting. Even if AI is used to manage sustainability, the decision to use it at a larger scale for many other applications could offset any gains in sustainability performance.

CONCLUSION

AI holds the promise of creating a sea change in sustainable business practices, but the environmental costs of collecting, storing, and processing data and the social costs of relying on algorithms for decision-making are becoming visible. We hope that, over time, the benefits will prevail.

Our framework encourages business leaders to pause before using AI for sustainability. They can use it to assess which tasks they intend to use AI for, how their reliance on AI will change how they manage data, what drives their social and environmental performance, and which decisions are most impactful. In this way, they are much less likely to lose sight of sustainability when applying AI in their business.

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DIGITAL TALENT: THE KEY TO THE CLIMATE TRANSITION

Author

Alessia Falsarone

The climate transition of the global economy requires entire sectors to digitally transform their value chains. This shift is crucial since data and digital systems are vital for measuring and reducing emissions, increasing transparency, and ultimately driving sustainable practices. Corporate investments in emerging technologies are a starting point, but they don't guarantee lasting environmental or commercial impact. Amid discussions around human capital, responsible deployment of sustainable products/services, and growing evidence of bias, addressing the digital talent gap has become a priority.

Without a blueprint, companies are experimenting with setting attainable goals for their increasingly digital recruits. As climate innovations reach the market, they face scrutiny from multiple stakeholders — from reporting requirements to environmental and social due diligence by suppliers and customers.

By intentionally transforming these stakeholder networks into learning laboratories, organizations can gain invaluable experience. This approach can activate digital talent and ultimately turn collaborative experimentation into scalable digital solutions for climate action.

DIGITAL TALENT'S RELEVANCE FOR CLIMATE ACTION

There is no single roadmap for closing the digital talent gap across sectors. Instead, climate goals receive a reality check via verification set out in regulations like the EU's Corporate Sustainability Reporting Directive (CSRD), Germany's Supply Chain Due Diligence Act, and the US Inflation Reduction Act's greenhouse gas corporate reporting requirements.

Foundational skills and competencies are ballooning for a digital talent pool that can sustain the timely deployment of technology solutions across an organization while adhering to sustainability standards and balancing the consumption and regeneration of natural resources. With rapid advances in cloud-focused platforms and AI applications, the definition of digital transformation (DX) is moving beyond the continuous deployment of technology at scale. From operational efficiencies brought by digital automation to the creation of new ways of working, DX is set to reshape the organizational design of companies across economic sectors.

> **WITHOUT A BLUEPRINT, COMPANIES ARE EXPERIMENTING WITH SETTING ATTAINABLE GOALS FOR THEIR INCREASINGLY DIGITAL RECRUITS**

This is even more critical as organizations increase their DX investments while aiming to reduce the environmental footprint of their products and operations.[1] The concept of "own it first, centralize second," embraced by industrial technology giants like Schneider Electric captures the early incentives DX initiatives need to create internally to find commercial and environmental success externally. Building trust in the transformative power of technology hinges on owning the cross-team experiences it creates, tracking its impact on job satisfaction, and acknowledging the talent-retention gains it must generate before smarter business decisions can be realized.

An own-it-first mindset suggests that an organization must clearly define success and its role in delivering environmental sustainability as an outcome that aligns with its business strategy and the way it generates value. This may entail establishing internal operational targets, including product and process specifications that enable environmentally sustainable value delivery to customers.

Core to an own-it-first DX is owning the upside as much as the downside of each business decision. One example is Amazon's efforts to embrace the circularity of packaging materials as a tangible efficiency goal of its shipping platform by creating a playbook for suppliers to follow, starting with those contributing more than 50% of its supply chain emissions.[2] Although strong-arm tactics may draw the attention of Amazon's suppliers, creating positive outcomes across the entire procurement cycle will require educational resources and digital literacy, starting with connecting the shared experiences of customers and suppliers across its global marketplace.

A network of shared experiences is a necessary step in breaking the organizational inertia that threatens to keep digital talent from designing solutions to the global problems posed by climate change. For example, what may have started with internal champions and dedicated efforts led by a transformation officer is now the responsibility of virtually everyone in the firm.

In highly matrixed organizations, centralization may dilute the desire to ensure localized knowledge and practices are used to address local issues. However, the ability to recover localized know-how is even more relevant when it comes to mapping the environmental sustainability of the entire procurement cycle, especially for hard-to-abate industries.

Examples include industries with energy-intensive production that releases CO2 as a byproduct, including aviation, construction, chemical manufacturing, and shipping. Therefore, the ability of high-carbon-emitting industries to join the 90+ countries that have set net zero emission targets so far may be highly dependent on removing the information divide by depositing local knowledge about environmentally harmful disruptions to a central intelligence network accessible across industries.[3]

GROWING THE RIGHT TALENT POOL

Digital literacy and responsible technology use are prevailing topics in talent discussions for senior leaders, but many believe building sustainable practices that consider the environmental impacts of digital innovation is, inevitably, a trade-off. That trade-off is often left to hyperscalers (the so-called Magnificent 7[4] that have taken center stage in global financial markets for developing exceptionally sophisticated technology infrastructure at scale) to resolve.

It's no surprise that the race to establish carbon markets and deliver financial incentives for companies to offset their carbon production has followed the wide accessibility of IT infrastructure. This includes mechanisms such as carbon taxes, access to carbon-trading systems, and the availability of carbon offsets as tradable rights linked to funding projects that reduce or remove an equivalent amount of CO2 from the atmosphere.[5]

However, there's more to the conversation than the role played by large technology innovators. Global communities of digital natives are entering the workforce, providing valuable insights as early adopters of those solutions, and there are generations of consumers who were not "born" digital but don't want to feel left behind.[6] Research shows that tech-savvy employees are most likely to adopt an eco-friendly lifestyle, champion the earth's environmental well-being, and have the ability to influence sustainability-first buying decisions.[7]

FIRST STEPS

What can organizations do to develop and retain a talent pool equipped for a sustainable DX led by climate technologies without alienating industry veterans and pockets of their consumer base? First, they should identify the skills and capabilities specific to their organization that directly address the climate-resilience needs of their internal ecosystem and their external marketplace.

Beyond the immediate reward of dissolving internal silos of specialized knowledge, the rollout of a digital-native capability toolkit can enhance an organization's innovation roadmap while helping to develop a community of digital learners.

The international research community agrees.[8] The deployment of open, collaborative databases and global climate simulators like En-ROADS is already informing decision-making about optimal land use, carbon-neutral transportation routing, renewable energy consumption, and the impacts of rising temperatures on natural ecosystems.[9]

Beyond gaining functional experience in business roles, coupled with personal and professional alignment with the organization's mission, the right talent pool must be able to navigate both digital and ecological disruptions. The design of digital communities enhanced by pilot projects for faster learning and detection of key operational trends can streamline internal processes. This includes document analysis, previews of calculation methodologies like testing environmental assessment reports, configuring carbon-emission models with specific corporate inputs, and offering specialized dashboards for external dissemination.

For example, a pilot launched by Microsoft earlier this year aims to streamline and expedite the sustainability lifecycle of the company's products and support the creation of value chain–specific solutions for its customers across various economic sectors.[10]

Beyond the immediate learning and training advantages that generative AI pilot projects and autonomous agents could directly transfer to suppliers as they align their talent, products, and operations with climate priorities specific to Microsoft and its peers, there is the potential for longer-term feedback gathering and knowledge transfer. This feedback can be applied to new domains to further advance climate R&D (see sidebar "Best Practices to Grow the Right Talent Pools for Digital Climate Transformation").

BEST PRACTICES TO GROW THE RIGHT TALENT POOLS FOR DIGITAL CLIMATE TRANSFORMATION

1. **Identify climate-resilience skills and capabilities:**
    - Assess your organization's specific needs for climate resilience in both internal operations and external market impact.
    - Develop a toolkit of digital-native capabilities that address these needs.

Upside: A climate-focused toolkit can enhance your innovation roadmap and foster a community of digital learners, breaking down silos of specialized knowledge.

2. **Leverage collaborative tools and research for learning:**
    - Use open, collaborative databases and global climate simulators like En-ROADS to inform decision-making on optimal sustainability practices.
    - Design digital communities and pilot projects for faster learning, trend detection, and process streamlining.

Upside: Open collaborative networks can provide valuable experience in navigating digital and ecological disruptions.

3. **Embrace AI and feedback for advancement:**
    - Explore generative AI and autonomous agent pilots to streamline sustainability efforts and create sector-specific solutions.
    - Recognize the potential of these pilots for knowledge transfer to suppliers, aligning their talent, products, and operations with climate priorities.

Upside: Gather long-term feedback from these initiatives to advance climate R&D in new domains.

CONDUCTING BOTH IMPACT & RISK ASSESSMENTS AS PART OF A STAKEHOLDER NETWORK ENCOURAGES DIVERSE PERSPECTIVES

BEST PRACTICES TO BUILD & LEVERAGE STAKEHOLDER NETWORKS FOR DIGITAL TALENT

1. **Leverage living laboratories:**
   - Participate in existing living laboratories or establish one to enable collaborative research and tailored strategy development.
   - Use experiential learning from field labs with diverse stakeholders for knowledge gain and innovation.
2. **Foster diverse networks:**
   - Build stakeholder networks with diverse perspectives.
   - Conduct regular impact and risk assessments within these networks to address potential biases and improve innovation reach.
3. **Champion collaborative initiatives:**
   - Consider participating in cooperative climate initiatives.
   - Establish clear climate policies and benchmarks within these initiatives, balancing knowledge sharing with antitrust and intellectual property protection.

STAKEHOLDER NETWORKS FOR CLIMATE INNOVATION

One important question to consider is: beyond environmental purpose and mission, are open innovation ecosystems all about maximizing productivity gains for a digital talent pool that prioritizes automation of existing processes and infrastructure instead of innovating? Not quite.

The importance of stakeholder collaboration in holistically addressing climate challenges is a focal point of attention for executive leaders in the private sector, as the financial community and the general public continue to ponder the legitimacy of environmental claims and challenge those corporate advocacy initiatives favoring conflicting business priorities (see sidebar "Best Practices to Build and Leverage Stakeholder Networks for Digital Talent").

It is worth looking at what researchers call "living laboratories": communities of knowledge advancing climate literacy and innovation through continuous user engagement.[11] These include companies, governments, nongovernmental organizations, and academic institutions experimenting with environmental solutions and advancing equitable economic transitions. Living laboratories have been established in several major cities, providing a testbed for participative research and leading to individualized strategy development for companies looking to explore specific environmental challenges in an urban area.

The Amsterdam Institute for Advanced Metropolitan Solutions (AMS) created a living lab for logistics companies looking to gain insights about a circular economy network.[12] Launched early this year, LogiCELL is a two-year pilot for corporate participants. By enabling a digital ecosystem through the lived experience of a field lab with a digital backdrop that involves employees, customers, suppliers, and the public sector, digitally delivered experiential learning has the potential for faster scale-up and more effective resource allocation through business model innovations that resemble entrepreneurial clusters.[13]

Another benefit of active stakeholder networks like living laboratories is their ability to address bias in the assumptions underpinning climate scenarios at early development stages. Conducting both impact and risk assessments as part of a stakeholder network encourages diverse perspectives while improving the reach that climate innovations can achieve and mitigating potential biases.

This is particularly relevant in the context of cooperative climate initiatives, in which private and public sector participants (along with investors and civil society representatives) have shown tangible progress in regulating each other's contributions.[14] This includes designing actionable climate policies (mitigation or adaptation) and benchmarking individual and network-level progress, such as:

- **Climate targets** — energy efficiency, emission reduction, renewable energy projects
- **Business-level targets** — market share gained, revenues per scale of adoption of products or solutions
- **Investment returns** of pooled financial resources mobilized to meet climate and business targets — direct technology investments, funds mobilized in partnerships, funds raised as a result of increased customer demand

Collaborative climate initiatives may prioritize compliance with antitrust laws and intellectual property protection of any potential innovation generated by a stakeholder network, but the organizational value of developing digital talent through such initiatives far exceeds the enormous risk of tackling it alone.

CONCLUSION

In the fight to address climate change, developing an effective digital talent pool and fostering active stakeholder engagement go hand in hand (see Figure 1). Corporate leaders seeking to scale up their digital innovation efforts need to rethink the way digital talent generates value.

We can all agree that developing a deep digital talent bench does not guarantee that digital innovation will succeed in the face of sudden climate threats. However, increasing critical digital talent capabilities by establishing collaborative stakeholder networks can help industries and markets build resilience to climate disruptions within the core of each organizational function.

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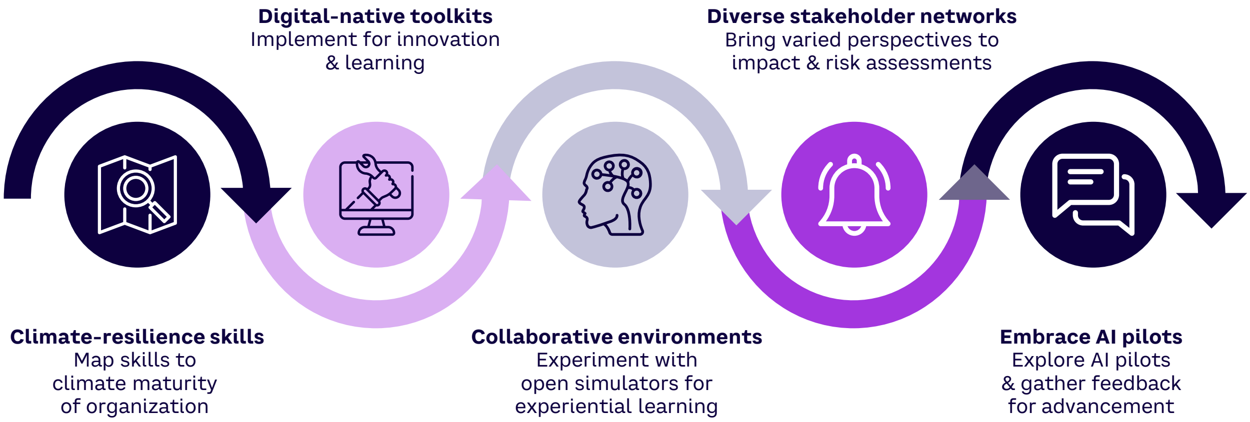

Figure 1. A framework to grow digital skills and leverage collaborative networks

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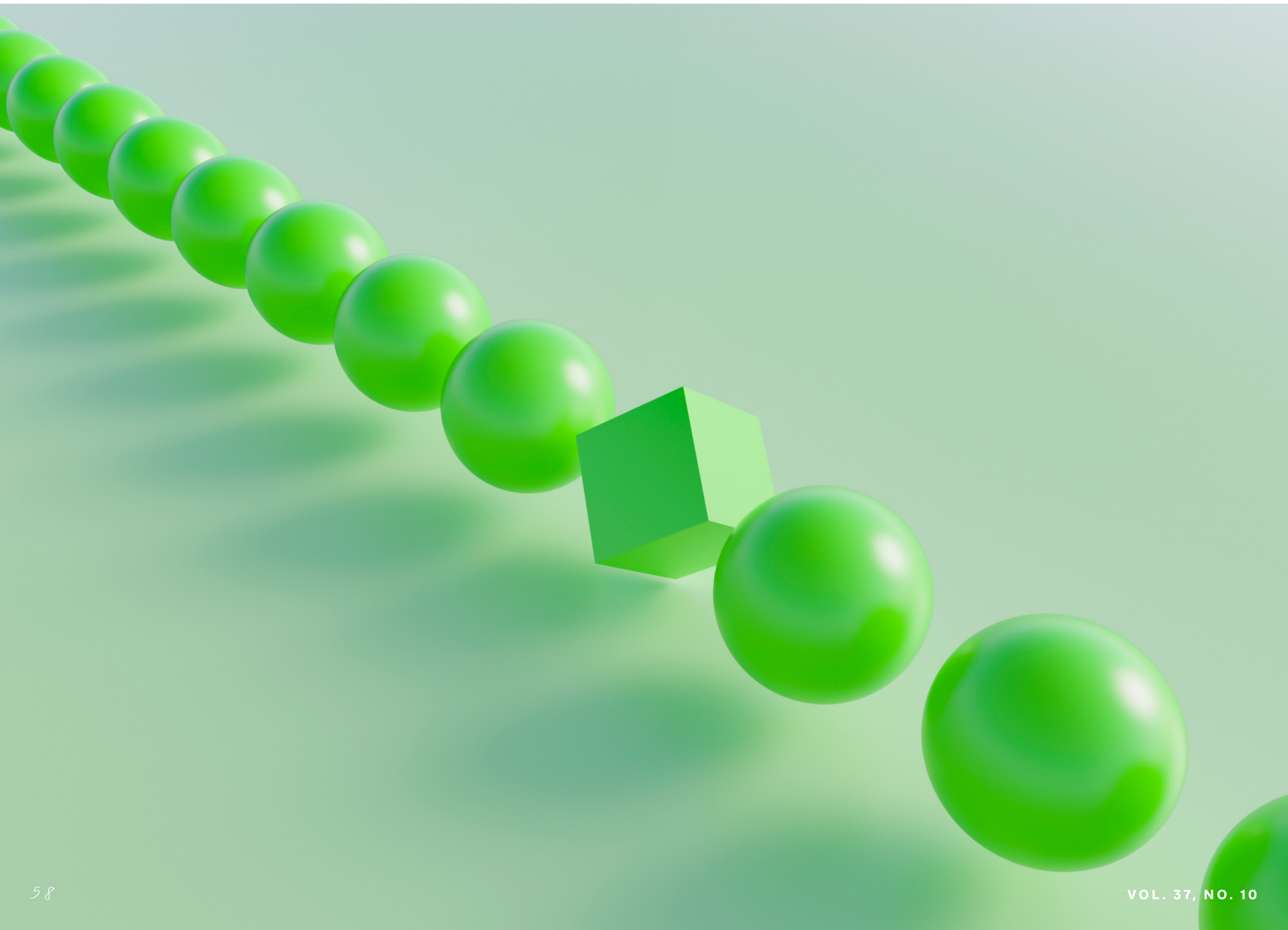

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