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Sovereign and Sustainable Infrastructure Powered by Open Standards and Open-Source

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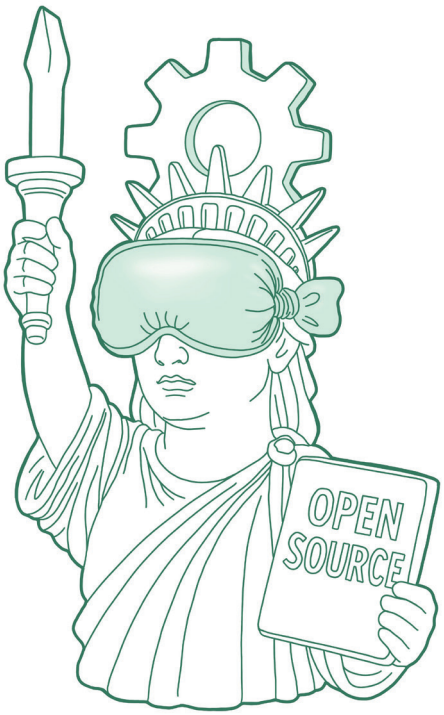
Introduction: Rebuking the proprietary status quo

Disentangling digitalisation and the environment is a complex and multi-faceted discipline. Not only do digital infrastructures consume resources and energy, but the design, use, and implementation of digital technologies have profound societal consequences. Traditional sources of power reflect how digital technology is molded and implemented, perpetuating structural gender, race and social disadvantages and injustices. Human, environmental, and social costs are shifted from where digital technologies are used and enjoyed to those involved in the most fundamental levels of the production chain. Examples are plenty, like the metal extraction workers for mobile devices or the "*mechanical turks*" involved in AI training. Simplistic approaches based on promises of quick and easy fixes (*tech solutionism*) misguide the persistent narratives claiming that digital innovation is apt to solve environmental issues via unfettered economic growth.
Notwithstanding such profound challenges, alternative circular models of digitalisation respecting ecological boundaries, promoting human rights and fostering societal development and progress are possible. The first step is to recognize the need for alternative mindsets, constructions and approaches rebuking the status quo of digital technologies.

The unsustainable practices of surveillance capitalism and the injustices of the gig economy should be corrected with policies promoting democratic forms of control over digital assets and infrastructure.

At the same time, the challenging dynamics of the digital economy, characterized by ever-concentrating power of tech oligopolies, extreme returns to scale, network externalities, and dependence on data, should be met with approaches fostering fairness, contestability and strict accountability of corporate behavior in digital markets. Ultimately, there is a need for strengthening transparent, decentralized, inclusive, and democratic institutional arrangements for the production, development, and governance of digital technologies. Such alternatives would translate into robust policies safeguarding end-user freedom of choice, the dissolution of monopolies over device-related bottlenecks, and the promotion of interoperability policies for data and software.
Within this reasoning, *open technologies* present a particular importance for alternative democratic governance of digital assets. Free and Open Source Software (FOSS), Open Data (OD) and Open Source Hardware (OSH) are consolidated concepts which translate into institutional arrangements giving primacy to collective forms of sustainable and persistent access,



Proprietary tech blindfolds freedom.
Tom Dietel, CC-BY-4.0.

use, and distribution of software, hardware, and data. As innovation itself is seldom practiced in isolation, *open innovation* underscores the abilities for collective coordination of sharing, reuse and distribution of assets.

Copyright, patents, trade secrets, and technological protection measures (such as Digital Rights Management (DRM)) make access to knowledge artificially scarce.

Contrarily, licenses protecting free software, open-source hardware and open data seek to establish an open and democratic control over these assets, establishing rules over collaborative development, access, use, reuse, modification and distribution. Organizations like the Free Software Foundation (FSF), Open Source Initiative (OSI), Open Source Hardware Association (OSHWA), and Creative Commons (CC) are key for developing, maintaining, curating, and improving licenses that are used worldwide by a multitude of individuals, organizations, and public institutions sharing software, hardware, and data.
Notwithstanding the central role of open licenses in the open economy, they are alone not enough for a sustainable and sovereign transformation. The emergence of big tech and unregulated corporate power in the digital markets revealed the vulnerability of unsustainable extraction from common digital assets and infrastructures.
This paper provides a short introduction to how regulation, standards, and public policies represent valuable instruments for effective interventions in a process of deep and structural reorganization of how wealth is produced and owned in the digital age.

Resetting the sustainability compass: Democratic tech depends on fair competition

A just, fair, sustainable and future-proof digitalisation needs an emancipatory attitude to equalize power asymmetries over technology. Digital markets in the EU are highly concentrated and inefficient. Member states are mostly dependent on imported digital services and expertise provided by very few gigantic corporations. Critical infrastructure elements like operating systems in mobile devices and cloud services are examples of extremely concentrated and dissonant markets. Google and Apple dominate 99 per cent of the market for mobile operating systems, while AWS, Microsoft, and Google share two-thirds of the market for cloud services.

Such profound dependence prompts the urgent question of how to reacquire a more democratic control over critical infrastructure. A strategic vision is necessary. Simplistic assumptions will most likely fail.

Instead, a bold, pragmatic, comprehensive, and responsible reaction should encompass robust policies safeguarding just and balanced solutions respecting the environment, individual empowerment, freedom of choice, social justice, and economic equality. As an illustration of such complexities, the next sections will dive into the intersection of standards and interoperability.

Preventing monopolies with Open Standards

As societies grow in complexity, interoperability of assets and infrastructure becomes inevitable. However, historically, interoperability is marked by a striking contradiction: while market actors benefit from interoperability, they step back and react when their assets become important enough to be subject to interoperability obligations. Besides impeding interoperability, these actors can engage in strategies aimed at distorting innovation by preventing access to the market, depriving small innovators of scaling, limiting disrupting companies' access to long-term funding, and performing killer acquisitions. Private monopolies derived from such anti-competitive practices existed way before the digital age. Breaking them happened in several ways: sometimes they were nationalized or treated as a common carrier, sometimes they faced very strict obligations or the state provided competition. Sometimes, competition required measures of cooperation among competing firms. Standards development is one of those areas. In the digital age, keeping digital markets open, contestable, and fair faces the ever-concentrating aspects of tech companies, also in relation to standardization. In that sense, *Open Standards* represent a key instrument to keep a fair balance among industry players in digital markets.
Over the past hundred years, standards have been responsible for enabling independently manufactured products to remain interoperable and safe. While *de jure* standards are developed following formal procedures by a nationally recognized standard-setting organization, *de facto* standards do not need to deploy any democratic principles and simply become standards by a widespread

adoption in the market. The importance of standards for compatibility and interoperability can substantially leverage the power of companies developing standards. One can say, for instance, that the history of mobile telecommunications is the history of standard setting. *De jure* standards are published by recognized standards bodies, such as DIN/DKE (in Germany), CEN/CENELEC (in the EU) or ISO/IEC (internationally). Such a standardization process brings together actors from different perspectives, e.g. developers, manufacturers, service providers, users, public authorities etc., to create a *societal consensus* on a given technical issue – and disclose this consensus as a standard everyone can refer to. The final documents are (with few exceptions) not open-access but generally available behind paywalls. Parties engaging in *de jure* standardization must register all of their relevant patent claims to the standard-setting organization. Since a *de jure* standard should be free of any patent claims, in order to facilitate widespread implementation, it should generally avoid conflicting with the claims of relevant patents – or, in case this is unavoidable, make these standard-essential patents (SEP) available under "Fair Reasonable and Non-Discriminatory" (FRAND) license terms. Examples are patents involved with Wi-Fi, USB and 4G LTE standards.

Notwithstanding the critical role of *de jure* standards in avoiding monopolistic domination via proprietary *de facto* standards, it is important to notice that they are not necessarily compatible with other open assets, for instance, open-source software. Standards involving patents royalties that are not waived and require negotiation to be implemented in open-source material are generally incompatible with the "*permissionless nature*" of open-source software. As a matter of fact, digital products have become more complex and interlinked. For example, over 1000 patents can be considered "essential" to a single standard (2500 in the case of ISO/IEC 23008-2:2025, to be more precise). For providers aiming to implement standards in open-source technologies, it can be quite challenging, sometimes even impossible, to acquire licenses for all SEPs. On top of that, FRAND conditions are far from being standardized and only apply to SEPs registered at the standard-setting organizations by the participants. So in some cases, the FRAND promise might not mean much in practice.
As an alternative concept to *de jure* standardization, open standards provide a safe ground for open-source communities to engage in standardization while keeping the freedom to implement the standard in open-source technologies afterwards.

While there is currently no general consensus on a complete definition of open standards, most actors agree that an open standard shall be available free of charge and must not restrict any (open-source) implementations of it, ruling out any patent claims subject to royalties.

This principle allows open standards to deploy a fast, implementation-driven (bottom-up) method, where widely tested and adopted variants of open-source solutions merge to a standard by consensus – much in contrast to the much slower expert-driven (top-down) approach in de jure standardization. Despite the fact that these ecosystems act in independent networks, some bridges have been built over time. For instance, organizations like the Linux Foundation, OASIS, W3C or the Eclipse Foundation can submit their standards and specifications as "Publicly Available Specifications" (PAS) to ISO/IEC and can thereby convert them into standards.

Filling the gap between open standards and open-source hardware

Another way to standardize products and make their designs available for all is to publish all design files under an open-source license so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design. The design would become a standard by widespread adoption, while "competing" against independent modifications (forks) of the design, ultimately featuring an open *de facto* standard. Innovation and iteration happens on a design level and the designs can be directly implemented as products and put into circulation.
An intermediate layer between *de jure* standards and open-source hardware implementations involves the publication of open-source specifications. Formal processes of *de jure* standardization would include open-source principles for the development. The outcome would implement the requirements of relevant *de jure* standards (e.g. safety standards) and define requirements for downstream implementations, e.g. licensing terms or what documents to provide in the technical documentation. Downstream, compliant open-source implementations are effectively standard products that can be produced and sold with a very low threshold. The experience from the deployed products can, upstream, fuel iterations of the open-source specification and even of relevant *de jure* standards.

As an illustration, this methodology might provide a resource-efficient and democratic way to break current market oligopolies, e.g. for magnetic resonance imaging (MRI) scanners: If clinics, manufacturers, service providers, patients etc. would come together to create such a specification under open-source terms, relevant communities (such as the Open Source Imaging Initiative) could implement the specification as the design of a new open-source MRI scanner (e.g. a new version of the OSI^2 ONE model). Manufacturers could sell scanners based on the published design files (similar to manufacturing according to product standards) permitting clinics to buy scanners designed according to their needs without vendor lock-in. The machines could be maintained by independent service providers.

Committing to openness: Public money, public code!

Due to strategic and competitive advantages, open assets are key elements for a sustainable digitalization. Recent debates over the future of the digital economy in Europe involve a proposal for privacy-by-design and security-by-design frameworks based on "de-proprietarization" by promoting open assets and federated digital infrastructure to reduce reliance on foreign proprietary platforms, as well as investments aligned with fairer climate goals.

Digital infrastructures are not monolithic but an intricate combination of software, hardware and data components that are integrated in different environments. For instance, differently from Silicon Valley, the software industry in Europe is 94 per cent composed by Small and Medium Sized Enterprises (SMEs) with less than 9 employees. While 96 per cent of all software produced contains open-source components, funding and financial maintenance for open-source projects still remain critical. A current example is the open-source email program Thunderbird, used daily by millions of people and companies worldwide but receiving donations only from less than three per cent of the user base.

The economic sustainability of the open-source industry requires substantial investment from the public and private sectors.

It is necessary to consolidate funding mechanisms providing sustainable and long-lasting investments for the development, maintenance and support of open-source projects and communities. Such schemes should incorporate public and private actors to support ongoing maintenance and vulnerability mitigation for open-source projects they depend on. Such a program could encourage more small and non-IT-sector companies to take part. Over the past years, public policies in the EU have been acknowledging open-source on a rising scale not only at the high Union level but also in the national, regional and municipal ranks.

The European level: Leveraging the debate to critical infrastructure

Currently, on the Union level, debates around the *Eurostack* propose to build sovereign digital public infrastructures (DPIs) by reducing dependencies and strengthening strategic autonomy, fostering local industries and driving competitiveness in the fields of AI, semiconductors, cloud infrastructures and IoT with open-source software. The debates include not only the promotion of open-source technologies but also their development as ways to realize knowledge and technology transfer, create a dynamic culture of innovation within open-source ecosystems and build inclusive partnerships on a European and international level.

Another pan-European initiative is the Next Generation Internet (NGI) project which has been promoting digital commons as modes for production, forming complex and intertwined stacks of technologies for governments, industry and the civil society. From addressing aspects of avoiding vendor lock-ins and increasing transparency, interoperability, and cost-efficiency the present focus of regulators has shifted from just promoting openness to addressing governance and collective management of digital infrastructures.

Worth mentioning are projects like *Gaia-X*, working toward federated and transparent cloud ecosystems governed by European values as an answer to the dominance of non-European hyperscalers and the risks related to surveillance and data sovereignty.

EU Member States: Increasing open-source adoption

On a national level, several European countries have been conducting policies fostering the development and support of open-source technologies. France and Germany are two examples worth mentioning.

France's continuous waves of procurement policies

favoring FOSS over proprietary software in recent years have led to a yearly increase in companies working with FOSS from 0.6 to 5.4 per cent, a 9 to 18 per cent yearly increase in the number of IT-related startups, a 6.6 to 14 per cent yearly increase in the number of individuals employed in IT related jobs and a 5 to 16 per cent yearly decrease in software related patents.

These numbers underline the high potential of state actions supporting open technologies in order to create and support productivity, competitiveness, innovation and economic growth, especially in relation to lowering entry barriers to markets by SMEs.

Germany, at the federal level, has implemented some policies fostering FOSS. For instance, the decision by the IT Planning Council in March 2021 on a "Strategy to Strengthen Digital Sovereignty for Public Administration IT" already signals a clear shift toward demand-driven, open-source-based IT solutions, characterized by modularity, open standards, and interfaces. This is underlined by the creation of the *Centre for Digital Sovereignty of Public Administration* (ZenDiS) which has the mission to strengthen the digital sovereignty of the public institutions at federal, regional, and local levels. The initiative provides, for instance, code repositories like *Open Code* and the office suite *OpenDesk*. Supported by the *German Cloud Strategy*, the project also aims for a sovereign national data structure with unified platforms (infrastructure-as-a-service), shared standards and interfaces as well as the provision of software applications and their management. Diverse German regional administrations are in the process of setting up or have already implemented digital strategies, sometimes including distinct open-source and open-data strategies (e. g. the state of Schleswig-Holstein with its "*Open Innovation und Open Source Strategie*" and the Open-Source Competency Center Berlin) aiming at the creation of diverse and open digital economies, open standards and procurement policies prioritizing FOSS. In addition to this, a few federal states have started to run data centers providing administrative clouds (infrastructure-as-code).

Avoiding the hype trap: A critical view on open-source policies in the EU

The diverse EU policies towards open technologies are not free from shortcomings. Lack of harmonized strategy encompassing proper implementation steps and monitoring, incompatibilities with how open assets are developed and distributed, and enforceable mechanisms for clear commitment from public institutions are some of the challenges. Failing to push forward effective policies runs the risk of consolidating the proprietary status quo. Ultimately, ineffective policies may inadvertently hamper open innovation and disrupt the whole circular economy. For instance:

- **"Nationalistic" approaches towards open-source**. Positions in the *Eurostack* debate promoting "nationalistic" or "patriotic" approaches to open technologies fail at a fundamental level. Concepts involving sovereignty that discard the global nature of the development and production of open technologies are not compatible with the core consistency of the driving ideologies behind the ideas and principles over which open technologies operate. Such sources of tension demonstrate this cleavage between visions of "Europe first"- and "open-source first"-principles: While some views defining *Eurostack* create an economical vision of a digital "Single Market" prioritizing European companies, the objectives of open-source lie in barrier- and discrimination-free products.
- **Persistent dependency on proprietary technologies**. The development of the Gaia-X program revealed the shortcomings of the project in relation to dependence on proprietary technology dealing with critical flows of data (e.g. personal identifiable data). The complex integration challenges posed by services not subjected to EU laws and security policies may lead to "sovereignty-washing" solutions. Microsoft's recent decision to block access to the email account of International Criminal Court (ICC) Chief Prosecutor Karim Khan is a clear example. Gaia-X has been facing challenges based on different member objectives and its inability to enforce standards due to its governance structure opening up the question of "technology openness" policies and tech giants corrupting the project's governance structures, effectively leading to the exit of smaller commons-oriented open-source advocates. Besides, lobbying, under the guise of technological neutrality, can undermine the very goal of building digital sovereignty — particularly when non-European tech giants are included in ways that dilute the role and agency of European actors. Examples like the decision to deploy Google Cloud infrastructure within

the German army's cloud strategy demonstrate ambivalence between the objective of digital sovereignty and its implementation. Proprietary software, although being set up in an isolated "air gapped" cloud, still carries all the risks open-source software could lever out.

- **Lack of enforceable commitment in sustainable funding.** Critical voices of civil society organizations still see deficiencies within the actual federal and state policies regarding contradictory fiscal policies between financing open-source efforts (*Sovereign Tech Fund, ZenDiS*) and sticking to proprietary software and services. In addition to insufficient funding structures, the competencies and preferences within public administration play a crucial role—contributing to an ongoing imbalance between proprietary and open technologies. Initial and partial advances in the adoption of FOSS at the administrative level indicate some momentum, yet they also reveal substantial gaps in comprehensive strategic thinking. Specifically, there is a lack of integrated approaches that place software, hardware, and data on an equal footing in terms of their relevance and strategic importance.

Looking forward: Policy recommendations for a just transition to open source

This paper analyzed the intersections of regulation standards and open-source for effective interventions of structural reorganization for digital markets. As a key takeaway, open-source software, open data and open hardware should be understood as catalysts for policies promoting alternative democratic governance over digital assets. Against this backdrop, the need for a robust, perennial and sustainable commitment from public and private actors depending on open assets is paramount.

#1 Keeping up the regulatory pace for open source

Open source can play a key role in enabling a just enforcement of diverse EU legislation aimed at fundamental aspects of the digital economy with key elements regarding open source: the AI Act, Digital Markets Act, Cyber Resilience Act, Interoperable Europe Act, the Right to Repair Directive and many more. However, translating such legislative efforts in a fertile ground for digital innovation that is sustainable and environment-friendly requires an evolved relationship between the communities that develop critical components, many of which are hosted at open-source foundations or incorporated communities, and downstream manufacturers.

#2 Modernizing standardization processes with open source

Standards have served the inexorable process of making economies, including the digital one, safer and more interoperable over the past 100+ years. At the same time, legacy standardization processes bring incompatibilities with development practices of open-source software and hardware. Modernizing the specification elements may provoke paradigmatic changes as great as those seen with the emergence of standards themselves in the dawn of the industrial age. Moving towards open standards would inevitably challenge the business model of nationally recognized standard-setting organisations (like DIN, CEN or ISO), as they mostly rely on the sales of information – and their contributor base (industry actors engaging in de jure standardization) – as SEPs tend to be very lucrative for their owners. However, as software standardization already moved strongly towards open standardization, and the similar shift can be expected as open-source hardware gains relevance, the relevance of standard-setting organizations unwilling to leave outdated business models may be heavily challenged.

#3 Making public policies for effective and future-proof open source

As open source becomes increasingly important digital infrastructure, the calls for long-term investments in people and ecosystem become louder. Debates around digital sovereignty are evolving in Europe at a fast pace, with a higher emphasis on open innovation and collaboration. However, the practical implementation of strategic projects involving open-source demonstrate challenges and shortcomings. Policy-making must take the specific characteristics of existing innovation and production ecosystems into account. Strategic dependencies will likely persist in these domains as long as European digital infrastructures remain unable to

independently manufacture the necessary technological components. Moreover, the development of sovereign open-source technologies reveals the vulnerability of the model to distortion. "Open washing" represents a transnational challenge when proprietary actors label their products as open without adhering to the principles of openness. This risk is amplified when large corporations act as free riders, leveraging their superior capacities to extract disproportionate value and entrench market dominance via strong lobbying, ultimately undermining the integrity and sustainability of open ecosystems.

#4 Transition to open source should be sustainable

While open-source policies in the public sector have been considered key for achieving technological independence, it is crucial to ensure that such policies address broader public policy goals, not just technological outcomes, and include measurable alternative circular models of digitalisation respecting ecological boundaries, promoting human rights and fostering societal development and progress. For that, creating collaboration mechanisms blending public and civic engagement to foster a more inclusive and sustainable digital ecosystem is paramount.

#5 Don't forget: Open source is about boundless collaboration

Even if the focus lies on securing Europe and "European values" it is key not to circumvent the unbound sharing ethics of open source. It is critical to assess how societies and their political representatives engage with open-source in shaping a truly holistic digital ecosystem — one that strikes a sustainable and public-interest-oriented balance between openness and necessary forms of closure, while still ensuring security and digital sovereignty. While openness is a defining characteristic of open-source, its integration with hardware and data governance must be approached in a carefully calibrated way — one that promotes openness without compromising sovereignty, safety, or long-term resilience. Therefore, it is crucial to take a cautionary approach via a responsible and conscious development and procurement of open assets in private and public sectors by establishing guidelines to develop and optimize open-source strategy, policy, and relationships.

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Martin Häuer is active in a variety of open-source hardware communities, coordinating projects, setting up contribution management and decision-making schemes, developing hardware, writing documentation – and presenting results on stage. He's currently a board member at the Open Source Imaging Initiative e.V. (non-profit) and administrator of its Conformity Assessment Body (according to DIN SPEC 3105-2) for open-source medical imaging hard- and software.

His research at Martin-Luther University of Halle-Wittenberg focuses on the intersection between de jure standardization and open-source hardware – and how both schemes can work together in order to generate "opensource standard hardware" that would be suitable to leverage so-called "Commons Public Partnerships", e.g. in public procurement or public infrastructures.

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Benjamin Kashlan's current focus is on open and collaborative ecosystems in the context of open source technologies (software, hardware, data) and their combination with approaches from commons research. In this context, he conducts research on forms of open source governance, their implementation in the form of commons- public partnerships and other networks of relationships, and their regulatory dimensions with regard to standardization and normalization. In addition, he examines the embedding of these concepts in overarching theories of socio-ecological transformation and circular economic and social forms (circular economy/society, circular literacy) against the backdrop of sustainable (regional) evelopment.

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As a designer, Tom Dietel works at the intersection of circular economy, civil society participation, and scientific research into co-creative and transformative processes. In addition to freelance design projects and workshops, he is the lead designer of the open source product development "LibreWater." He advocates for open knowledge exchange, decentralized collaboration, and local implementation. This requires fair collaborative projects. Since September 2024, he has been conducting research on this topic as part of the JTC research project, focusing on sustainable and networked business models in the context of open source.