ECLIPSE® FOUNDATION

The Vital Role of Open Source in Europe

White Paper

HiPEAC

RESEARCH @ ECLIPSE FOUNDATION

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Introduction

This white paper is the outcome of the 'Consultation on Open Source' organised in September 2024 by the Eclipse Foundation as a partner in the HiPEAC research project. During this event, stakeholders from across Europe convened to discuss the critical challenges and opportunities related to open source in the European tech ecosystem.

The European tech ecosystem stands at a critical crossroads where its digital sovereignty and competitiveness are at stake. Europe risks being outpaced between the government-driven innovation models of China on the one hand and the business-driven success of the United States on the other.

The urgency to act is clear: Europe must take immediate steps to strengthen its position in the global tech landscape. Fostering technological success in Europe requires a joint effort, bringing together major tech companies, startups, governments, and other stakeholders rather than relying on a single entity to drive progress. And much like its geographical location, the European technology community must find its best position somewhere between the U.S. and China in terms of business-friendliness versus government leadership, and bottom-up versus top-down governance. Europe must take the lead in charting its own path toward competitive innovation, an approach that is proactive yet remains open, collaborative, and globally engaged.

In this white paper, we elaborate on the fact that the most viable path to sustainable competitiveness is collaboration, and we emphasise how open source is not necessarily the solution, but certainly a strategic enabler of competitive collaboration in software. By embracing open source as a central component of its digital strategy, Europe can foster innovation, create future-proof technological autonomy, and build resilient industries

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capable of leading the next wave of digital transformation. Through collaborative ecosystems and well-designed policies, open source can boost Europe leadership and offer a path toward long-term success on the global stage.

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Open Source for EU Sovereignty and Competitiveness

Yassir SELLAMI (Gaia-X), Aad Nales (Almende), Marco Roodzandt (Empero)

Europe's innovation lag is becoming a problem

The EU is currently lagging behind key competitors like the U.S. and China in several digital domains, including the Internet of Things (IoT), Artificial Intelligence (AI), cloud computing, cryptography and distributed ledger technology, cybersecurity, and quantum computing. The Draghi Report (see Fig.1)[1] highlights critical areas of underperformance, emphasising the EU's lack of hyperscale infrastructure and its dependency on external technologies.

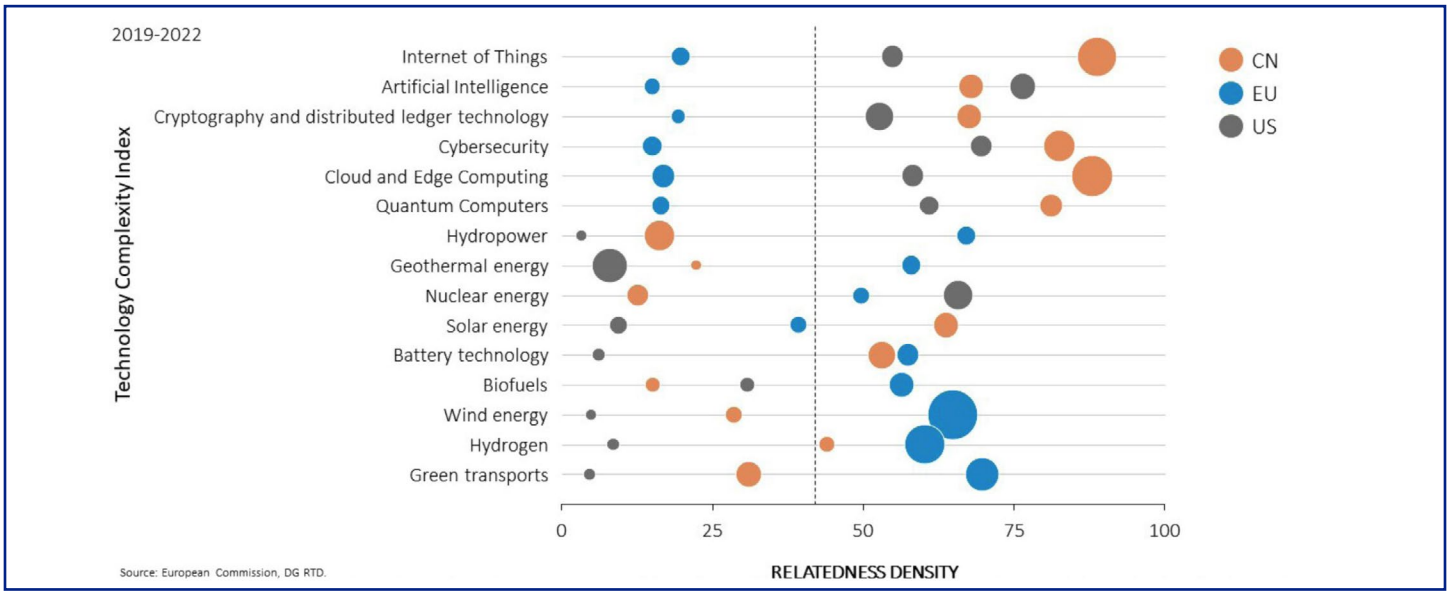

Figure 1: The EU's position in complex (digital and green) technologies

[1] Mario Draghi, The future of European competitiveness – Part B: In-depth analysis and recommendations (henceforth referred to as "Draghi Report"), p. 233, https://commission.europa.eu/topics/eu competitiveness/draghi-report_en

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Notes: The results are based on an analysis of patent data to understand the complexity and potential for specialisation in different technology areas. On the y-axis, technologies are ranked according to how advanced or complex they are, with scores ranging between 0 (less complex) and 100 (more complex). The x-axis (showing the relatedness density) represents how easily a country can build comparative advantage in a particular technology, depending on how closely related it is to other technologies the country is already strong in. The size of the bubbles shows how much each country has already specialised in a technology, using a measure of "revealed comparative advantage" (RCA), which reflects their competitive strength in that field.

Source: European Commission: Directorate-General for Research and Innovation, Science, research and innovation performance of the EU, 2024 – A competitive Europe for a sustainable future, Publications Office of the European Union, 2024, https://data.europa.eu/doi/10.2777/965670. Reproduced with permission.

For example, U.S. companies are currently building Gigawatt data centres such as the Cumulus data centre in Berwick, Pennsylvania[2], which is connected to the nation's largest nuclear power plants. Datacentres of this scale are essential for advancing technologies like AI.

In 2023, the EU was home to only 8% of the world's unicorns, i.e. startups valued at over 1 billion dollars. By contrast, two thirds (66%) of unicorns were in the U.S., and 26% were in China[3].

A similarly grim outlook emerges regarding research and academic excellence. In the global ranking of S&T clusters, Europe boasts 11 in the top 50 but none in the top 10[4]. A similar phenomenon is evident in the Nature Index, which tracks the affiliations of high-quality scientific articles in natural sciences[5].

Although the Draghi report only mentions "open source" once, the latter could be a remedy for Europe's lagging competitiveness.

Homegrown technologies to reduce dependencies

Open source offers a path to reducing Europe's reliance on non-EU technology providers by promoting homegrown alternatives. For example, initiatives like Gaia-X use open standards and open source components to foster European control over key digital infrastructures.

Established in 2019, Gaia-X aims to build trusted,

[2] https://www.theregister.com/2024/05/30/amazon_nuclear_campus_grows/
[3] Draghi Report, p. 232
[4] Draghi Report, p. 240
[5] Ibid.

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decentralised digital ecosystems and develop in alignment with EU policies, specifications, and standards. The initiative focuses on several layers of interoperability such as technical, semantic and legal interoperability through a compliance engine, architecture, data exchange rules, and identity and access management. Key components include registries, compliance libraries, and accredited clearing houses. Gaia-X establishes a 4-tier label system ensuring compliance with EU values and data protection, ranging from standard to highly restrictive (data exclusivity within the EU).

Gaia-X uses an open source model under the Eclipse Public licence 2.0 for software, and it employs standards like W3C DID, Verifiable Credentials, JSON-LD, and others to ensure compatibility. Gaia-X also fosters community engagement and open communication through weekly open source software (OSS) calls, an open Slack channel for feedback on specifications, and collaborative events like hackathons. Through these efforts, the Gaia-X initiative lays the foundations for fostering innovation and technological competitiveness. However, it is up to European companies, policymakers, and stakeholders to seize these opportunities and collaboratively turn them into tangible success.

Open source as a strategic pillar for EU sovereignty and competitiveness

"In order to achieve market dominance, network effects, compliance, and ecosystem development, Europe must assume leadership by setting technological standards. Without this, it risks becoming a follower in the global tech race."

– Aad Nales, Almende

Setting standards requires rapid growth and large-scale players – areas where Europe has traditionally struggled. Compared to the US and China, the EU faces challenges from fragmented markets and moderate government support. In 2023, only 8% of the top 500 companies by market capitalisation were European, underscoring the need for stronger regional players.

In light of these weaknesses, the EU has only one path to setting standards: competitive collaboration. Notably, setting standards requires a collaborative framework, including education, community building, regulatory engagement,

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and demonstrating value across sectors.

Many European programs require large enterprises to demonstrate impact. However, open source delivers more distributed benefits, particularly early in the technology cycle. Enterprises should consider this profit structure when making investment decisions in open source. Overall, this dynamic should benefit a strong industrial region like the EU.

Horizon Europe[6], the EU's key funding programme for research and innovation, supports open source initiatives, but programs like ITEA and Chips JU remain focused on proprietary IP. Closing this gap is essential to leverage open source's distributed innovation and cost-saving potential.

Open source offers Europe a pathway to technological sovereignty, fostering long-term competitiveness through collaboration, reduced costs, and enhanced innovation.

How open source can contribute to strategic autonomy

Aligning with its need to establish technological independence and leadership, Europe is striving for strategic autonomy and economic stability. To effectively evaluate the potential of open source in addressing these challenges, we must gain a deeper understanding of its economic impact. This impact is often underestimated, including the total cost of ownership of open source ecosystems, their potential to drive industry disruption and cost reduction, and the risk of unintended dependence on non-European tech giants. Once we understand this economic significance, it will be easier to advocate for leveraging European innovations, rather than relying on U.S. and Chinese tech leadership.

From a geopolitical standpoint, maintaining control over critical technological components through open source will allow the EU to protect its industries from external risks and ensure uninterrupted access to essential software and data, boosting European digital sovereignty.

Finally, achieving European leadership in open source requires a shift in mindset and strategy. Rather than prioritising non-European technologies, Europe should focus on its own technological ecosystem and leverage open source research and development projects it has already invested in. Strong leadership with a strategic understanding of both business and technology is essential, leveraging existing assets while fostering innovation to achieve true strategic autonomy. In addition, OSS projects need to better align with industrial requirements to ensure their adoption. Finally, success demands risk-taking, courage, and perseverance, ensuring long-term commitment to open source initiatives that can drive competitiveness and sovereignty.

[6] https://commission.europa.eu/funding-tenders/find-funding/eu-funding-programmes/horizon-europe_en

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Open Source and Artificial Intelligence

Simon Phipps (OSI), Manuel Betin (OECD)

Opportunities for open source in AI

With AI titans such as ChatGPT and DeepSeek quickly gaining ground and taking over big shares of the market in a fierce competition, making up ground in the rapidly expanding field of AI is essential for Europe's competitiveness. Open source can serve as a catalyst for AI development, as it helps reduce entry barriers and drive rapid adoption of AI technologies across European industries, thus democratising access to cutting-edge technologies. With major tech companies driving proprietary AI systems, open source AI models and frameworks provide alternative pathways for startups, SMEs, and research institutions to compete and innovate without heavy initial investment.

Challenges

However, applying the concept of open source to this emerging field presents challenges, as AI is a hybrid construct consisting of: 1) a data store, 2) distinct sets of software for creating and utilising the data store, 3) a body of data, and 4) parameters known as weights. These components fall under different IP regimes, each with varying relationships to copyright, patentability, trademarks, and trade secrets. What's more, the subject of training data is difficult to approach, given that, for example, the duration after which material enters the public domain varies across countries. This has made it necessary to include the concept of Data Information as a particular type of metadata into the Open Source AI Definition:

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"Data Information: Sufficiently detailed information about the data used to train the system so that a skilled person can build a substantially equivalent system. Data Information shall be made available under OSI-approved terms.

In particular, this must include: (1) the complete description of all data used for training, including (if used) of unshareable data, disclosing the provenance of the data, its scope and characteristics, how the data was obtained and selected, the labelling procedures, and data processing and filtering methodologies; (2) a listing of all publicly available training data and where to obtain it; and (3) a listing of all training data obtainable from third parties and where to obtain it, including for fee."[7]

Open Source AI Definition

Drawing on the experiences in creating the Open Source Definition in 1999, the Open Source Initiative (OSI) embarked on a two-year multi-venue, multi-stream consultation process. This collective endeavour resulted in the current 1.0 version[8] of the Open Source AI Definition, released in late October 2024.

Such a definition of open source AI is essential, not least because the AI Act of the European Union[9] exempts organisations from some compliance requirements to the Act if they are producing "free and open source AI components,"[10] but does not clearly define "free and open source." Without a proper definition, proprietary systems posing as open source (like Meta's LLaMA) risk exploiting the loophole. Establishing a formal open source AI definition will help guide regulatory enforcement and prevent misuse.

The economic effects of open source in AI

As stated above, there are currently no metrics to measure the true value of open source software due to its indirect value. However, open source AI models have emerged as critical tools for reshaping the competitive landscape, fostering the development of smaller, cost-effective models that compete directly with closed solutions, according to OECD research data. This has led to substantial reductions in quality-adjusted prices – by as

[7] https://opensource.org/ai/open-source-ai-definition
[8] Ibid
[9] https://www.europarl.europa.eu/topics/en/article/20230601STO93804/eu-ai-act-first-regulation-on-artificial-intelligence
[10] https://www.europarl.europa.eu/legislative-train/theme-a-europe-fit-for-the-digital-age/file-regulation-on-artificial-intelli 01gence

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much as 80% in some instances – through price competition and enhanced transparency across the AI ecosystem.[11]

Open source also sustains AI development through its role in reducing market entry barriers and switching costs for firms. With the availability of over 125 open weight AI foundation models available for local deployment and cumulating round 50 million downloads as of October 2024 from the Ollama platform[12] and thousands of custom open weight models available from the 40 million downloads reported,[13] platforms such as Hugging Face[14] demonstrate the scalability and competitiveness of open source based solutions that have increasingly closed the performance gap with close solutions. By enabling multi-homing across providers and developers, open source promotes a decentralised cloud provisioning environment, diminishing dependency on dominant players like the "big three" cloud providers.

Moreover, open source innovation has driven advancements in both hardware and software, including breakthroughs in model distillation, quantisation, and efficient scaling methods. These improvements benefit not only OSS developers but the wider AI market by incentivising more efficient resource use and accelerating technological progress. By fostering skills development, OSS also has a profound "alumni effect", where developers gain transferable knowledge, further propelling the adoption of AI technologies across sectors.

Despite its transformative potential, challenges remain. Issues surrounding restrictive licences and "open-washing" – the practice of falsely labelling software as open source – highlight the need for clear legal frameworks to ensure sustained growth without regulatory or operational risks. Policymakers must address these concerns, e.g. by drawing on the official Open Source AI Definition when assessing emerging AI technologies. They must also balance the societal benefits of open source, which include innovation diffusion, cost reduction, and enhanced knowledge sharing across industries.

[11] André, Bétin, Gal and Peltier (forthcoming) Developments in Artificial Intelligence markets: empirical evidence on AI models, prices and providers, OECD working paper
[12] Ollama is MIT-licenced: https://github.com/ollama/ollama
[13] OECD.AI policy observatory (https://oecd.ai/en/data?selectedArea=ai-models-and-datasets&selectedVisualization=evolution-of-new-ai-models)
[14] For Hugging Face Licences, see https://huggingface.co/docs/hub/repositories-licences

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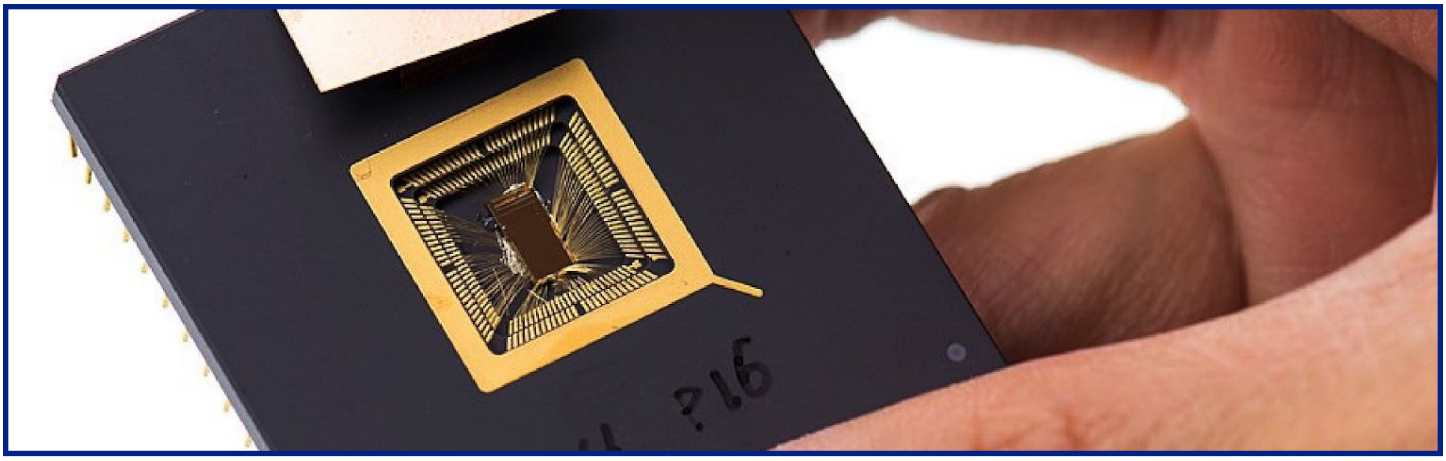

Open Source and the New Regulations on Hardware

Stefan Wallentowitz (HM University of Applied Sciences), Florian Wohlrab (OpenHW Foundation)

The role of open source in hardware innovation

Open source is identified as a key driver in Europe's approach to regaining control of hardware development and reducing dependency on external providers, particularly in critical sectors such as high-performance computing and embedded systems. With new regulations promoting hardware and software integration, open source is seen as a way to standardise and regulate hardware development in a manner that reflects European goals such as security, privacy, and sustainability.

New EU regulations and the recent semiconductor shortage necessitate reducing reliance on non-European hardware suppliers. This includes creating incentives for open source hardware projects that can help develop European-specific chip architectures, processors, and embedded devices. The open nature of hardware designs allows faster adaptation to regulatory changes and enables collaborative R&D efforts, fostering innovation while adhering to compliance standards.

The concept of open source hardware[15] has gained traction as an enabler of innovation, democratisation, and European sovereignty in semiconductor design. Open source software has long demonstrated the benefits of collaboration, transparency, and rapid iteration, but hardware development has traditionally been more restrictive due to high costs, proprietary constraints, and complex manufacturing processes. However, with the rise

[15] In the context of this white paper, "hardware" refers to silicon chips rather than physical objects in the broader sense (i.e. chairs, architecture, computers).

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of open source chip design initiatives such as the OpenHW Foundation, the FOSSi Foundation, lowRISC, the Chips Alliance, the Beijing Institute of Open Source Chip, or the PULP Platform, new opportunities have emerged to make hardware development more accessible and competitive.

Open source chip design facilitates broader participation in semiconductor innovation. By leveraging shared efforts and reducing entry barriers for startups, SMEs, and academic institutions, open source silicon allows for experimentation and novel designs that would be impractical under proprietary models. Europe, in particular, has recognised the strategic importance of developing its own semiconductor capabilities to reduce dependency on external suppliers and enhance technological sovereignty.

Regulatory challenges and the open hardware movement

With increasing government focus on securing supply chains and regulating critical technologies, open source hardware must navigate a complex regulatory landscape. The introduction of strategic ambitions such as the European Chips Act[16] underscores the need for a strong domestic semiconductor ecosystem, balancing open innovation with compliance and security concerns. While open source chip design promotes transparency and reduces vendor lock-in, it also needs to address certification, trust, and sustainability to align with emerging regulations.

One of the key challenges in regulatory compliance for open source silicon is ensuring that all elements of the design and fabrication process meet stringent security and reliability standards. Unlike software, hardware modifications are costly and often irreversible, making early validation crucial. The development of open source Process Design Kits (PDKs), such as Google's SkyWater PDK and Europe's IHP (Leibniz Institute for High Performance Microelectronics)[17] initiative, plays a critical role in bridging this gap by providing commercially viable and regulatory-compliant open source manufacturing solutions.

Future directions for open hardware in a regulated market

To thrive within the evolving regulatory environment, open source hardware initiatives must integrate structured governance, certification frameworks, and sustainable funding models. Collaboration between industry, academia, and policymakers will be essential in establishing open hardware as a credible and secure alternative to proprietary systems.

[16] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-chips-act_en
[17] https://www.ihp-microelectronics.com/

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Initiatives such as the Free and Open Source Silicon Foundation (FOSSi) and collaborative projects under the Chips Joint Undertaking (Chips JU) are already laying the groundwork for a robust open source silicon ecosystem. By addressing gaps in Electronic Design Automation (EDA) tools, fabrication access, and intellectual property management, the open hardware movement can align with regulatory expectations while maintaining its core principles of accessibility and innovation. An open letter from European academics emphasises that open source Electronic Design Automation (EDA) tools are essential for advancing chip design education and innovation in Europe, recommending that funding agencies prioritise support for these tools to democratise chip design and foster collaboration.[18]

As regulatory frameworks continue to evolve, open source silicon presents a unique opportunity to redefine how hardware is developed and deployed. With the right balance of openness and compliance, it can serve as a foundational pillar for a resilient and competitive semiconductor industry.

RISC-V Cores in industrial quality and open source

The adoption of open source hardware, particularly through the RISC-V instruction set architecture (ISA), is reshaping the semiconductor industry by offering a cost-effective, flexible, and licence-free alternative to proprietary designs. As a standardised yet open ISA (Instruction Set Architecture), RISC-V provides a foundational framework for CPU development without vendor lock-in, enabling companies, research institutions, and startups to innovate freely. This open approach not only accelerates technological advancements but also contributes to European digital sovereignty by reducing dependency on proprietary chip architectures.

RISC-V is already in use across various industries, including IoT, AI, storage, and mobile computing. Smartphone manufacturers, for example, are integrating RISC-V cores for functions such as network processing, AI acceleration, and peripheral control. European companies, including Thales, Infineon, Bosch, and NXP, have also recognised its strategic importance and are actively incorporating RISC-V-based solutions into their product lines. This growing adoption underscores the potential of open source hardware to drive competitive innovation while aligning with national and regional technology policies.

[18] https://open-source-eda-letter.eu/

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Open source hardware and regulatory considerations

The increasing reliance on open source silicon raises regulatory considerations, particularly in the context of security, standardisation, and long-term sustainability. Governments and industry bodies are beginning to recognise the need for structured governance frameworks that ensure the reliability and security of open source chip designs. Organisations such as the OpenHW Foundation[19] play a critical role in addressing these challenges by providing industrial-grade, verifiable open source RISC-V implementations with rigorous testing and validation.

A key aspect of regulatory alignment is the development of permissive licensing models, such as Apache 2.0/Solderpad, which facilitate collaboration while protecting intellectual property rights. Additionally, initiatives like the JU projects (TRISTAN, ISOLDE, RIGOLETTO, etc.) are working to reinforce Europe's strategic autonomy in semiconductor technology through RISC-V based research and development. These efforts demonstrate how open hardware can comply with emerging regulations while fostering innovation, education, and digital independence.

Overcoming barriers to open hardware adoption

Despite its advantages, open source hardware faces structural challenges, including a smaller developer ecosystem compared to open source software and the high cost of tooling, fabrication and verification. Unlike software, where iteration and deployment are relatively inexpensive, hardware design requires significant investment in third-party tools, verification methodologies, and fabrication processes, making iterations cost and also time intensive. Collaborative initiatives like OpenHW's Technical Working Group (TWG) seek to mitigate these challenges by pooling resources, sharing best practices, and ensuring that open RISC-V cores meet industrial quality standards and be reusable.

To fully realise the potential of open source hardware, industry and policymakers must work together to develop certification frameworks, funding mechanisms, and educational programs that support sustainable adoption. By addressing these barriers, open RISC-V hardware can play a crucial role in shaping the future of semiconductor innovation while aligning with regulatory requirements for security, transparency, and digital sovereignty.

[19] https://openhwfoundation.org/

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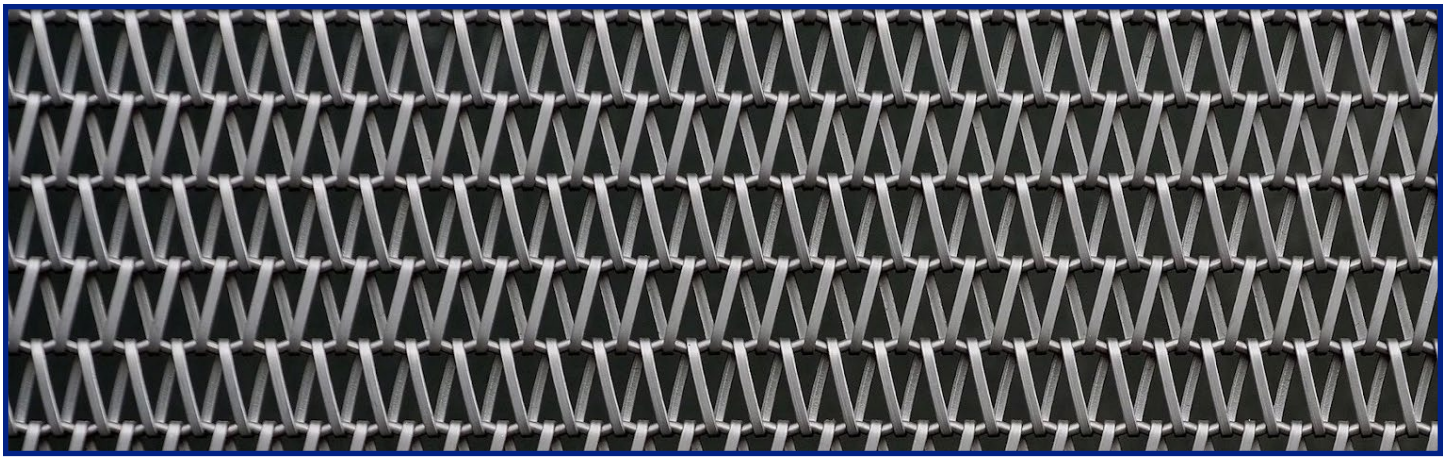

Open Source and the Emerging Fourth Sector

Simon Phipps (OSI)

The idea behind free and open source software is more than 40 years old, arguably even as old as source code itself.[20] Over the past 25 years, ever since the internet became mainstream, open source as a term and philosophy has evolved from a niche movement to a cornerstone of digital infrastructure, powering industries across the globe. As legislation increasingly impacts open source projects, it is critical to ensure that regulation is both informed and intentional, rather than reactionary. In addition, the emerging Fourth Sector dynamics should be taken into account. Only by addressing these factors and proactively connecting open source communities with EU legislation can the European digital products market maintain its competitive edge.

The evolution of open source and the rise of regulation

Open source software development is rooted in principles of collaboration, transparency, and shared innovation. It comprises nearly 80% of all software and contributes between €65 and €95 billion to the European Union's GDP.[21] With maturity comes scrutiny, and governments and regulatory bodies are now stepping in to impose new governance structures.

Several legislative efforts in the European Union (EU) aim to regulate various aspects of digital

[20] https://en.wikipedia.org/wiki/History_of_free_and_open-source_software
[21] https://digital-strategy.ec.europa.eu/en/library/study-about-impact-open-source-software-and-hardware-technological-independence-competitiveness-and

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products and services. These include:

- Cyber Resilience Act (CRA)
- Product Liability Directive Update (PLD)
- Digital Markets Act (DMA)
- AI Act & AI Liability Directive
- Interoperable Europe Act (IEA)
- Data Act

These initiatives seek to enhance security, accountability, and fairness in digital markets. However, they often overlook the open source model, albeit not intentionally. As a result, new compliance burdens are being placed on open source communities that were not designed to operate within traditional corporate regulatory frameworks.

The Fourth Sector and its unique challenges

Historically, society has been structured around three economic sectors:

1. Public sector – Government entities that provide public services.

2. Private sector – Businesses operating for profit.

3. Nonprofit sector – Organisations focused on social good without profit motives.

There is an implicit assumption that goods are funded, produced, and controlled centrally and citizens purchase goods with money earned by working for companies that produce them.

However, open source communities operate within a **Fourth Sector** or **meshed society**, distinct from these traditional models.

The Fourth Sector consists of decentralised, community-driven initiatives where individuals and organisations collaborate to develop, maintain, and improve non-rivalrous digital goods. These initiatives do not conform to the conventional corporate structure assumed by regulatory frameworks.

The EU regulatory model tends to view digital production through the lens of corporations producing goods and services for consumer consumption. This approach does not account for open source projects, which rely on voluntary contributions and non-traditional business models. As a result, open source stakeholders find themselves largely unrepresented in legislative discussions.

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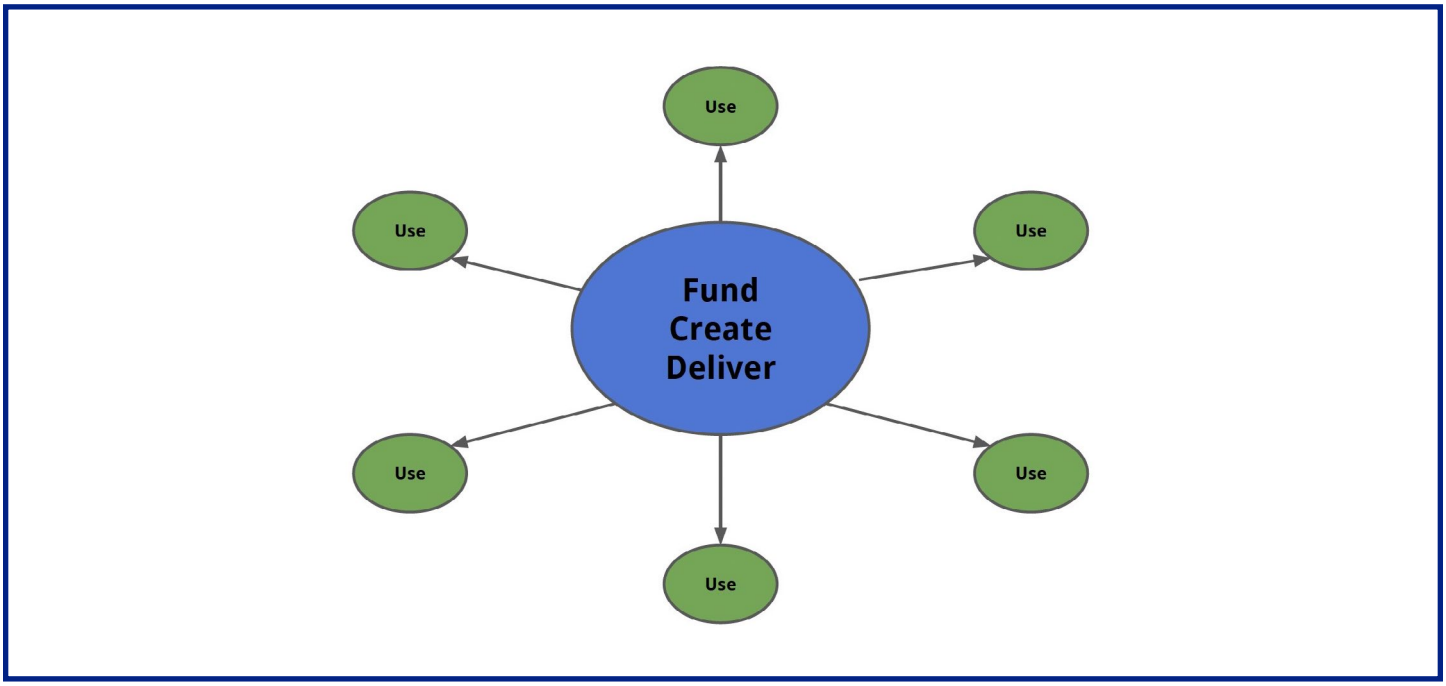

Figure 2: The traditional production model

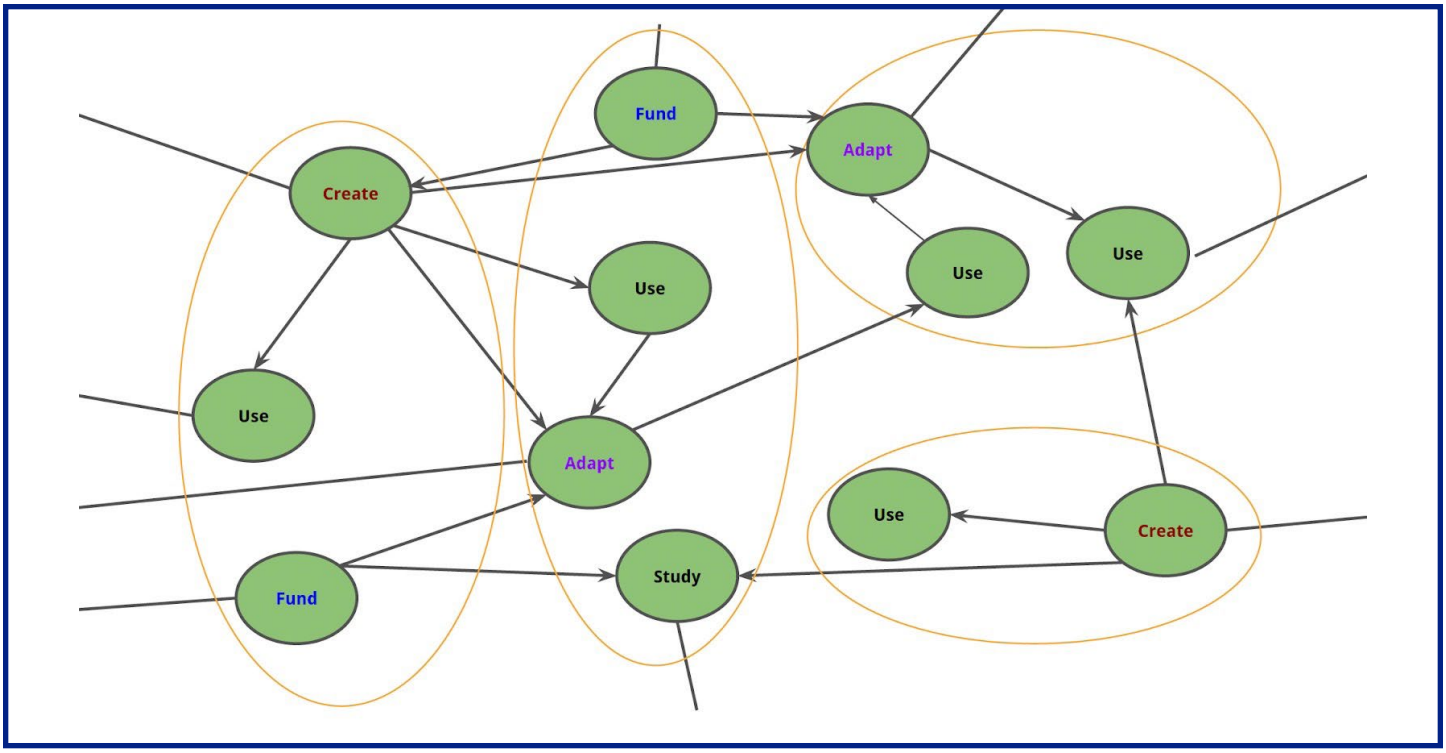

Figure 3: Vs. the meshed society model

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Closing the representation gap

To mitigate these risks, the open source community must actively engage with policymakers and advocate for a more nuanced regulatory approach. Lessons from past advocacy efforts, such as the successful campaign against the Software Patent Directive in 2005,[22] demonstrate that coordinated efforts can influence policy outcomes.

A structured approach to policy engagement should include:

- **Coordination** – Open source advocacy organisations must collaborate, e.g. in monthly meetings, to monitor legislative developments and respond collectively.
- **Segmentation** – Dedicated task forces should convene regularly, e.g. weekly, to address specific regulatory challenges, such as the Cyber Resilience Act (CRA).
- **Mentoring** – Knowledge-sharing initiatives should equip open source contributors with policy expertise.
- **Peer review** – Position statements and advocacy efforts should be presented to others and collectively refined to ensure coherence and impact.
- **Inclusiveness** – Broader community participation should be encouraged to amplify the open source voice in policy discussions.

Conclusion

The regulatory landscape is shifting, and open source software is increasingly falling under its scope. While some level of oversight is necessary, it must be designed with an understanding of open source dynamics to avoid stifling innovation and collaboration. The open source community must work proactively to bridge the representation gap, ensuring that regulation supports rather than hinders the Fourth Sector's contributions to society. Through strategic advocacy and engagement, it is possible to shape a regulatory framework that strengthens Europe's digital sovereignty and competitiveness while recognising open source's critical role in the ecosystem.

[22] https://eur-lex.europa.eu/procedure/EN/172020

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Open Source in Europe Amid Geopolitical Tensions

Astor Nummelin Carlberg (Open Forum Europe)

Introduction

Technology has long been a space where individuals, businesses, and nations both compete and cooperate. These overlapping interests and dependencies shape global geopolitical dynamics. In this context, open source emerges as a powerful tool – not just for innovation, but for shifting the balance from overdependence on a few players toward more distributed, in- or interdependent ecosystems.

With its commitment to digital sovereignty and strategic autonomy, Europe needs to navigate the complex intersection of open source, national security, and global competition. This chapter explores the role of open source in Europe's geopolitical landscape, analysing both its opportunities and challenges.

The softwareisation of society

As digital transformation accelerates, software has become ubiquitous and integral to strategic sectors, including defence, energy, telecommunications, and healthcare. More software also implies more open source: According to the 2025 Black Duck Open Source Security and Analysis Report, 97% of codebases scanned contained open source software.[23] The widespread adoption of open source across industries has made it a focal point for political

[23] https://www.blackduck.com/resources/analyst-reports/open-source-security-risk-analysis.html

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and economic decision-making. Governments now recognise that software supply chains – many of which rely on open source – are critical infrastructure requiring oversight and investment.

A path to technological sovereignty ...

For European policymakers, open source offers an opportunity to reduce reliance on proprietary solutions, where an over dependence is experienced. It is not limited to an over dependence on solutions from vendors who are non-European, but in the current climate that can be expected to be a core consideration. But the solution is not only "buy European", at the end of the day Europe's IT users need to be able to increase its options: buy software, and at times be able to co-create or themselves build and maintain software. This is part of maturing non-software organisations in a "softwareised" world. This is done by policymakers by fostering domestic open source ecosystems of developers, EU member states can only gain greater control over critical technologies, ensuring security, innovation, and competitiveness if we have the skills to do build, re-build, credibly fork (link) and maintain software. This is at the core of the European Union's broader strategy to enhance digital sovereignty by promoting open standards and reducing dependency on non-European software vendors.

... or commoditisation machine?

While some view open source as a tool for sovereignty, others argue that it undermines proprietary software industries by commoditising technology. Open source levels the playing field, potentially benefitting some economies more than others. Examples such as Open RAN (ORAN) for telecommunications, AV1 for video codecs as an Android alternative demonstrate how open source can disrupt traditional software markets while enabling new geopolitical power shifts. Commoditisation and sovereignty are however two sides of one coin: open source is a strategic tool to manage dependencies in software.

National open source approaches

A small number of governments worldwide are actively shaping their open source approaches to align with national interests. Europe's approach contrasts with those of the United States and China, each with its own priorities and challenges. The

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European Commission is placing increasing emphasis on **digital sovereignty** and **strategic autonomy**, aiming to reduce its dependence on foreign technology providers. This approach is not only about securing greater control over digital infrastructure, but also about **lowering costs** and **fostering innovation and competitiveness** within the EU's digital ecosystem. Central to this vision is the **support for open standards**, which serve as a foundational pillar of the EU's strategy to ensure interoperability, transparency, and independence in the digital space.

In contrast, the **United States** is prioritising **software supply chain security** and **maintaining its leadership in the tech industry**. With a growing awareness of the threats posed by increasingly complex and opaque software systems, the US is focused on **strengthening resilience against cyber threats** by promoting transparency in software components. This includes the adoption of **open source audits** and **security-focused initiatives** to bolster trust in the nation's digital infrastructure. At the same time, the US seeks to **sustain its global leadership in software innovation** while proactively **mitigating security risks**.

China has adopted a s**tate-led approach to open source development**, marking a significant shift in direction with the introduction of its **14th Five-Year Plan (2021–2025).**[24] This plan signals a turning point, emphasising the strategic importance of open source in achieving **technological independence.**

As part of this effort, the Chinese government is **encouraging state-backed enterprises** to take a leading role in building and nurturing domestic open source communities. At the same time, there is a strong focus on **patent risk management**, aimed at addressing potential **intellectual property concerns** that could hinder innovation or adoption.

China is also looking beyond its borders, **promoting active participation in international open source organisations** to gain influence, align with global standards, and contribute to the broader open source ecosystem. Key areas of development include **AI, blockchain, and mobile technologies,** which are being positioned as foundational elements in China's broader strategy for **technological self-reliance and innovation.**

[24] https://jamestown.org/program/open-source-technology-and-prc-national-strategy-part-i/#:~:text=MIIT%27s%20%E2%80%9C14th%20Five-Year%20Plan,%2C%20November%2015%2C%202021

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Balancing benefits and risks: The role of governments

Governments must carefully balance the advantages of open source with the potential risks associated with funding, regulation, code contributions, and export controls.

Key considerations

Funding: Public investment in open source projects can drive innovation, but may also require mechanisms to ensure trust in the open source ecosystem.

Regulation: Striking a balance between open collaboration and national security concerns is essential to avoid unintended restrictions on innovation.

Code Contribution: Governments and enterprises must decide how and where to contribute to global open source projects, ensuring alignment with strategic interests.

Export Controls: Policies that restrict access to certain open source technologies could disrupt global collaboration and innovation while reshaping the competitive landscape.

Open source in a geopolitical crisis: Are we prepared?

Geopolitical instability introduces new challenges for open source communities, raising critical questions:

- What is the impact of sanctions or export controls on open source ecosystems?
- How can open source be weaponised in international conflicts?
- How should open source governance evolve to address geopolitical risks?

As geopolitical tensions rise, open source and permissive intellectual property models often benefit challengers seeking alternatives to dominant technology players. It is imperative that Europe acknowledge its role as a challenger and leverage open source strategically to strengthen its digital resilience and innovation capabilities.

Conclusion

The intersection of open source and geopolitics is reshaping Europe's digital landscape. As the EU seeks to enhance digital sovereignty, it must navigate the complex dynamics of open source governance, economic competition, and national security. By adopting a proactive approach, and by leveraging permissive intellectual property, Europe can harness the power of open source to drive innovation while mitigating geopolitical risks, ensuring a secure and competitive digital future.

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Open Source and the Skill Shortage

Roberto Di Cosmo (Software Heritage & INRIA)

As the demand for software development grows, the role of the next generation of free and open source software developers is crucial. However, a key challenge to European competitiveness is that Europe's talent pool is increasingly mobile, with many developers moving to the U.S. or other regions where tech ecosystems are better integrated and resourced. Open source can play a key role in addressing this skill shortage by creating an ecosystem where developers and researchers can build their expertise locally. Unlike proprietary systems, open source allows developers, engineers, and researchers to freely access, experiment, and contribute to cutting-edge technologies providing real-world, hands-on experience.

The role of academia in OSS

Academia has long been a driving force behind OSS. Many fundamental projects across academic disciplines (s. figure below) have originated from university research labs and open collaboration among scholars. According to the French National Plan for Open Science (2021), software production should be recognised in research careers, ensuring that researchers and support staff receive proper credit for their contributions. However, the integration of open source into academic evaluation and funding remains a challenge.

[25] https://www.ouvrirlascience.fr/wp-content/uploads/2019/08/National-Plan-for-Open-Science_A4_20180704.pdf
[26] https://www.enseignementsup-recherche.gouv.fr/fr/presentation-du-rapport-sur-l-etat-des-lieux-des-logiciels-issus-de-la-recherche-publique-francaise-93726

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Findings from the French National Survey on Research Software (2023) show that:

50% of research software is over nine years old.

- 36% has more than 100 users.
- 62% has an impact beyond academia.
- The majority of research software is FOSS, with only 10% being proprietary.
- 23% of projects undergo tech transfer.
- These statistics highlight the importance of maintaining and updating research software while ensuring proper funding and institutional recognition.

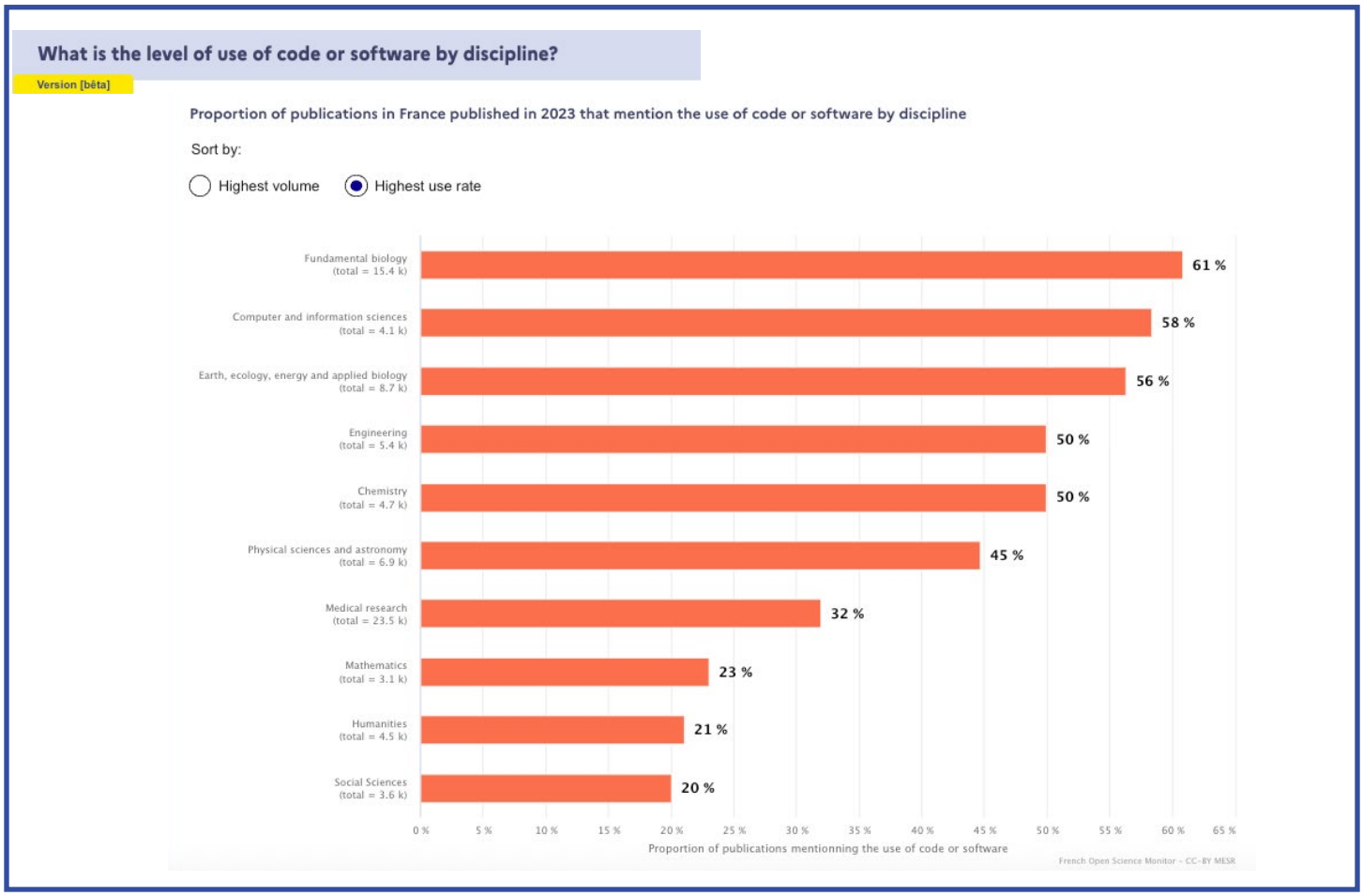

Figure 4: Software shared all around [27]

The elephant in the room: Skill shortages and AI's role

A robust tech ecosystem is a shared concern of academia, industry, and governments, and requires collaboration. Open source is an ideal platform for retaining, upskilling and reskilling Europe's workforce to meet growing demands in sectors such as AI, cloud computing, and cybersecurity.

[27] Source: https://frenchopensciencemonitor.esr.gouv.fr/software/fields?id=disciplines.utilisation Last accessed June 3, 2025

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The 2024 State of Open Source Report[28] and the State of 2024 Tech Talent Report[29] both indicate a growing concern over the lack of skilled developers. While only 16.4% of organisations do not face a skill shortage according to the State of Open Source Report, nearly half address the issue through upskilling and training. According to the 2024 Tech Talent Report, 98% of organisations consider upskilling an important strategy, with 36% rating it extremely important.

At the same time, artificial intelligence (AI) is reshaping software development. AI-powered code assistants can reduce development time and lower the barrier for transitioning to safer programming languages. However, this shift also brings challenges:

- New skills are required to manage and optimise AI-assisted development.
- The volume of software that needs maintenance will increase (see figure below)[30]
- There is a risk of losing traceability in software origins, a key concern for security and compliance.

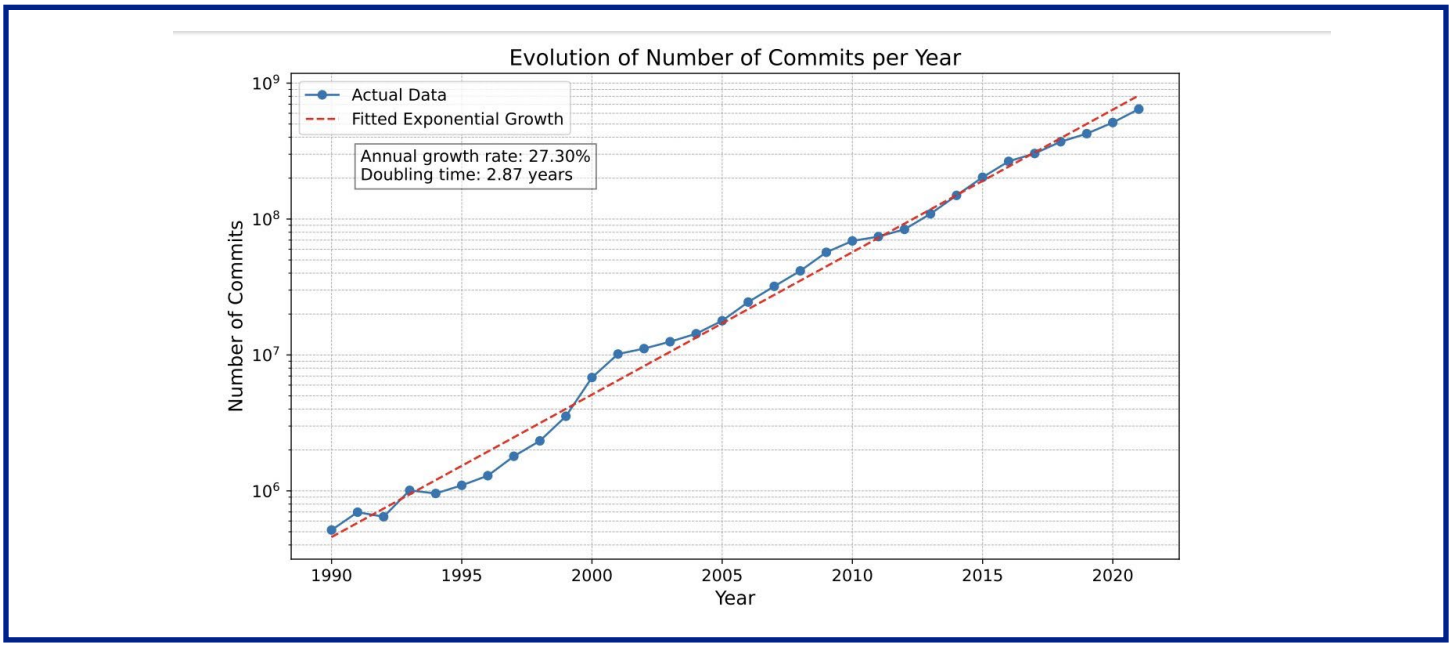

Figure 5: Evolution of original commits as seen in the Software Heritage archive

Jensen Huang, CEO of NVIDIA, recently argued that "kids shouldn't learn to code; they should leave it up to AI."[31] While this perspective sparks debate, it underscores the importance of adapting software education to the evolving technological landscape.

[28] https://www.openlogic.com/sites/default/files/pdfs/report-ol-state-of-oss-2024.pdf
[29] https://www.linuxfoundation.org/blog/the-2024-state-of-tech-talent-report
[30] Data taken from: https://archive.softwareheritage.org/
[31] https://www.tomshardware.com/tech-industry/artificial-intelligence/jensen-huang-advises-against-learning-to-code-leave-it-up-to-ai

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Looking forward: A coordinated effort

A resilient and sustainable ecosystem for OSS development requires collaboration between academia, industry, and governments. Key areas of focus include:

Policy

- Better integration of OSS in open science initiatives
- Streamlining funding mechanisms for OSS projects, making them as accessible as proprietary software procurement

Education

- Enhancing OSS training at both academic and professional levels
- Preparing developers for upcoming regulations like the Cyber Resilience Act (CRA)
- Incorporating AI-powered coding tools into curricula while maintaining core programming skills

Infrastructure

- A universal software archive for preservation, reference, and integrity
- Improved traceability and quality assurance mechanisms
- Large-scale collaborative tools for better code analysis and sharing

Going Global: The future of OSS collaboration

Software development is inherently international. A study on Geographic Diversity in Public Code Contributions (MSR 2022) highlights the extensive global participation in open source projects (see figure below).[32]

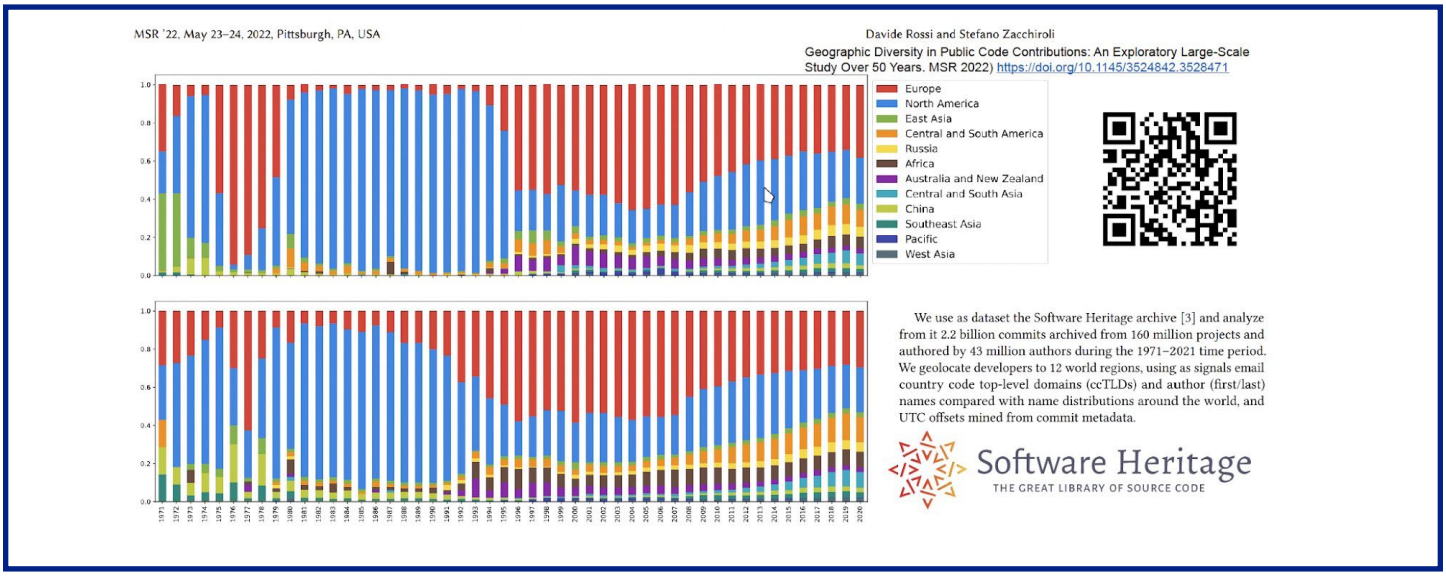

Figure 6: Ratio of commits (above) and active authors (below) by world zone over the 1971-2020 period

[32] https://dl.acm.org/doi/10.1145/3524842.3528471

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Software Heritage,[33] an initiative launched in 2016, plays a crucial role in preserving and cataloguing open source contributions for future generations.

A vision for the future of OSS must include:

- A globally coordinated reference infrastructure for better software development
- Recognition and funding mechanisms that support long-term sustainability
- Stronger public-private partnerships to maintain and expand open source ecosystems

Conclusion

Open source is not only a tool for software development, but also a catalyst for education, training, and talent retention. By aligning open source projects with structured upskilling programs, Europe can address its digital skills shortage and build a competitive workforce that supports its ambition for technological sovereignty. By fostering collaboration, investing in education, and ensuring sustainable funding, we can secure the future of open source as a driver of technological and scientific progress. With initiatives like Software Heritage and national policies advocating for open science, the foundation is set for a more inclusive and resilient open source ecosystem.

[33] https://www.softwareheritage.org/

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Summary: Open Source as a Cornerstone for Europe's Digital Future

Europe stands at a pivotal moment in shaping its digital sovereignty and competitiveness. As the global technology landscape continues to evolve, the European Union must find a path that balances government leadership, business innovation, and collaborative technological development. This white paper has highlighted the major role of open source in achieving these objectives, demonstrating how it can serve as a catalyst for innovation, economic growth, and strategic autonomy.

Open source: A winning strategy

Open source is more than just a technical approach to software development; it is a collaboration model and a fundamental driver of digital innovation, economic resilience, and industrial independence. By leveraging open source, Europe can:

- Reduce dependence on foreign technology providers, mitigating risks related to economic and geopolitical instability
- Foster a competitive and innovative tech ecosystem by enabling broad participation from startups, SMEs, academia, and large enterprises
- Ensure compliance with European values and regulations, such as data sovereignty, security, and privacy
- Promote interoperability and standardisation, positioning Europe as a leader in setting global technology benchmarks

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Key takeaways and challenges

Throughout this white paper, we have explored how open source can transform various domains, from AI, cloud solutions, and hardware development to regulatory frameworks and skills training. However, the success of open source in Europe depends on several factors:

- **Policy and Investment:** Policymakers must recognise open source as a strategic asset and integrate it sustainably into funding programs, research initiatives, and industrial strategies.
- **Standardisation and Governance:** Establishing clear open source frameworks and regulatory guidelines will ensure transparency, security, and long-term sustainability, with open source foundations playing a key role in their implementation and stewardship.
- **Education and Skills Development:** Addressing the skill shortage through open source training programs and academic collaborations will empower the next generation of developers and innovators.
- **Collaboration and Ecosystem Growth:** Strengthening partnerships between public institutions, businesses, and open source communities will drive collective progress and market competitiveness.

Open source to fast-track European technological leadership

Open source is not a silver bullet or the ultimate solution that will transform Europe and achieve digital sovereignty and sustained technological leadership, but it is a strategic instrument to improve collaboration not only in the single market, but also with the other geopolitical blocs. Thus, Europe should embrace open source as a central pillar of its digital agenda. This requires a shift in mindset – from passive adoption of available technologies developed elsewhere to proactive investment in open source solutions made in (or led by) Europe and a common, vendor-neutral resources infrastructure, with open source foundations as stewards. Prioritising European technologies is not about limiting its technological scope; rather, it focuses on leveraging Europe's existing innovative potential and collective strengths to lead in global digital transformation.

By committing to open source principles, Europe can:

- Secure its digital infrastructure and mitigate external dependencies
- Cultivate an innovative and self-sustaining technology sector
- Strengthen its position as a global leader in ethical and responsible technological development

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Final call to action

Europe's future in the digital age will be determined by the choices it makes today. Open source presents a strategic opportunity to build a resilient, competitive, and independent digital ecosystem. Policymakers, industry leaders, and the broader tech community must seize this moment to collaborate, invest, and drive forward an ambitious open source strategy that ensures Europe's place at the forefront of global innovation.

By harnessing the power of open source and its collaboration model, Europe can secure its digital sovereignty, foster inclusive growth, and lead the next era of technological transformation.

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Supported by the European Commission, HiPEAC (High Performance, Edge And Cloud computing) is the premier focal point for networking, dissemination and training activities in Europe for researchers, industry, and policy related to computing systems. First established in 2004, the project is now in its seventh edition. Today, its network – the biggest of its kind in Europe – numbers over 2,000 specialists.

The latest edition of the project, HiPEAC7, began on 1 December 2022, steered by a consortium of 11 partners led by Ghent University. It focuses on networking and roadmapping activities: bringing the computing community together in Europe, exchanging ideas, building thriving European value chains and exploring the long-term vision for computing systems in coordination with other major stakeholders.

To learn more, follow us on social media (@HiPEAC, LinkedIn), or visit hipeac.net.

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The Eclipse Foundation provides our global community of individuals and organisations with a business-friendly environment for open source software collaboration and innovation. The Eclipse Foundation hosts the Eclipse IDE, Adoptium, Software Defined Vehicle, Jakarta EE, and over 420 open source projects, including runtimes, tools, specifications, and frameworks for cloud and edge applications, IoT, AI, automotive, systems engineering, open processor designs, and many others. Headquartered in Brussels, Belgium, the Eclipse Foundation is an international non-profit association supported by over 300 members.

The Eclipse Research department plays a key role in advancing open source innovation through strategic collaborations with academic and industrial partners across Europe. By participating in EU-funded research projects, Eclipse Research bridges the gap between cutting-edge research and sustainable open source ecosystems, fostering technology transfer, promoting standards, and accelerating adoption of innovative software solutions.

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