ZOOOM

Contents

Executive Summary

Open hardware refers to physical devices and products whose design specifications are publicly available. This means that anyone can access, modify, distribute, and manufacture the hardware based on these specifications. The concept is similar to open source software, but instead of code, it pertains to the hardware's design, schematics, and documentation. Open source hardware (OSH) offers viable alternatives to conventional (proprietary) product creation. It also prevents monopolisation of technologies and thus structural dependencies.

Open hardware plays a crucial role in driving innovation, offering a realm of possibilities for collaboration and economic growth. In science, open hardware solutions improve access to technology and facilitate scientific research, particularly in countries with limited access to science funding. Supporting hardware openness can lead to a transformative increase in technology access and technological, scientific and economic development. Advocating for hardware openness can also serve as a cornerstone for fostering European technological sovereignty and open strategic autonomy.

However, compared to open source software projects, open hardware projects often encounter unique challenges that hinder their widespread success. These challenges stem from the inherent complexities of hardware replication, testing, cost, and regulatory hurdles, which are less prevalent in software-centric initiatives.

To foster the growth of open hardware projects, it is imperative to develop strategic approaches that address the unique challenges and opportunities within the open hardware ecosystem.

These policies should support OSH in its transition from a niche to a more mainstream position within hardware industries.

In our policy brief, we outline the following actionable recommendations to enhance the success of open hardware initiatives:

- Provide resources and guidance on legal aspects of Open Hardware, including licensing
- Facilitate sharing – creation of an Open Hardware repository
- Establish Open Hardware incubation centres
- Allocate funding specifically for Open Hardware research and development projects.

Introduction

Open Source Hardware (OSH)[1] is hardware whose design is made publicly available so that anyone can freely study, modify, make and distribute it (OSHWA, 2020). OSHW) OSHWA defines hardware as “tangible artefacts — machines, devices, or other physical things”. Within this broad definition, OSH now includes electronic boards, medical equipment, 3D printing, vehicles (predominantly bicycles), toys and games, optical products, materials, wetware and so on (Bonvoisin et al 2020, 2).[2]

Key characteristics of open hardware include:

- **Accessibility:** The design files and documentation are freely available to anyone, typically hosted on platforms like GitHub or other repositories. Any person can take part in the product development process. This openness encourages collaboration and improvement by a community of developers, hobbyists, and companies.
- **Free use and modification:** Any person can physically reproduce the product if following the design guidelines. Any person can freely modify the hardware design to suit their needs.
- **Distribution:** Since the designs are open, anyone can distribute the hardware. This allows for a wide variety of manufacturers to produce the same device, potentially leading to lower costs and increased availability.

Open source hardware builds on the same sharing philosophy and rights of users that underlies the success of free and open source software. However, one of the major differences between developing open source software and developing open source hardware is that hardware results in tangible outputs, which cost money to prototype and manufacture. Furthermore, the distinction between tangible and intangible in hardware is less clear compared to software, as open hardware can include also embedded software.

Examples of open hardware projects include Arduino, an open source electronics platform based on easy-to-use hardware and software, and Raspberry Pi, a series of small single-board computers. These projects have thrived due to the open nature of their designs, fostering communities of developers and enthusiasts who contribute to their growth and improvement.

1 Some authors use the term “free and open source hardware” (FOSH). See Powell, 2012; Gibb, 2014.

2 Bonvoisin, J, et al. 2020. Standardisation of Practices in Open Source Hardware. Journal of Open Hardware, 4(1): 2, pp. 1–11.

The four freedoms of open source hardware are:

- the right to study,
- the right to modify,
- the right to make, and
- the right to distribute.

Open hardware projects typically provide their design files, schematics, and documentation publicly. This means that anyone can access these materials, often hosted on platforms like GitHub or other repositories. Users can take these existing designs and modify them to fit their specific needs or requirements. This might involve changing components, altering circuit layouts, or adding new features. Rather than starting from scratch, designers can save time and effort by reusing well-tested and established hardware designs. This is known as "design reuse".[3] Design reuse fosters innovation by allowing developers to focus on adding new functionality or improving aspects of a design rather than reinventing the wheel. It also encourages collaboration within the open hardware community, as developers can share their enhancements and modifications with others.

Challenges Faced by Open Hardware projects

Open hardware, while holding immense promise for innovation, collaboration, and accessibility, faces several challenges that impact its development, adoption, and sustainability. One major challenge is the complexity of intellectual property and licensing, which poses a significant hurdle for open hardware projects. Understanding and navigating various open hardware licences, such as the CERN OHL or TAPR OHL, can be daunting for creators and contributors. Concerns about licensing obligations and legal liabilities often discourage individuals and businesses from engaging fully in open hardware initiatives. Another legal challenge arises from regulatory standards, which can be intricate and demanding. Safety certifications and industry regulations add a layer of complexity and expense to open hardware projects. However, it is important to note that this challenge is not unique to open hardware; non-open hardware projects also face similar regulatory hurdles. Thus, while it is a challenge, we do not consider it inherently specific to open hardware.

[3] "Design reuse" in the context of open hardware refers to the practice of utilizing and building upon existing hardware designs to create new products or projects. It involves taking the designs, schematics, or specifications of an open hardware project and using them as a foundation for developing something new. Design reuse can be especially beneficial for hobbyists, researchers, and small companies with limited resources.

One of the key characteristics of open hardware includes accessibility. For open hardware projects, it is crucial that the design files and documentation are freely available to anyone. Any person can take part in the product development process. This openness encourages collaboration and improvement by a community of developers, hobbyists, and companies. Accessibility is therefore a “sine qua non” for free use of open hardware products. The level of accessibility of hardware documentation can influence replicability and modifiability of open hardware products. At the moment, open hardware projects use existing repositories like GitHub, GitLab, or Bitbucket (commonly used version control repository-hosting platforms for open source projects). While these open hardware platforms are indeed valuable resources for version control, collaboration, and sharing of code, they were developed for the needs of the open source software community and are not tailored to the needs and development of the open hardware community. They don’t support hardware specific file types and don’t include specialised tools for visualising and inspecting 3D models, circuit diagrams, and other hardware design files. They don’t provide licence compliance tools designed specifically for open hardware, or standardised open hardware licensing templates, making it easier for creators to choose appropriate licences such as CERN OHL, TAPR OHL, or Solderpad Hardware License.

Another significant challenge are the high costs associated with developing, prototyping and testing hardware products. Open hardware projects rely on specialised tools for designing, modelling, and testing hardware components. Specialised tools for designing open hardware product, such as Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) software, plays a crucial role in the development and modification of hardware designs. However, these tools are limited or not easily accessible. Commercial CAD and CAM software packages are often expensive, making them inaccessible to individuals, small teams, and community-based projects with limited budgets. There are some open source hardware design tools on the market, however they lack certain advanced features or functionalities available in commercial software. The adoption of these tools is also impeded by scarcity of comprehensive tutorials, guides, and training resources. This results in a steeper learning curve, particularly for those transitioning from proprietary software.

Developing hardware prototypes can be expensive also due to the need for specialised components and expensive prototyping tools. Tools and equipment for creating hardware prototypes, such as 3D printers, CNC machines, and electronic testing devices, come with substantial price tags. In addition to this, testing hardware products for functionality, reliability, and safety entails significant expenses. This includes acquiring specialised testing equipment and adhering to industry standards—all of which add up to substantial financial investments. The financial burden associated with prototyping and testing hardware products becomes especially challenging for open hardware projects with limited budgets. On top of that, manufacturing hardware can also be a costly endeavour, involving expenses for materials, components, and manufacturing processes.

Unlike software code, which can be copied at minimal cost, hardware replication requires physical resources that are inherently more expensive. This is especially challenging for small businesses and start-up companies, as small-scale production runs often result in higher per-unit costs. All of this can deter individuals and small organisations from participating in open hardware projects.

When talking about funding, another critical challenge for numerous open hardware projects is their lack of sustainability and long-term support. Difficulty arises in maintaining updates, documentation, and consistent support, particularly when projects heavily depend on individual contributors or volunteers. Exploring sustainable business models, monetization strategies, or crowdfunding options while maintaining openness and accessibility is very demanding. However, sustainability is a problem for all open source projects (not only for open hardware).

To foster the growth of open hardware initiatives and projects, adequate funding becomes imperative. As explained above, unlike their more mature counterparts in the realm of open software, open hardware projects face a greater need for financial support. This is due to the unique challenges of hardware development. Given the inherent openness of open hardware, abundant funding is often a rarity, thus underscoring the critical necessity for investment to drive innovation, enable accessibility, and cultivate a robust ecosystem of hardware developers, makers, and enthusiasts.

Another major challenge is associated with the “physical nature/result” of open hardware projects. The term “open hardware” refers to physical devices and products. Unlike open source software development, where contributors can easily collaborate online, hardware projects often require physical presence for testing, assembly, and troubleshooting. Access to simulation tools and testing equipment may be restricted or costly for individuals and small teams. The lack of physical spaces where hardware developers, makers, and enthusiasts could come together is another barrier, especially for newcomers entering the open hardware community. Establishing specialised open hardware centres (open hardware incubation centres) that provide access to essential tools and equipment would foster collaboration among open hardware projects. These centres would prove particularly invaluable during the nascent stages of open hardware projects, facilitating their development and growth.

One of the problems in the open hardware community is also a shortage of educational resources and training programs. Open hardware development can be complex and it often requires a diverse set of skills, including hardware design, electronics, programming and prototyping. Without adequate resources, newcomers may find it challenging to navigate. The shortage of educational resources and quality learning materials deters potential contributors from participating in open hardware projects.

Recommendations

Provide Resources and Guidance on Legal Aspects of Open Hardware, Including Choosing Appropriate Licences for Different Types of Open Hardware Projects

One of the primary legal challenges is ensuring that all components of the open hardware project have compatible licences. Understanding intellectual property rights that may apply to hardware is the first step in choosing the right open hardware licence.

In contrast to open source software, there is an array of diverse intellectual property rights that may apply to open hardware.

- **Copyright on documentation and software code:**
  Open hardware projects include design files, schematics and other documentation, which is copyright protected. This means that the creator of these files has the exclusive right to reproduce, distribute, and modify them. In addition to this, open hardware often includes embedded software to control its functionality. The code written for the hardware's microcontrollers or processors is also subject to copyright protection.

- **Patents**
  If the open hardware project includes novel inventions, processes, or functionalities, these aspects may be eligible for patent protection. The majority of open hardware projects intentionally avoid patenting their designs to keep them freely accessible to the public. Nevertheless, some open hardware projects may choose to obtain patents for specific aspects or features of their designs (innovative mechanisms, functionalities) while keeping the overall design open. This hybrid approach allows for certain elements to be protected while still fostering openness and collaboration.

- **Utility Models/ Short-term Patents (in Some Countries)**
  Some jurisdictions in the EU offer utility models, which provide a shorter-term and less expensive alternative to patents. They protect minor inventions that may not meet the criteria for full patents. If the open hardware project includes such minor inventions, processes, or functionalities, these aspects may be eligible for utility model protection of hardware.

- **Industrial Design Rights**
  If the open hardware project includes unique and ornamental designs for the physical appearance of the product, these may be protected under industrial design rights. These rights safeguard the visual aspects of the hardware.

- **Trademarks**
  Some open hardware projects develop trademarks to protect brand names, logos, slogans, and other identifiers associated with the open hardware project.

In addition to this, some open hardware initiatives develop certification marks to indicate compliance with certain standards or specifications. These marks ate not intellectual property rights, however they ensure quality and consistency across hardware products, which is typical for trademarks.

Ensuring that all components of the open hardware project have compatible licences includes the hardware design files and any other documentation, inventions that may be eligible for patent protection, industrial design right, software used to run the hardware and so on. Open hardware projects need to carefully consider which IP rights to retain, licence, or waive. Choosing the right open hardware license is crucial for defining how others can use and build upon the hardware design.

To address these legal challenges, open hardware projects often rely on carefully crafted licences, which are designed specifically for hardware projects, such as the CERN Open Hardware License (OHL), TAPR Open Hardware License and Solderpad Hardware licence. But also some other licences can be relevant to hardware, such as Creative Commons CC-BY SA or GNU GPL (both reciprocal licences); or non-reciprocal (permissive licences) such as Free BSD licence (BSD-2 Clause), MIT License (MIT) and Creative Commons CC-BY-3.0.

CERN Open Hardware License was developed by CERN (the European Laboratory for Particle Physics), who is a custodian of this licence and is responsible for releasing new versions and variants of the licence. CERN OHL licence focuses on design documentation. Authorship or ownership of the design must be clear and undisputed for the licence to be operational. The current version of the licence is version 2. The licence comes in three variants, two reciprocal and one permissive:

- CERN-OHL-S (strongly reciprocal)
- CERN-OHL-W (weakly reciprocal)
- CERN-OHL-P (permissive).

This licence provides a framework for sharing hardware designs while maintaining some control over how they are used. It allows others to freely use, modify, distribute, and sell the hardware, provided they adhere to the terms of the licence. CERN-OHL-W allows for combining the licensed hardware with other designs under different licences, as long as the CERN OHL-W terms are followed for the original design. In contrast, CERN-OHL-S mandates that any derivative works based on the licensed hardware must also be licensed under the CERN OHL-S.

The main difference between CERN OHL-W and CERN OHL-S lies in the distribution requirements for modifications and improvements to the licensed hardware designs. Both licences require that modifications to the design be made available under the same licence terms. CERN OHL-S goes further – it requires that anyone distributing a product based on the licensed design must also distribute the source [4] files and design documentation along with the product.

[4] The term “source” is used to define “[i]nformation such as design materials or digital code which can be applied to make or test a product or to prepare product for use, conveyance or sale, regardless of its medium or how it is expressed; it may include notices” (CERN-OHL V2-S, Section 1.3).

This “copyleft” provision ensures that downstream users have access to the full design details, enabling further modifications and improvements.

CERN-OHL-P offers the least restrictive terms among the CERN OHL licences. It allows users to use, modify, distribute, and commercialise the licensed hardware designs without requiring that modifications or improvements made to the design be shared under the same licence. It also allows for combining the licensed hardware with other designs under different licences, including proprietary licences.

TAPR Open Hardware License is similar to the CERN licence, as it also focuses on design documentation. However, the TAPR licence is not primarily a copyright license – does not cover software, firmware or code leaded info programmable device. It is essentially a copyleft licence, however it acts as a contract. It requests that anyone who rely on the licence to release any modification to the design under the same licence.

All the above-mentioned licences require attribution to the original creators. This typically includes mentioning the project name, authors’ names, and a reference to the CERN OHL-P licence. Example: “This product uses designs from the [Project Name] by [Author/Creator], licensed under the [CERN/TAPR…], license.”

All the above-mentioned licences also include a patent grant, providing users with a licence to any patents held by the original creators that cover the licensed hardware design. Licences with reciprocity or copyleft provisions, such as CERN OHL and TAPR, the patent grant extends to any modifications or derivative works based on the original licensed designs.

The Solderpad Hardware licence was developed as an alternative to TAPR and CERN-OHL v1, which did not include a permissive variant. It is a non-copyleft form of licence based on Apache 2.0. It covers not only copyright and patent grant, but also other relevant rights, such as design right, semiconductor topography rights and database rights.

As mentioned above, understanding the intellectual property rights that may apply to hardware and choosing the right open hardware licence is crucial for defining how others can use and build upon the hardware design. This is especially demanding for the newcomers in open hardware world/ecosystem. Therefore, it would be of great value to provide resources and guidance on legal aspects of open hardware, including choosing appropriate licences for different types of open hardware projects. This would help open hardware developers understand the legal implications of their projects. Many of them may not be familiar with the nuances of different IP rights and licences. Providing resources and guidance helps them make informed decisions about what type of licence aligns best with their goals. Clear, accessible information on IP rights and licensing also reduces the barrier to entry for newcomers to open hardware. It makes it easier for individuals and organisations to understand how they can participate and contribute. In addition to this, providing resources and guidance on choosing appropriate licences for open hardware projects not only protects the legal interests of creators but also fosters collaboration, upholds open source principles and empowers a wider community of contributors. It is therefore a foundational step in the success and growth of open hardware initiatives.

Create an Open Hardware Repository

As explained in the introduction, for open hardware projects it is crucial that the design files and documentation are freely available to anyone – this openness encourages collaboration and improvement by a community of developers, hardware enthusiasts, engineers, makers, and businesses. The level of accessibility of hardware documentation can influence replicability and modifiability. At the moment, open hardware projects use existing repositories like GitHub, GitLab, or Bitbucket (commonly used version control repository-hosting platforms for open source projects). While these platforms are indeed valuable resources for version control, collaboration, and sharing of code, they were developed for the needs of the open source software community. A specific /new Open Hardware Repository is needed, similar to open source software repositories, but tailored to the needs and development of the open hardware community. It would complement existing platforms and be a central hub for hardware projects. Developers looking to contribute or collaborate on open hardware projects could more easily discover relevant projects; those looking to replicate existing hardware designs would find a curated collection of projects with detailed documentation and instructions.

This open hardware repository should support hardware specific file types (such as CAD files) and include specialised tools for visualising and inspecting 3D models, circuit diagrams, and other hardware design files. It should also have graphical user interfaces (dashboards) used for giving visualisations of key performance indicators for projects (similar to those on websites such as GitHub). It should also provide licence compliance tools (built-in tools) designed for open hardware, and standardised open hardware licensing templates, making it easier for creators to choose appropriate licences such as CERN OHL, TAPR OHL, or Solderpad Hardware License. The repository might integrate tools for design validation, simulation, and testing of hardware components, helping developers ensure the functionality and performance of their designs. It could also include educational resources, tutorials, and guides for beginners, supporting learning and skill development in hardware design. In this way, a specialised open hardware repository would offer several advantages, tailored specifically to the needs of the hardware development community. It would provide specialised features, support hardware-specific file types, facilitates licensing compliance, but also serves as an educational resource hub.

A specialised open hardware repository would also enhance/facilitate the visibility of open hardware projects, which is crucial for their success. It would represent a targeted outreach to potential users, developers, and businesses about the existing open hardware projects.

Set up Open Hardware Incubation Centres

One of the problems that the open hardware community is facing, is a lack of a specialised open hardware repository. While the existing open hardware platforms, such as GitHub and others, are very valuable for open software developers, they were developed for the needs of the open source software community and are not tailored to the needs and development of the open hardware community.

Open Hardware Incubation Centres should be established as designated spaces, which would serve as hubs and collaboration spaces for developers, entrepreneurs, and hobbyists to work on open hardware projects, prototype designs, and collaborate with others. They would provide physical spaces where hardware developers, makers, and enthusiasts can come together and enable connections with like-minded individuals, potential collaborators, mentors, and industry experts.

Open Hardware Incubation Centres should be equipped and offer free access to a wide range of specialised hardware design tools, prototyping equipment (like 3D printers, CNC machines), and a wide range testing equipment. This would lower the barrier to entry for hardware developers, particularly those with limited resources or working from home. Developers could experiment with new technologies, iterate on designs, and validate prototypes in a supportive and well-equipped environment.

Open Hardware Incubation Centres could also assist in preparing pitches, connecting with investors, and navigating the fundraising landscape. In addition to this, they could provide access to funding opportunities, investment networks, and grant programs tailored to hardware start-ups. On top of that, they could offer legal advice and business development services. In this way, open hardware incubators would help bridge the gap between the development phase and realisation of open hardware projects. As hubs of open innovation, they would serve as advocates for open hardware licensing, standards, and best practices within the broader hardware community. By supporting the development of viable business models and

Allocate Funding Specifically for Open Hardware Research and Development Projects

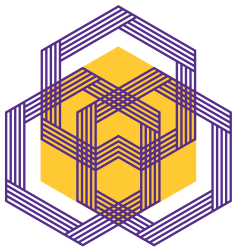
Open hardware communities are fragile communities, as they are still developing. In order for them to grow faster, supportive funding is needed. Since open hardware is free to use, funding is rarely abundant.

There is a variety of funding resources for open software, but there are no data and no systematic approaches to fund open hardware projects. Such funding should include grants, subsidies, or tax incentives to businesses, educational institutions, and individuals working on open hardware projects. Another possibility is to encourage and develop partnerships between public and private sectors to fund and support open hardware initiatives.

The funding of open hardware project would protect and possibly improve the existing open source hardware innovation pipeline. This pipeline is fed by hardware individual developers or small groups of developers. This is not enough if we want open hardware idea to gain such success as open source software idea. There needs to be a systematic approach towards funding. There is no state driven existing funding mechanisms for open hardware. There are however some private initiatives/ funding. The problem with those is that most of that funding is for new projects, hardly any for long term maintenance projects.

Even for new projects, funds favour more breakthrough/scientific innovation type of projects and do not address grass root innovation. In conclusion, there is a clear need for a European or state funding mechanisms to help sustain open source hardware communities and to support grassroots innovation in this field.

There are two ways to address the funding problem of open hardware projects. One option is to utilise an existing open source funding mechanism or technology programme, and use it (adapt it) for hardware. Another is a setting up a separate pan-European funding mechanism for open hardware projects.



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