Open Source Hardware Seminar
Introduction – OSH fields of application in technology science

Robert Mies, Julieta Arancio

Technische Universität Berlin, Institute for Machine Tools and Factory Management, Chair of Quality Science

Introduction

# Person responsible for module and contact persons

The team

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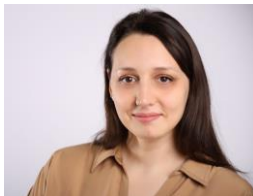
Dr. Julieta Arancio (lecturer and contact person for technical issues)
Guest researcher
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julieta.arancio@campus.tu-berlin.de

Consultation hour: by appointment

Communication

Group work and guidance

Synchronous

- **Open door** — Open door policy - at the institute on Mon., Wed., Thu. from 9am to 3pm
- **WebEx** — Office hours: 9am to 3pm by appointment

Asynchronous

- **E-Mail** — See contact details of lecturer/s
- **Forum** — Course page within ISIS portal
  - openly visible for all
  - within groups
- **Instant** — Discord channel (optional)

Organisational matters

Course assessment

Type of examination	Portfolio examination / 6 ECTS
Group presentations: interim presentation final presentation	10 out of 100 points / 15 min 20 out of 100 points / 15 min
Final report	70 out of 100 points / 10 – 15 pages - Technical report of a developed hardware / component / feature - Scientific paper (metaresearch or other) - Groups of 3-5 persons - Each group will be matched with a practice partner to jointly define a project scope

Organisational matters

Seminars and due dates

Seminars	Wednesday, 10 May, 14:15 – 15:45, room PTZ 407 / hybrid Zoom
Registration for ISIS course	Open for registration
Group allocation via ISIS course	Due date: 22 May
Registration via Moses	Due date: 31 May 2023
Presentation dates	Interim presenation: 21 Jun. 2023 Final presentation: 19 Jul. 2023
Final report	Submission due date: 31 Jul. 2023

OSHS | Open Source Hardware fields of application in technology science

TOC

- Background

- Empirical findings and best practices

- Technology assessment

- Standardisation of practices

- Fields of application

- Case examples

"if I have seen further, it is by standing on the shoulders of giants." Isaac Newton, 1675
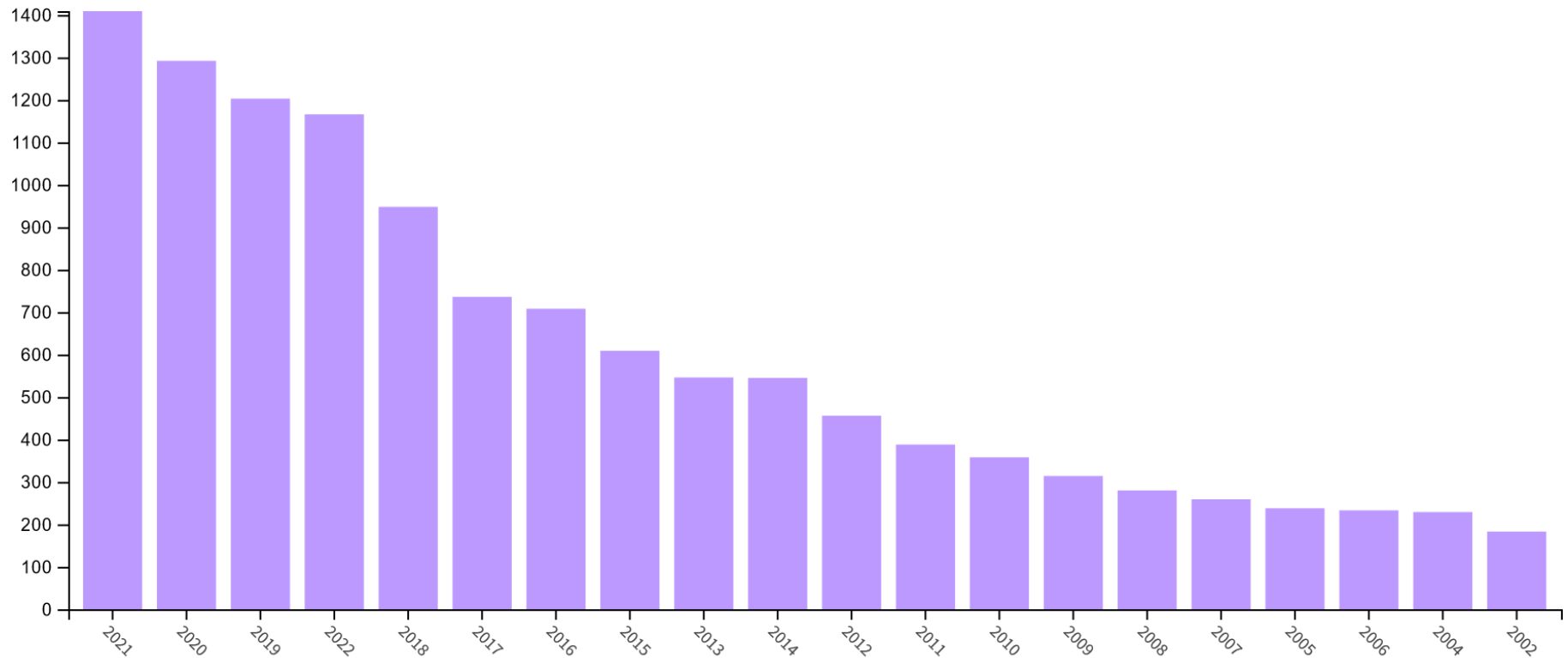
Background

Open source hardware-related publications

WOS results: open ? hardware (Topic) and Article (Document Types), 2000-2021

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Open source hardware-related publications

WOS results: open ? hardware (Topic) and Article (Document Types), 2000-2021

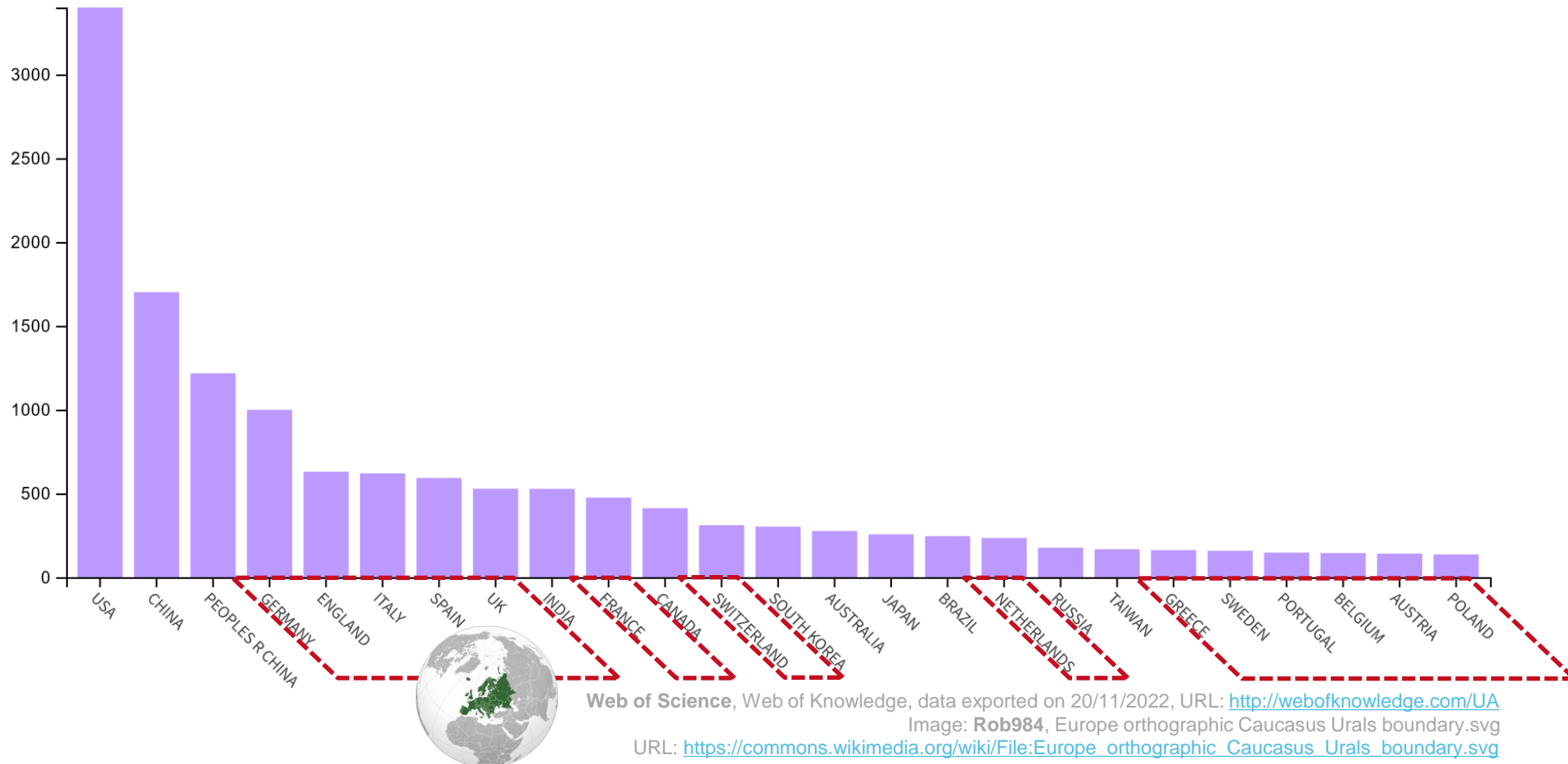Web of Science, Web of Knowledge, data exported on 20/11/2022, URL: http://webofknowledge.com/UA
Image: Rob984, Europe orthographic Caucasus Urals boundary.svg
URL: https://commons.wikimedia.org/wiki/File:Europe_orthographic_Caucasus_Urals_boundary.svg

OSHS | Open Source Hardware fields of application in technology science

Background

Open source hardware

What is open source hardware?

Image: **DIY Space Exploration**, CC-BY-SA, image cropped
URL: https://docs.google.com/presentation/d/1cCV_FQ5RgQSr3PTWNTLZ_e-Dgb-mM_IcRt4GdbQ-RdM/edit#slide=id.p13

Background

Open source hardware

Brief history

2016: Gathering for Open Science Hardware community (GOSH) founded

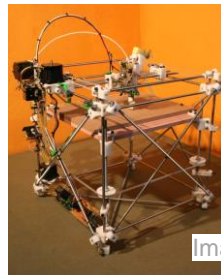2012: Open Source Hardware Association (OSHWA) founded

2011: CERN Open Hardware Licence & Repository introduced

2007: TAPR Open Hardware Licence introduced

2005: First Arduino & RepRap made

1991: Linux kernel released

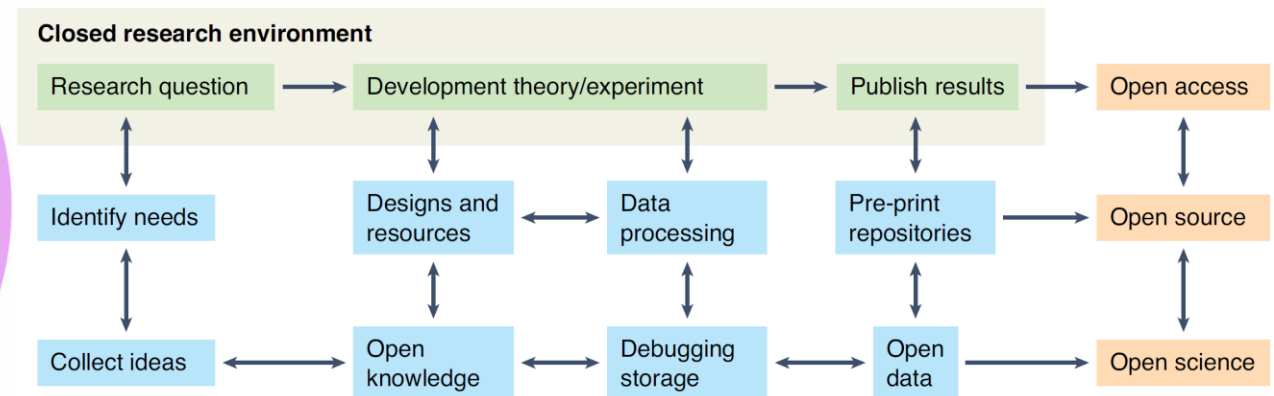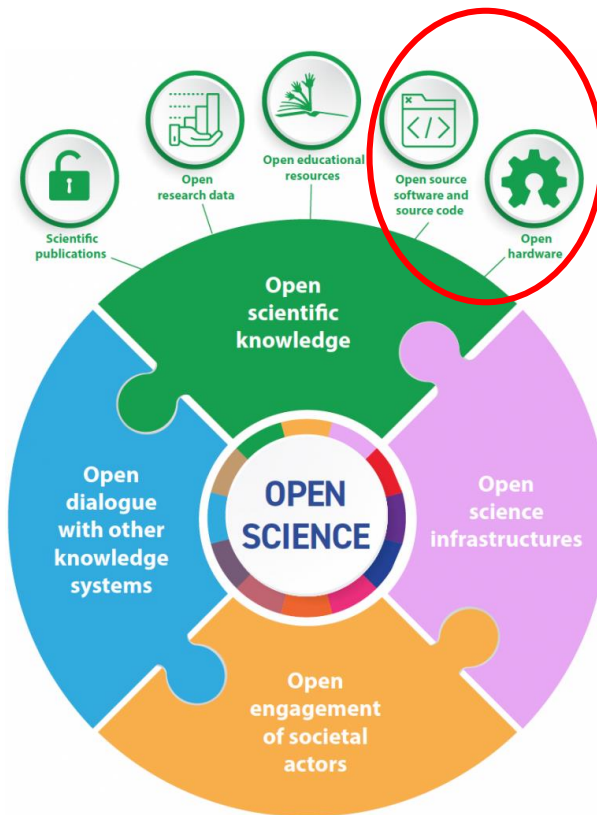Image: **Larry Ewing, Simon Budig, Garrett LeSage**, Tux.svg, CC-0, URL: https://github.com/garrett/Tux
Image: **SparkFun Electronics**, Arduino Uno - R3, CC-BY-2.0, URL: https://www.flickr.com/people/41898857@N04
Image: **The RapRap Project**, Reprap Darwin.jpg, CC BY-SA 3.0, URL: http://www.reprap.org

Background

Opening research hardware

Open research environments

Hohlbein, J., Diederich, B., Marsikova, B. et al. (2022). Open microscopy in the life sciences: quo vadis?. *Nature Methods 19*,1020–1025. DOI: 10.1038/s41592-022-01602-3

Background

Open source hardware

May and must

"

MUST

- – Allow anyone to study, modify, distribute, make, and sell the hardware.
- – Provide publicly accessible design files and documentation (the source).
- – Clearly specify what portion of the design, if not all, is being released under the license.
- – Not imply that derivatives are manufactured, sold, warrantied, or otherwise sanctioned by the original designer.
- – Not use the trademarks of other companies without permission.
- – Not be released as non-commercial or no derivatives.

MAY

- – Require attribution be given.
- – Use the open source hardware logo to signify their hardware follows the open source hardware definition.
- – Require derived works to carry a different name or version number from the original design.
- – Be copied directly or have derivatives created from it.
- – Require a viral license.

"

remix
remake
remanufacture
redistribute
resell
study and learn

Open Source Hardware Association, Open Hardware Month presentation, CC-BY-SA 4.0
URL: https://docs.google.com/presentation/d/1cCV_FQ5RgQSr3PTWNTLZ_e-Dgb-mM_IcRt4GdbQ-RdM/edit#slide=id.p13

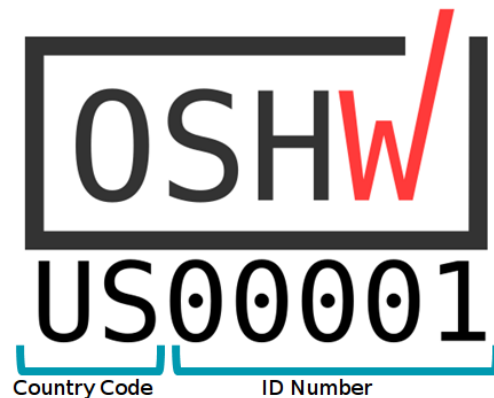# Technology assessment

Self-certification

Open Source Hardware Certification programme

Self-certification scheme that permits usage the OSHWA certification logo (see below)

- "[…] for producers to indicate that their products meet a uniform and well-defined standard for open-source compliance"

- generated identifier to help users find open source hardware projects along with their documentation

Four main elements:

- Hardware - The physical functional components/elements of the product (i.e. the product itself) (required)

- Software - Any code, firmware, or software involved in product's function

- Documentation - Design files, schematics, instructions, etc. (required)

- Branding - Brand names, product names, logos, and product designs (optional, but recommended)

Background

Physical product and process openness

Open source hardware *versus* open design
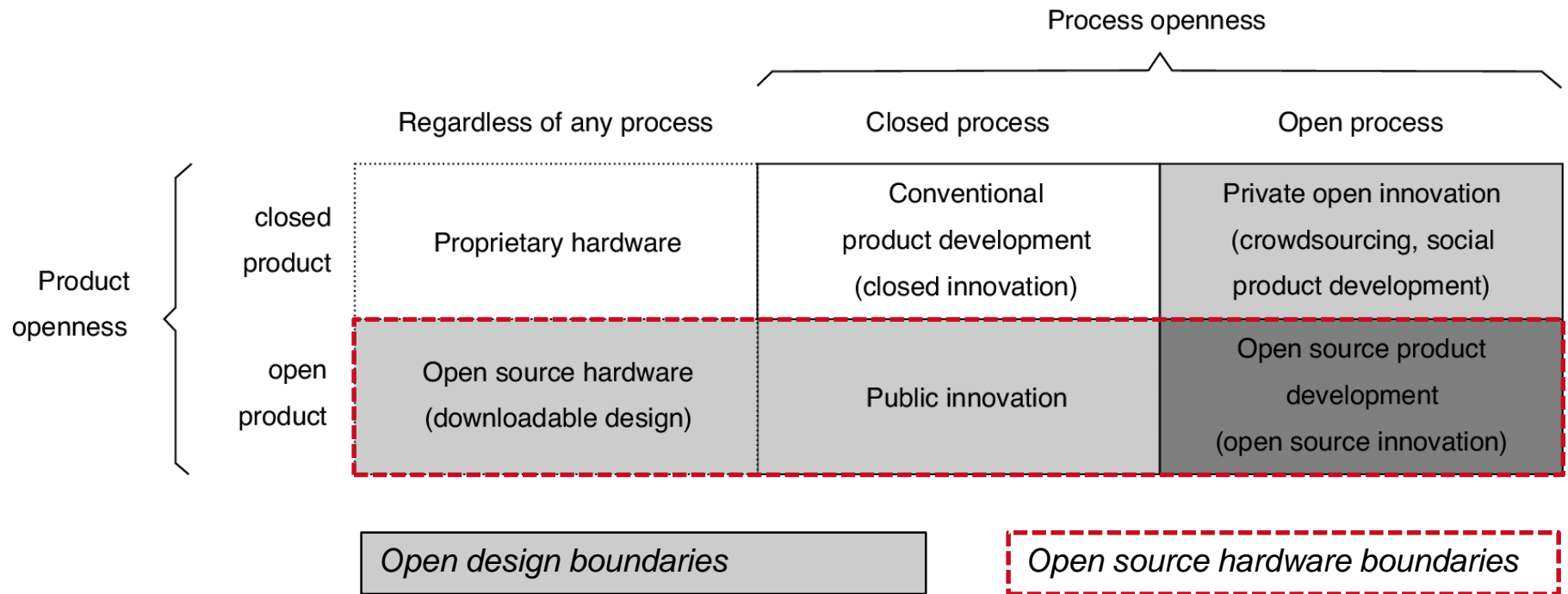
Bonvoisin, J., Mies, R., & Boujut, J.-F. (2021). Seven observations and research questions about Open Design and Open Source Hardware. *Design Science, 7*, e22. Cambridge University Press. DOI: 10.1017/dsj.2021.14

Technology assessment

Openness assessment

Measuring openness in open source hardware with the Open-o-Meter

Process openness
- Issue tracking system
- Contribution guide
- Version control system

Product openness
- Original files
- Assembly instructions
- Bill of materials
- CAD files
- OSH compatible license
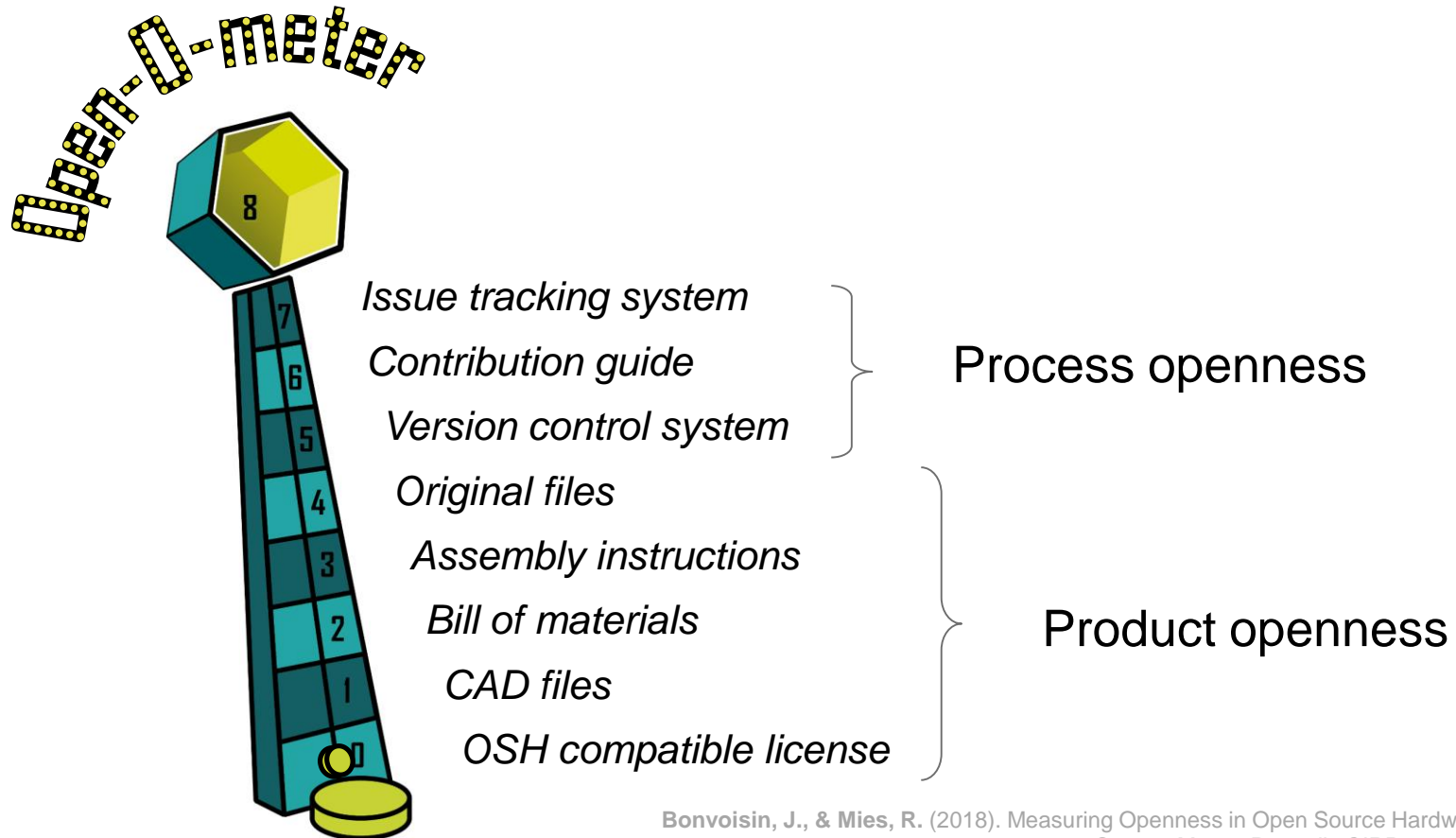
Bonvoisin, J., & Mies, R. (2018). Measuring Openness in Open Source Hardware with the Open-o-Meter. *Procedia CIRP*, *78*, pp. 388-393.

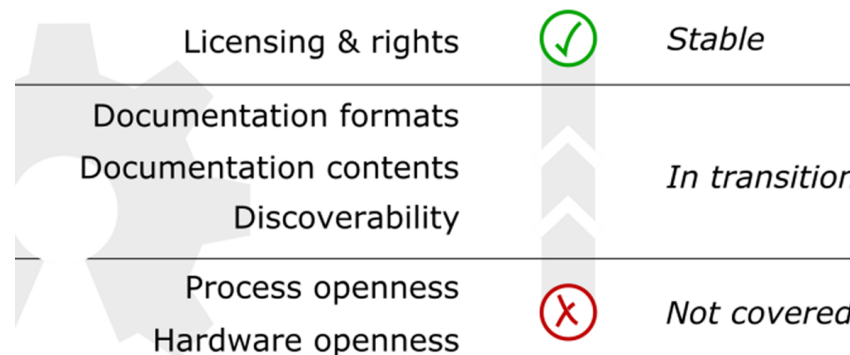# Standardisation of practices

Moving closer to the source
Challenges and current efforts

Challenges for standardisation of OSH

- Multi-faceted nature and different interpretations of openness in OSH

- Need for settlement of harmonised practices (relatively young field)

- *De jure* standard setting procedures *versus de facto* standards being adopted later (e.g. HTML, etc.)

Licensing & rights	✓	*Stable*
Documentation formats Documentation contents Discoverability		*In transition*
Process openness Hardware openness	✗	*Not covered*

Bonvoisin, J., Molloy, J., Häuer, M., & Wenzel, T. (2020). Standardisation of Practices in Open Source Hardware. *Journal of Open Hardware*, *4*(1), 2. DOI: 10.5334/joh.22

Standardisation of practices
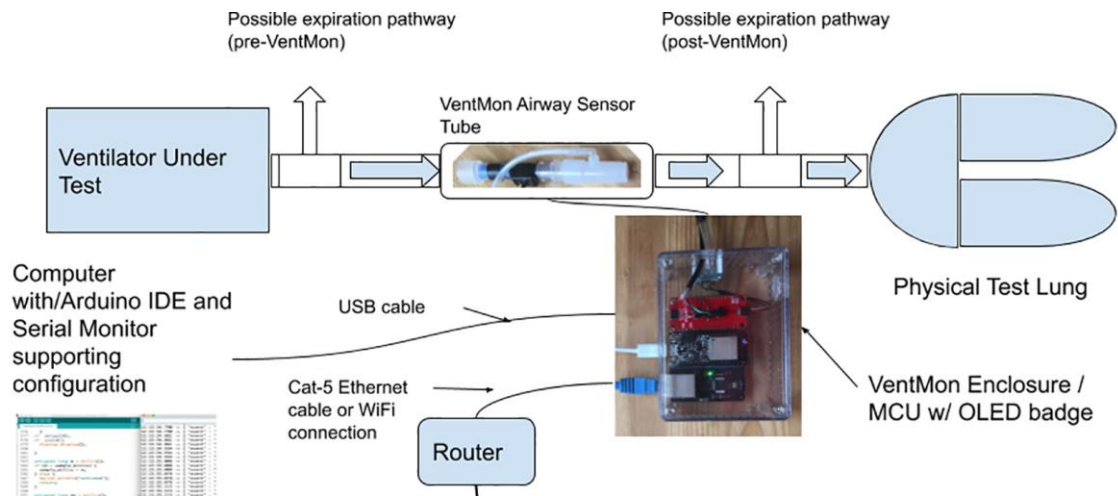
Moving closer to the source

Open source hardware ventilator tester and monitor (1of 2)

Emergence of 160+ projects by humanitarian engineers in response to ventilator shortage during the coronavirus pandemic with many qualifying as OSH

- Invasive ventilators that require intubation & non-invasive ventilators to support breathing

The VentMon test equipment was designed to help projects in times of lockdowns

- Modular, low-cost, open source hardware device that allows to test any ventilator anywhere

- Monitoring of all relevant parameters such as flow, pressure, etc.

- Plug-and-play solution is connected with the designed ventilator and a physical test lung

Read R. L., Clarke L., Mulligan G. (2021). VentMon: An open source inline ventilator tester and monitor. *HardwareX, 9*, e00195. DOI: 10.1016/j.ohx.2021.e00195

Standardisation of practices

Moving closer to the source

Open source hardware ventilator tester and monitor (2 of 2)

Platform for real-time recording, storage and visualisation of testing data

– Allows to grant access for various stakeholder groups

Openly published *de facto* data standa

– Enables verification of results and fosters repeatability

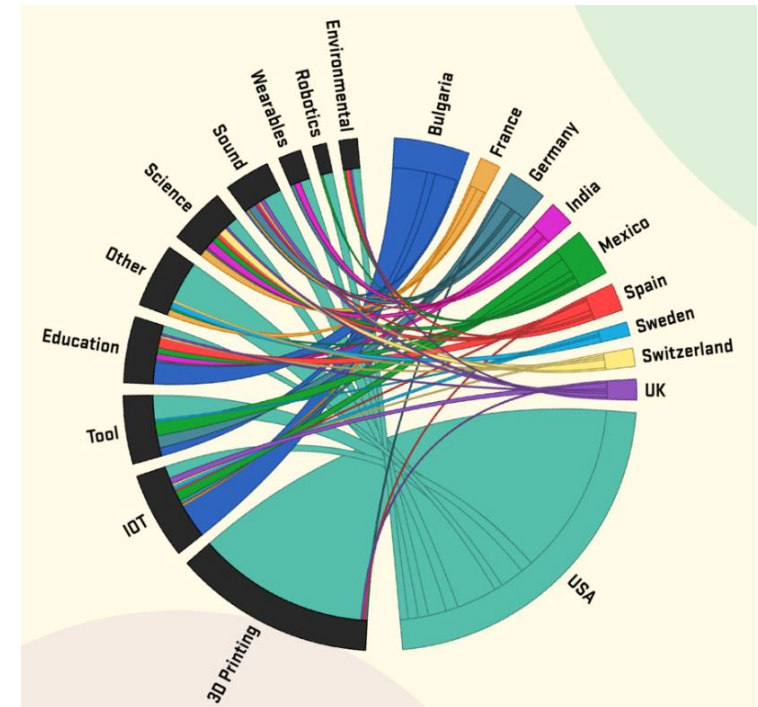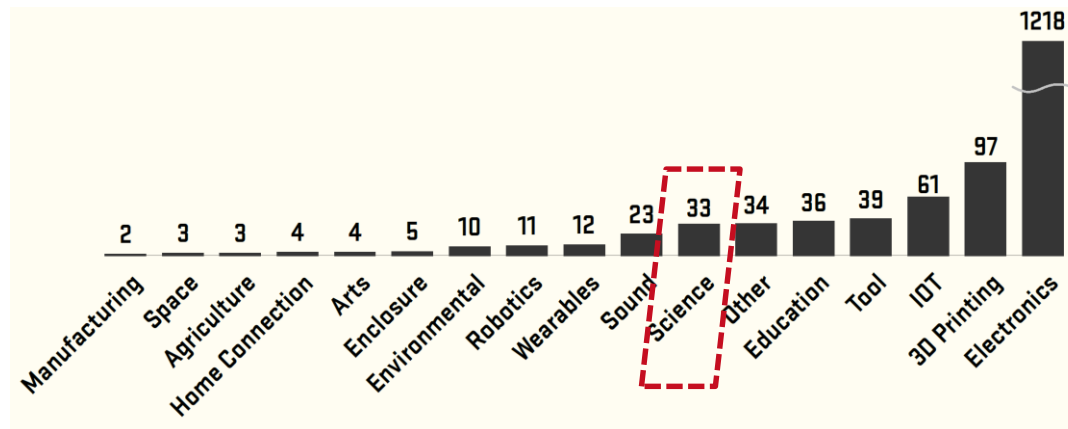– "[…] VentMon forms the beginning of an open system or eco-system of ventilation devices and data."
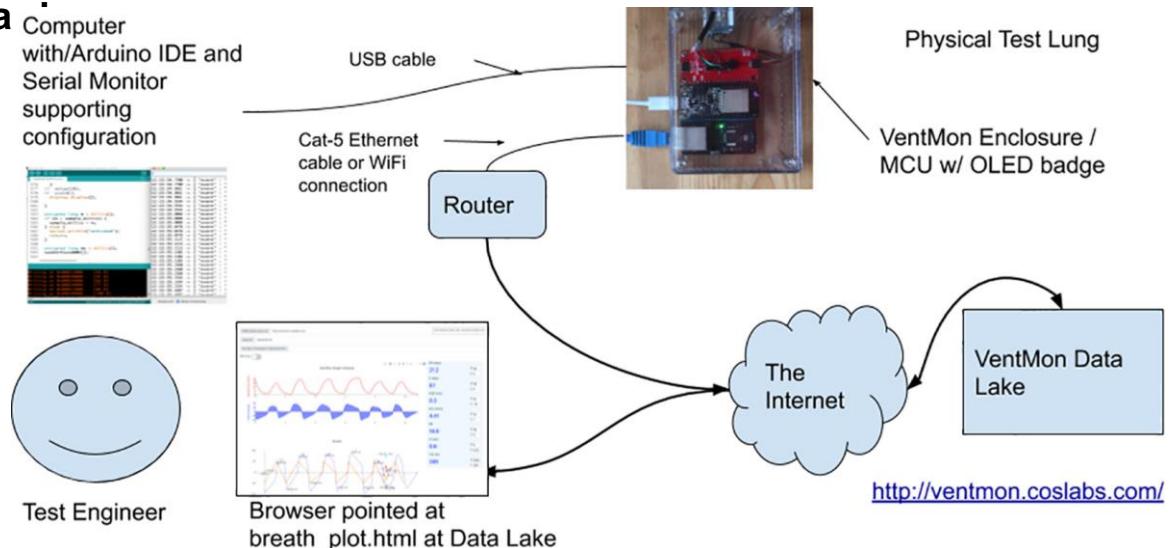
Read R. L., Clarke L., Mulligan G. (2021). VentMon: An open source inline ventilator tester and monitor. *HardwareX, 9*, e00195. DOI: 10.1016/j.ohx.2021.e00195

Fields of application

Sectors

Report - "The State of Open Source Hardware 2021"

Fields of application

Usage

Report - "The State of Open Source Hardware 2021"
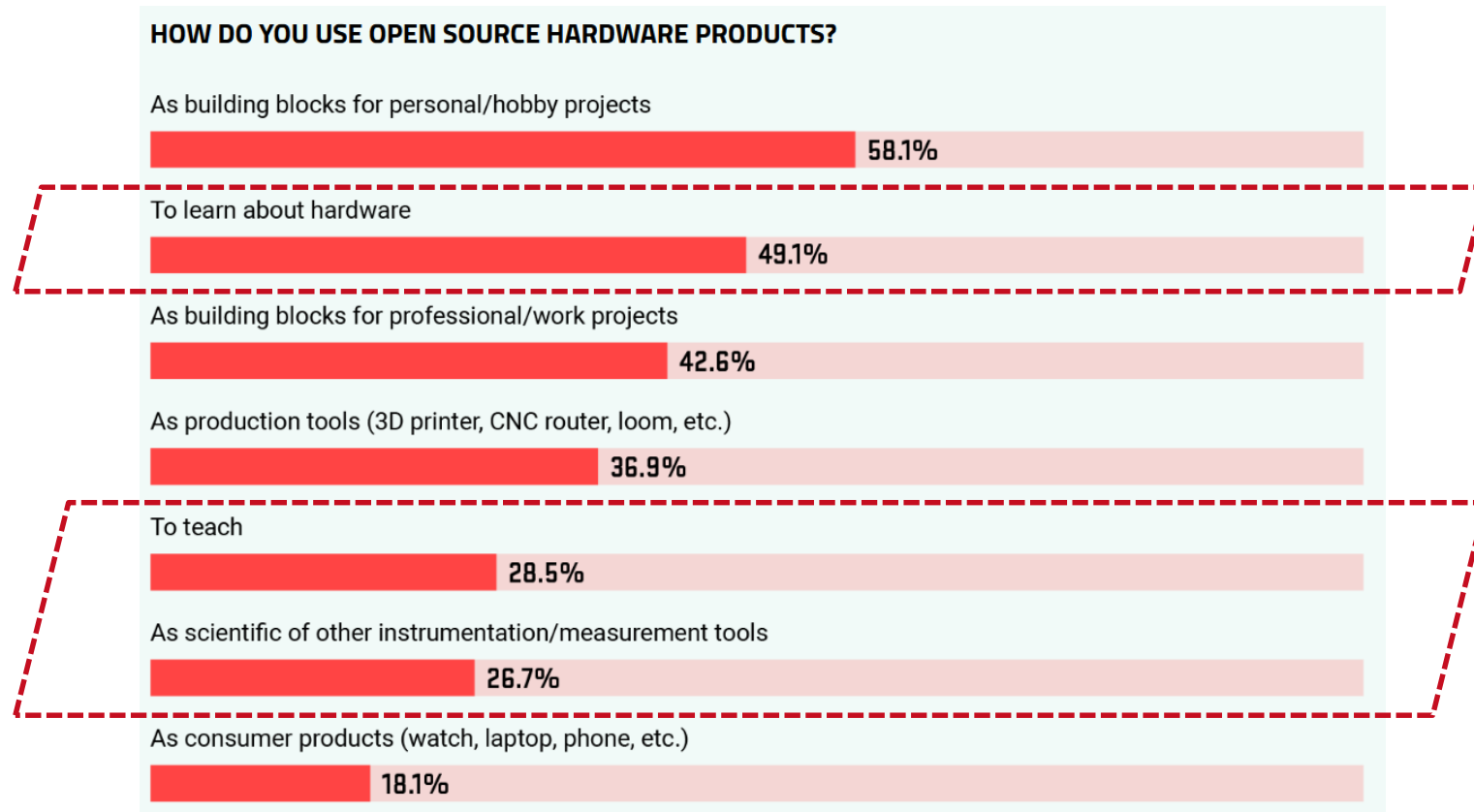
HOW DO YOU USE OPEN SOURCE HARDWARE PRODUCTS?

As building blocks for personal/hobby projects — 58.1%

To learn about hardware — 49.1%

As building blocks for professional/work projects — 42.6%

As production tools (3D printer, CNC router, loom, etc.) — 36.9%

To teach — 28.5%

As scientific of other instrumentation/measurement tools — 26.7%

As consumer products (watch, laptop, phone, etc.) — 18.1%

Fields of application

Publications

7,489 Computer Science
2,149 Automation Control Systems
1,307 Physics
1,274 Energy Fuels
1,107 Surgery
1,036 Orthopedics
2,110 Instruments Instrumentation
997 Mathematical Computational Biology
885 Science Technology Other Topics
884 Chemistry
818 Optics
6,039 Engineering
1,843 Mathematics
945 Radiology Nuclear Medicine Medical Imaging
2,275 Telecommunications
1,674 Communication
808 Robotics
669 Anatomy Morphology
925 Materials Science
656 Neurosciences Neurology
Medical technology

Web of Science, Web of Knowledge,

data exported on 20/11/2022, URL: http://webofknowledge.com/UA

Why people engage in OSH?

Open research hardware

Economic savings

According to review by Pearce (2020) open source technologies provide economic savings of 87% compared to equivalent or lesser proprietary tools

- Metareview based on 119 articles with 86 in *HardwareX* and 33 in the *PLOS Open Source Toolkit* (open access journal / resource)

- Particular focus on Arduino-based electronics and Use of RepRap 3D printing

- Supporting argument for sourcing of OSH alternatives in academia and national policies

- So, why is this not already done?

$$S = \frac{(P - O)}{P} (\%)$$

S ~ *economic savings*
P ~ *proprietary cost of a commercial system*
O ~ open source device cost in USD limited to the material costs
(assumptions: OSH self-built; labour costs not considered)

Pearce, J. M. (2020). Economic savings for scientific free and open source technology: A review. *HardwareX, 8*, e00139. DOI: 10.1016/j.ohx.2020.e00139

Why people engage in OSH?

Open research hardware

Flexibility and autonomy

- To try new hypotheses and advance science, researchers need to change and adapt their experimental settings easily and quickly

- Scientists are a niche market for manufacturers of scientific instruments, with very little negotiation power

- Vendor lock-in produces delays and increases costs when modifications or repairs are needed, and is also a threat to labs when companies go out of business

- OSH offers an alternative, providing rapid prototyping solutions that can be shared and improved (see ref.)

- CERN is experimenting with the strategy of using OSH to lower vendor dependence in the LHC (see ref.)

Baden T, Chagas AM, Gage GJ, Marzullo TC, Prieto-Godino LL, Euler T. (2015) Open Labware: 3-D Printing Your Own Lab Equipment. PLoS Biol 13(3): e1002086. pmid:25794301

Kauttu, P. M. V. (2018). Open hardware as an experimental commercialization strategy: challenges and potentialities. *CERN IdeaSquare Journal of Experimental Innovation*, 2(2), 25–31. https://doi.org/10.23726/cij.2018.826

Why people engage in OSH?

Open research hardware

Access to science & technology

- The manufacturing of scientific instruments is concentrated in the Global North, making science more expensive in the Global South due to long supply chains and import restrictions

- Being designed far away from implementation, tools often need to be adapted to the local context which may require some appropriations where limited resources or manufacturing capabilities exist

- Lack of access to designs, (global) supply chains and official technical services makes adapting hardware a problem in the Global South

- OSH provides a way of easily accessing design information, adapting designs to local contexts

- Greater access to better instruments allows researchers to run more significant and powerful studies

Arancio, J., Tirado, M. M., & Pearce, J. (2022). Equitable Research Capacity Towards the Sustainable Development Goals: The Case for Open Science Hardware. *J. Sci. Policy Gov*, *21*.

Fields of application

Open research hardware policy

GOSH 2021 international policy brief

Open hardware can champion progress for research and technology development (RTD)

1. Enhances participatory, transparent and sustainable science practices

2. Provides an effective multi actor approach integrating civil society, academia and commercial interests

3. Adopting and prioritizing of "may or should" OSH requirements in public funding programs

   a. Public funding should be re-directed not just "for promoting but also for sustaining innovation"

   b. [This kind of demand adopts the logic of the campaign "public money, public code"]

4. Create new opportunities for technology transfer for technical cooperation with the Global South

OSHS | Open Source Hardware fields of application in technology science
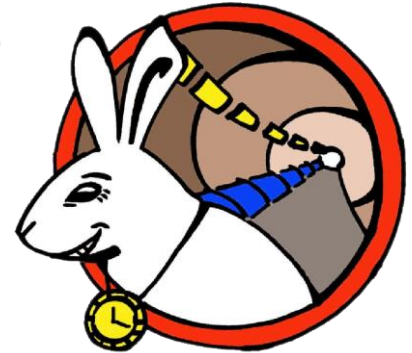
Case examples

Metrology

White Rabbit project

A distributed real time system to ensure all components are synchronized at sub-nanosecond accuracy

- Developed at CERN
- Project start: 2006
- Core development team size: 5-10

Hardware

- Usage of optical fibers with two different wavelengths of light going in different directions
- Main product is the White Rabbit switch
- Recipe for people who want to design White Rabbit nodes as no two nodes are equal
- Extension of ethernet with additional functions

Hardware maturity

- "These things are in the market, but they could be improved for sure."
- Different companies commercialize White Rabbit switches which are built to specifications

Read more on our blog post from OpenMake team, Javier Serrano and Amanda Diez Fernandez
URL: https://www.openmake.de/blog/2022/10/20/2022-10-06-interview-white-rabbit/

Case examples

Environmental sensing

Smart Citizen Kit
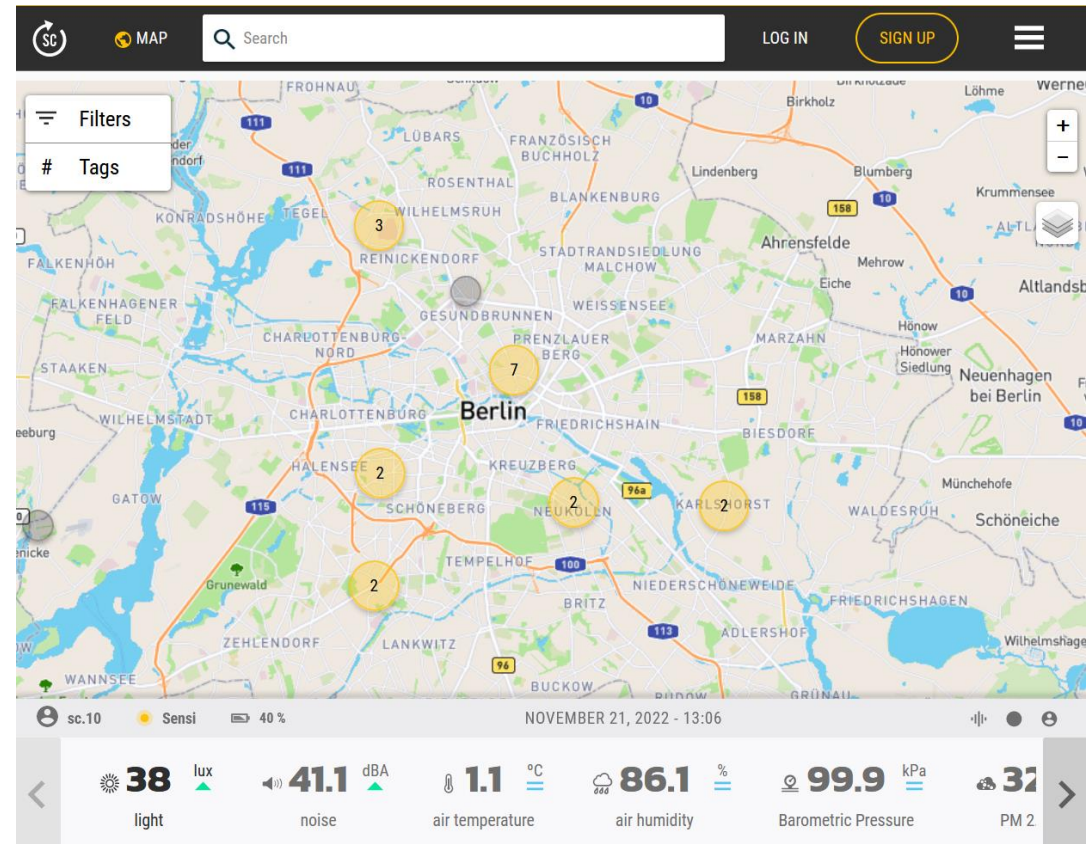
Image: **Smart Citizen Project**, new_sck.jpg, CC-NC-SA 4.0, screenshot made on 21/11/2022
URLs: https://smartcitizen.me/; https://smartcitizen.me/kits/

Summary

– Open source hardware emerged from free and open source software (FOSS) in the mid-2000s and transfers the idea of open source from software to physical objects.

– Since then, open source hardware has emerged in various sectors including science and there are many different usages. However, there are barriers in academia that should be overcome. Policy work is needed to target specific stakeholders such as funding agencies, technology transfer offices, etc.

– Assessment and standardisation of open source hardware is not straightforward, yet it can create transparency and trust.

– Economic savings of open source hardware need to be better understood in order to evaluate the economic impact of OSH.

– Each project case has its own uniqueness which is fascinating and intriguing at the same time. This leads to the question whether open source hardware can be viewed as a homogeneous field or it is maybe "just" a tool?

Important info

- All materials are uploaded to the ISIS platform

- Join the Discord server: https://discord.gg/Pr6Y9gyG

- Confirm your participation until May 31st

- Questions? Write to Dr. Julieta Arancio: jca88@drexel.edu

Thank you for your attention!