Exploring Open-Source Hardware as a Global Phenomenon

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Abstract

With the current global challenges of climate change, ecosystem collapse, and the energy transition, exploring different tools which can bring about systemic change is important. There is a growing movement towards open-source hardware (OSH), but its full potential for growth and even the extent to which it is desirable has yet to be agreed upon in academia. In this research, a literature review and interviews were used to explore the OSH movement, attempting to shed light on the extent to which it can be considered global, and how such a movement might be influenced by external factors. From the research the following was discovered: academic research on OSH tends to implicitly focus on the Global North (GN); differences in terminology when discussing OSH are likely to lead to misunderstandings and miscommunications between the GN and Global South (GS), and hinder the development of OSH globally; some shared perspectives on OSH amongst academics, entrepreneurs and individuals in the renewable energy field were identified; and a tentative framework to developing a thriving OSH ecosystem was developed, by exploring the influence of four key factors: *culture*, *awareness and knowledge about OSH*, *Funding*, and *Collaboration*. Furthermore, the explorative nature of the research opened numerous avenues for further research, including OSH and systemic change, GN/GS differences in OSH applications, and OSH for the energy transition.

Keywords: Open-Source, Open-Source Hardware, Global North, Global South, System Change

Preface

Since as long as I can remember, I have been feeling a sense of growing urgency with regards to our world. News are always dire, I'm very aware, but few moments in history can claim to be as influential to the fate of humankind as today is. And it is entirely our fault. Challenges that are global and incredibly complex, are popping up with no clear solutions to them. Climate change, the sixth mass extinction, ecological collapse. Basically, the end of the world as we know it.

Some are calling it a civilisation collapse. Which also means we are in the midst of a civilisation rebirth. New ways of thinking, working, and living are emerging all over the world with one thing in common: they acknowledge the need for change. My generation is calling for a 'system change, not climate change', and slowly (way too slowly) but surely, we are seeing it take place.

Considering how pivotal we are to the fate of most species on earth right now, including ourselves, it seems evident that this change should be understood and acknowledged by all of us "everyday individuals." Yet, this is not the case. Only rarely do we as individuals get the time to reflect and acknowledge the changes that are taking place, and only rarely do we get a glimpse of how fast these changes are taking place. Our world is way too overwhelming for that.

And so, I decided to make my master thesis about one of those things that has the potential to change the system – open-source hardware (OSH). Considering I have been working on an OSH start-up for the past two years, it is unsurprising that this is the topic I chose to focus on.

What I did not expect, was leaving this thesis more confused than when I started it. I wanted it to be an answer to my questions (will OSH help us solve the energy transition, inequality, knowledge sharing, etc? can OSH really work in our world today? Are we crazy thinking that we should stick to OSH with our start-up, when the dominant paradigm is clearly not supporting it?). I wanted to end this thesis satisfied and content, not overwhelmed.

But ending this thesis, I realise that being overwhelmed from OSH and how immense its potential is, might not be such a bad thing. On top of that, I end this thesis with enthusiasm. Enthusiasm for OSH and its movement; enthusiasm for pushing past the boundaries of capitalism and the world as we know it; enthusiasm for the coming years which are going to drastically change the way our society functions. For this, I want to thank some of you.

My supervisors and those I interviewed: Udo, you have no idea how supportive and great you were even when I thought I was getting nowhere. Fatima, your perspective and enthusiasm for my work was so, so valuable, there is no way it would be as it is today if it wasn't for you. All the people I interviewed and chatted about my thesis to, I'm so grateful! Thank you for the insights, the perspectives, suggestions, and support.

My familyyyy : Maman, Papa, merci pour tout ce que vous m'avais offert, pendant ma thèse, mais surtout les 23 années précédente qui on fait de moi la personne qui a pu écrire ce dossier-si. Jahna, Romane, Nathanaël, you guys are the bestest. You know how much I love you eheh. Timour, thank you for the studying, the swimming, the support, the laughs, and the horizons you brought me – you made finishing my thesis even more fun than it already was.

The whole Biosphere Solar team, Puck, Liam, Judit, Sujith, Maitheli, and I'll stop here I'm sorry, but the list goes on! In particular though, Siemen and Tim(othy): I think it goes without saying that I'm so

grateful we're changing the world together 😉 There's no-one I'd rather have by my side working on the next step in solar energy.

And finally, my (love, life, work) partner who I've just thanked, I know, but need to thank again: Si, I don't want to make this too cheesy, but you're everything I could hope for, and so much more. There is literally no way my thesis would be as it stands today if it wasn't for you – thanks to your continuous insights, the work we've done together leading up to my thesis, and of course, the incredible feedback you gave when I needed it most (thank you so much for that proof-read coupon!). I don't think anyone will ever read this as thoroughly as you read it.

Here's to closing off this thesis so that I can (finally!) focus entirely on taking OSH to the next level.

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List of Abbreviations

Abbreviation	
A&K	Awareness & Knowledge
CAPEX	Capital Expenditure
CE	Circular Economy
COP	Conference of Parties
GN	Global North
GS	Global South
IE	Industrial Ecology
OS	Open-source
OSS	Open-source software
OSH	Open-source hardware
OSSH	Open-source software and hardware
NDA	Non-Disclosure Agreement
P2P	Peer-to-peer
PV	Photovoltaic
RE	Renewable Energy
RQ	Research Question
SDGs	Sustainable Development Goals
TDs	Transition Discourses
USP	Unique Selling Point
WoS	Web of Science
WEIRD	Western, Educated, Industrialized, Rich and Democratic

Chapter 1. Introduction

The world has been experiencing the consequences of exiting the Holocene for a few decades now, but only the past few years have allowed humanity to truly experience the impacts of the Anthropocene. Today, climate change, catastrophic weather events, the sixth mass extinction, and increasing wealth disparity are just a few of the global scale challenges which humanity is tasked with overcoming (Adger et al., 2006; Pievani, 2014; UNEP, 2019; Wiedmann et al., 2020). Despite having never lived in an era with such low mortality rates, high gender equality, and reduced absolute poverty, humanity is now faced with challenges on a planetary scale which undermine the long-term benefits of these improvements.

Through the Sustainable Development Goals (SDGs), the Conference of Parties (COP), and other agreements, some of the world leaders come together to attempt solving these challenges (Häyhä et al., 2016; Jung et al., 2020). In 2016, the Paris Agreement was a significant event which brought together 194 parties to legally bind them to meeting the target of maximum 1.5 degrees Celsius global warming. Despite discussions and agreements, legally binding or not, the world is currently not on track for meeting such targets (Healy & Barry, 2017; Rogelj et al., 2016; Tong et al., 2019). Global warming is one of the major challenges which humanity is attempting to overcome and failing to do so fast enough to avoid global catastrophe.

1.1. Systemic Change and Sustainability

To meet the 1.5 degree Celsius targets of the Paris Agreement, the SDG goals and other targets, it is therefore clear that changes need to be implemented faster than they are currently being implemented (Rogelj et al., 2016; Tong et al., 2019). Academics and activists alike argue that systemic change is essential to solving the pressing problems of climate change, poverty, scarcity of resources, ecological collapse, etc. (Boisseau et al., 2018; Escobar, 2018; Extinction Rebellion, n.d.; Fridays For Future, n.d.; Healy & Barry, 2017; Pearce, 2015).

Such a systemic change can be found first-hand in the energy transition taking place. The Renewable Energy (RE) sector is growing exponentially, and evidence suggests that from the past decades of a nearly entirely fossil-based system, we are now moving towards a RE-based system (IEA, 2021). There is a growing body of literature on how to tackle this change, including thorough research on the steps required for establishing a 100% RE-dependent world (Bogdanov et al., 2019; Breyer et al., 2022; Hansen et al., 2019; Ram, 2019). Yet, there are aspects of a 100% renewable energy world which suggests politicians, academia, and industry should be exploring it from a systemic point of view – for example when looking at the materials required to enable such a change, it becomes apparent that systemic changes for the energy transition are yet to be holistic (Owen et al., 2022). Studying the energy transition is therefore compelling not only because it is a crucial aspect of our society that needs to change if we are to move towards a sustainable future (Rifkin, 2015), but also because it is a demonstration of a current systemic change that is still encountering drawbacks and resistance.

The term ‘sustainable’ is often widely used and a myriad of definitions are continuously cropping up, leading to misunderstandings. In this context, sustainability is defined as it is most commonly cited: “development that meets the needs of current generations without compromising the ability of future generations to meet their needs and aspirations” (Brundtland et al., 1987). Following this definition, sustainability is seen as encompassing three main pillars: economic, social, and environmental sustainability. To experience a systemic change towards sustainability requires tackling all three of these pillars (Bell et al., 2020; Healy & Barry, 2017). Current discussion on a Circular Economy (CE)

reflects the movement towards the three-pronged approach to sustainability. The CE provides an alternative to the take-make-waste disposal system currently in place, and although a broad range of definitions have been coined, its definition can be boiled down to an economy in which materials are circulated within society as long as possible, for the highest value possible (Kirchherr et al., 2017).

1.2. Transition Discourses (TDs), Buen Vivir and the Commons

Research on systemic changes has been explored from various perspectives, including 'civilisation collapses'. Bauwens (2022) is one of many academics who argues that the systemic change required to move towards more sustainable systems is a reflection of the 'civilisation collapse' our society is experiencing. The study of these 'civilisation collapses' and systemic changes has been coined Transition Discourses (TDs), and is well-explored in dozens of different fields, including ecology, food, energy, social movement research, and digital technologies (Escobar, 2018). The exploration of various TDs has not only been carried out extensively in different fields of study, but also across different geographies which includes both the Global South (GS) and Global North (GN) perspectives[1] (Escobar, 2018).

Of the discourses held in the GN for systemic change, the rise of the Commons is apparent (Bauwens, 2022; Benkler, 2006; Gerhardt, 2020; Ostrom et al., 1999; Rifkin, 2015). The 'Commons' is a reflection of concepts long established in the GS such as 'Buen Vivir', 'Sumak Kawsay' and 'transitions to post-extractivism' (Altmann, 2020; Escobar, 2018). These ideas denote the sharing of resources by all in a society, independent of one's social status, to enable a 'good life' (Altmann, 2020; Ostrom, 2002). They entail a different way of structuring our society from what it is today (Escobar, 2018). In the GS, the terms 'Buen Vivir' or 'Sumak Kawsay', which have been rooted in the indigenous culture of Latin America and particularly in Ecuador, are well-established (Escobar, 2018; Fatima Delgado, personal communication, March 2023); these concepts promote the living in harmony with nature, and were coined long before the 'commons' arose as a concept in the GN (Altmann, 2020).

Bauwens (2022), after researching the rise and fall of civilisations, has argued that "when things go well, the commons decline and weaken; when things go bad the commons grow and become stronger". According to Bauwens, it is therefore not surprising that the commons and similar concepts are being paid increasing attention considering the looming crises of climate change and other global existential threats.

1.3. Open-Source Hardware

Surrounding the topic of the commons/Buen Vivir, and because of social trends, new terminologies have emerged in the GN. This includes peer-to-peer (P2P), open-source software (OSS) and open-source hardware (OSH). OSH is "hardware whose design is made publicly available so that anyone can study, modify, distribute, make, and sell the design or hardware based on that design" (OSHWA, n.d.). Such a definition suggests the potential for global collaboration, and indeed, a global movement. But is the rise of OSH really a global movement? Is there a discrepancy to be seen between the GN and GS, and how OSH is developing in these areas? Unlike OSS, which is well-established and was first seen to emerge in the mid-1990s (Lee et al., 2009), OSH is a relatively novel concept, and therefore these questions have yet to be explored.

[1] In academia and politics, the terms GS and GN have emerged to replace more valuing ones such as developing and developed country, or first world and third world (Hollington et al., 2015; Trefzer et al., n.d.).

OSH largely developed from the OSS movement, as individuals working in makerspace and Fablab[2] spheres were inspired by the collaborative nature of OSS (Gupta et al., 2016; Lee et al., 2009). Similarly to OSS, OSH reflects a movement towards decentralised production, with the aim of achieving greater economic, environmental and social sustainability (Moritz et al., 2018). As highlighted in a previous MSc thesis, although research to date has yet to quantify the impact of OSH on environmental sustainability, the idea that OSH designs tend towards environmental sustainability more than closed source designs has repeatedly been suggested (Brinksma, 2021; Kohtala, 2015; Kostakis et al., 2015; Kostakis & Bauwens, 2014).

In addition to potential environmental sustainability, the emergence of OSH as a topic of research in academic literature has led to the identification of various benefits. These benefits include increased safety in national security (Pearce, 2022), increased innovation, reduced costs of production, and reduced risks of lock-ins (Arancio et al., 2022), reduced costs of R&D and IP protection (Buitenhuis & Pearce, 2012; Giotitsas et al., 2015; Moritz et al., 2017), amongst others.

1.4. Relevance to Industrial Ecology and Research Gap

Industrial Ecology (IE) is one amongst various disciplines which have emerged over the past decades as a result of the acute awareness that our society needs to change in order to overcome the challenges of the Anthropocene. It studies ways of transitioning to more sustainable industrial systems by bridging the gap between nature and society (Ayres & Ayres, 1996). IE employs systems thinking, studies material and energy flows in our society and its environment, and thereby attempts to provide solutions to the sustainability challenges of our times (Jelinski et al., 1992).

The newly emerging TDs reflect some of the solutions that have been investigated by the field of industrial ecology (IE). According to some scholars, TDs are a manifestation of the limitations and inadequacies of the existing dominant economic system, i.e., capitalism – they represent a paradigm shift towards more sustainable economic models (Escobar, 2018; McKay, 1997; Raworth, 2017; Rifkin, 2015; Schumpeter, 1942; William & Avaria, 2020). Fredric Jameson amongst others, has said that for many, “it is easier to imagine an end to the world [rather] than an end to capitalism”. And yet, capitalism is only an ‘evolutionary process’, as Schumpeter (1942) has highlighted, and it is bound to constant change (Klein, 2015; Mason, 2013; McKay, 1997). Assuming that the capitalist system will evolve and be replaced, we therefore need to ask ourselves questions such as: What will replace capitalism? When will it be replaced? And how will it be replaced? Exploring such questions is highly relevant to IE researchers, as an understanding of our future economic, cultural, and social system is crucial to develop solutions to our current societal challenges (Jelinski et al., 1992).

Of the many TDs explored in academia, research uniting the commons, capitalism and the use of OSH to tackle current world challenges and notably the energy transition is beginning to emerge (Buitenhuis & Pearce, 2012; Giotitsas et al., 2015; William & Avaria, 2020). Various books have been published on these topics and how they interlink (Benkler, 2006; Klein, 2015; Kostakis & Bauwens, 2014; Rifkin, 2015). But there is still much left unexplored.

[2] Makerspaces and Fablabs are places where individuals can gather and work on projects, using both low-tech and high-tech methods. These have become increasingly common around the world notably on university campuses (Girdzijauskaitė et al., 2018; Hellenes, 2016)

1.5. Research Questions

This master thesis therefore explores the role of open-source hardware in a systemic transition, with a particular interest in the differences in its application in the GN and the GS. This exploration aims to explore the overarching question of: "**How is OSH as a global movement being perceived and explored?**"

During this research, the extent to which OSH can be considered a *global* transition was first explored. Literature research was done on the current work of OSH in the academic field for both the GN and the GS, guided by the following research question (RQ):

- RQ1a: What is the current state of knowledge on OSH in academic literature
- RQ1b: To what extent is the OSH research in academic literature about both the Global North and Global South?

Little research to date has explored how individuals from different lines of work view OSH as a potential tool for systemic change. Therefore, the author aimed to identify some of the opportunities and challenges which an OSH global transition might encounter by exploring the opinions of various individuals in academia, the energy transition and entrepreneurship. The research therefore aimed to explore the following question:

- RQ2: What are some of the main themes which individuals in academia, entrepreneurship, and the renewable energy sector express when discussing OSH?

Finally, knowledge obtained from RQ1 and RQ2 were combined to develop a basic framework which further explored the main research question and a third research question:

- RQ3: What are the main factors influencing the development of a global OSH ecosystem, and how do these interact with one-another?

Chapter 2. Methodology

2.1. Overall Methodology

Due to the novelty of OSH in academic work, this thesis research was very explorative. The research followed the Grounded Theory approach, which entails carrying out research, developing hypotheses, and repeating this cycle with the goal of exploring a specific topic (Charmaz, 2006). This approach enabled the research to adapt its approach to findings which emerged over time. The research involved iterations of literature research and semi-structured interviews to answer the research questions (Figure 1).

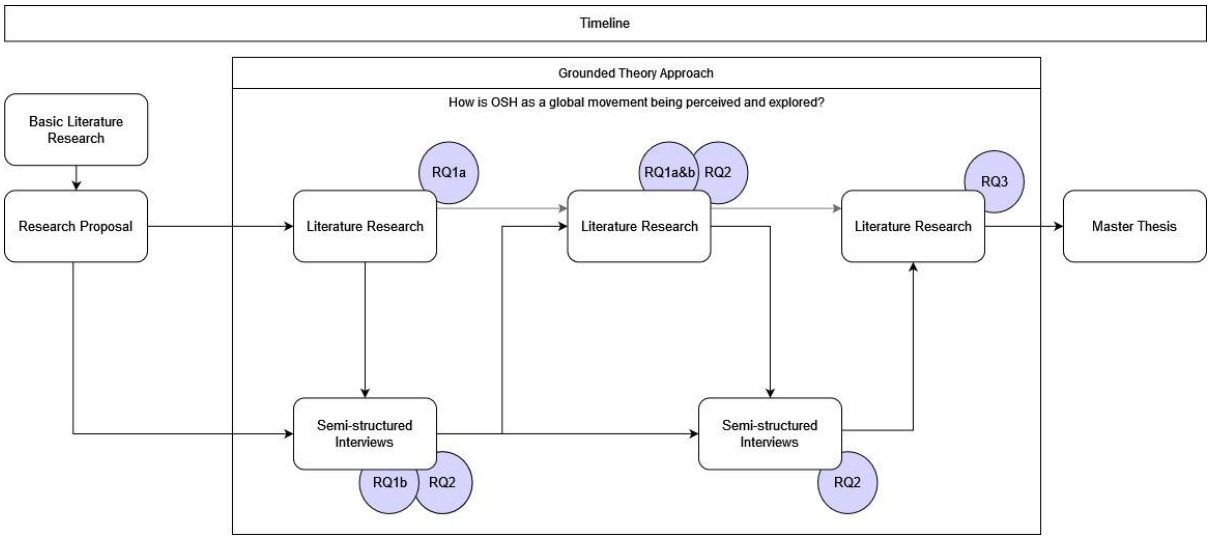

Figure 1 Methodology of the research (arrows indicate flow of information; blue circles showcase where the research questions were answered).

Using the Grounded Theory approach in this research meant exploring the topics of OSH and how these related to the GN and GS. The knowledge gathered from both interviews and literature was then used to develop hypotheses about the state of OSH in the GS and GN.

In Figure 2, the concepts explored in this thesis are visualised in a theoretical framework. The research explores the Maker and OSS movement which formed the foundations of the OSH movement and explores how this movement ties into Transition Discourses (TDs) and system change. In the TDs explored, concepts from the GS ('Buen Vivir', 'Sumak Kawsay' (Escobar, 2018)) and GN (the Commons (Ostrom, 2002)) are touched upon.

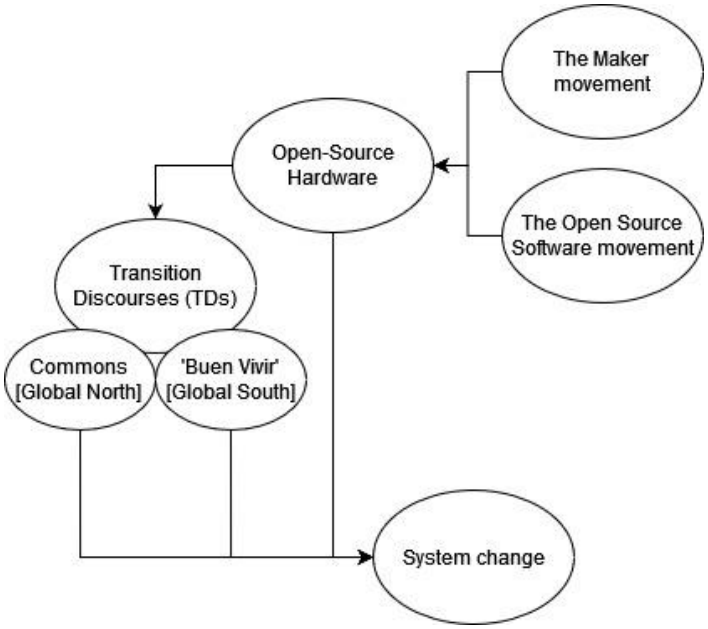

Figure 2 Theoretical framework behind the methodology

2.2. Desk Research Methodology

For RQ1a, an academic literature research was done and analysed using a trends analysis on the academic literature database Web of Science (WoS). The search query used was: "*open-source hardware" OR "open source hardware"*. Using the *Analyse Results* tool of WoS, the number of publication research results per year of the keyword was obtained. Only data for the years 2000 to 2022 was used due to the novelty of OSH in academic research leading to very few papers published before 2000, and to ensure only complete years were included (therefore excluding 2023). The results were compiled in a spreadsheet and analysed (Appendix 1). The step-by-step procedure can be seen in Figure 3.

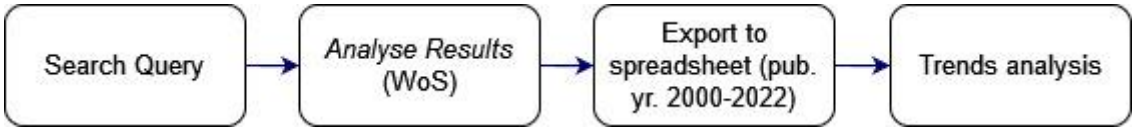

Figure 3 Research methodology of RQ1a, trends analysis

The literature research for RQ1b was carried out using the methodology exemplified in Figure 4. Keywords (Table 1) were identified and used as input for WoS to collect research articles, using the constraining boundaries of published date (2010-2022), and language (English). Note that search queries which did not yield any results were omitted in Figure 4.

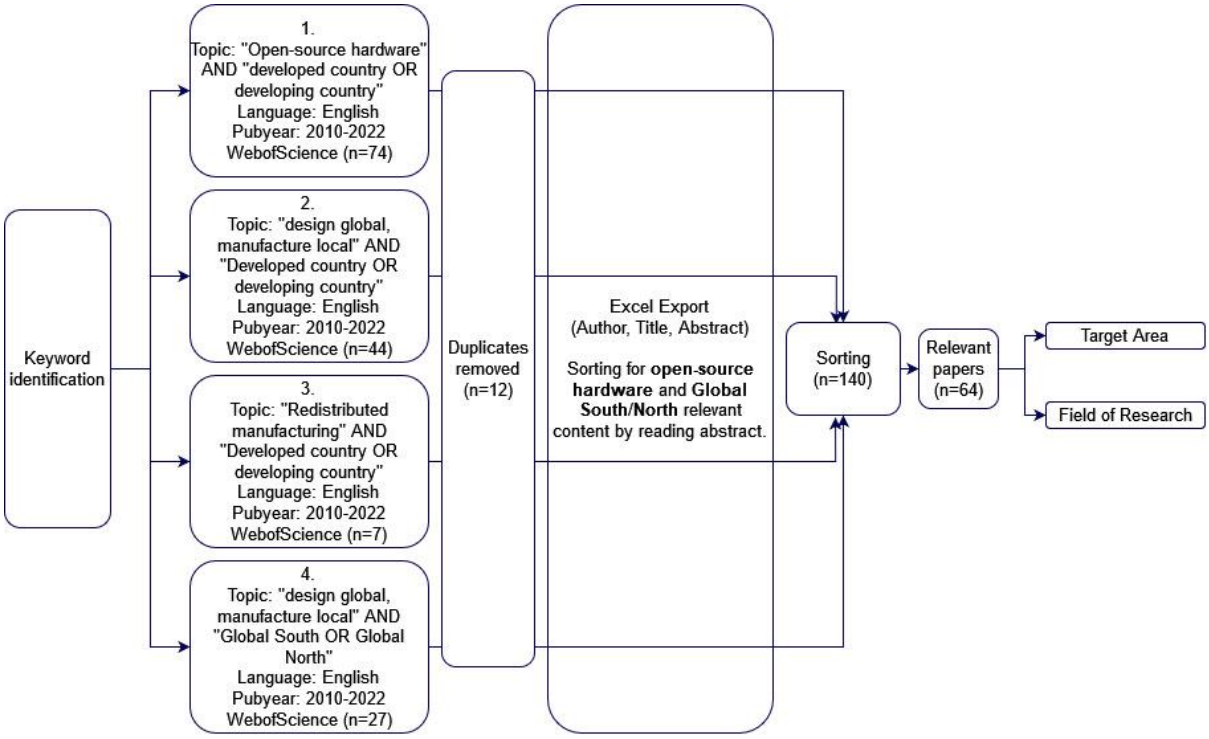

Figure 4 Research methodology for RQ1b.

Table 1 Keywords used for RQ1b

Query	Keywords
1	"Open Source Hardware" AND "developed country OR developing country"
2	"design global, manufacture local" AND "developed country OR developing country"
3	"Redistributed manufacturing" AND "developed country OR developing country"
4	"Design global, manufacture local" AND "Global South OR Global North"
5	"Open source hardware" AND "Global South"
6	"Open source hardware" AND "Global North"
7	"Redistributed manufacturing" AND "Global South"
8	"Redistributed manufacturing" AND "Global North"

Author, title, and abstract from each paper was extracted from WoS and the articles were combined in an excel sheet. Duplicates were then removed. A screening was carried out on the 141 resulting papers: each abstract was read and papers discussing OSH were kept, whilst others were removed (n=76). This included papers discussing OSS, redistributed manufacturing without the OS aspect to it, and papers which discussed developing countries or developed countries without reference to OSH.

A screening was carried out on the remaining papers (n=64) by once more reading through the abstracts of the articles and giving them a label in two categories: target area, and topic. Decision of the target area was carried out by noting when papers explicitly mentioned the research being carried

out for the GN, the GS or having both target areas in mind (note that alternative terminology to GN and GS was employed – see Table 1); papers which did not mention target area were labelled as 'not specified'. Topics were decided in conjunction to reading the papers, and labels were allocated accordingly. See Figure 5 for a visualisation of the screening procedure.

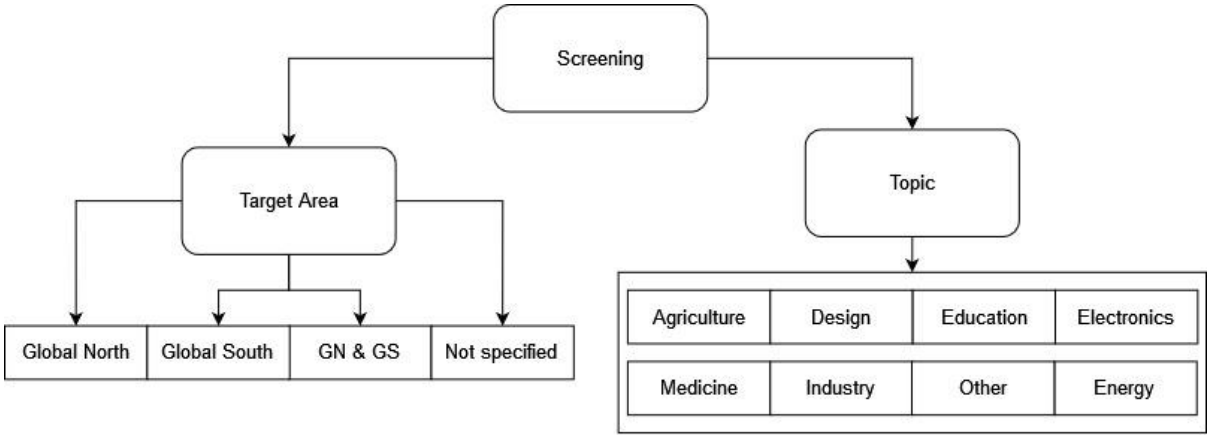

Figure 5 Screening procedure for the allocation of target area and field of research

2.3. Interview Methodology

The interviews carried out were done over a period of five months and were done in a semi-structured interview manner (see Bhattacherjee, 2012). Table 2 gives an overview of the interviewees and expertise (n=9). The interviewees were found through the author's network, research papers individuals had authored/co-authored, and through snowball sampling. Consideration was placed in interviewing people with diverse gender identities, however this proved difficult to balance due to the limited number of women and gender divergent people that could be found working in this field.

Additionally, emphasis was made on attempting to find individuals based in different countries across the world and representatives of the GN and the GS. However, this once more proved to be difficult, both due to lack of responses, and the few possible interview candidates which were found (highlighting a potential lack of representation from the GS when exploring systems change or TDs). Prior to each interview, a basic understanding of the interviewees and roles in their respective jobs were researched via LinkedIn and Google Scholar to confirm their relevancy to the research.

Table 2 Interviewee list and description

Interviewee	Abbreviated name	Location	Gender	Expertise description
OSH Entrepreneur 1	Int.OSHE1	US	M	An entrepreneur living and originating from the US, who has been working in the field of OSH for three decades. He has developed his own OSH company that is considered highly successful due to its financial stability, project developments, and social work.
OSH Entrepreneur 2	Int.OSHE2	Brazil	M	An entrepreneur living and originating from Brazil. He has been working in the field of OSH for two decades. He is passionately

				involved in many active projects including OSH product developments and OSH-related teaching.
OSH entrepreneur and Renewable Energy Engineer	Int.OSHE3	Germany	M	A renewable energy engineer that has been working in the field of wind energy for nearly a decade, and joined an OSH project turned cooperative, developing wind turbines in Germany. He is currently one of two heads for the cooperative and is working on it part-time.
OSH entrepreneur 4	Int.OSHE4	US	M	An OSH enthusiast who experienced a change in career path in the past few years and became an entrepreneur after being exposed to a large OSH company in the US. Since then, he has been working on various OSH projects and on doing research to help guide an OSH transition.
Renewable Energy Researcher	Int.RER	US	M	A French researcher working at the National Renewable Energy Lab in the US. He has published papers on solar recycling, LCA and circular economy.
Peer-to-peer academic	Int.P2PA	Netherlands	M	An academic from the Netherlands who has been working on P2P and blockchain technology for a decade at the Technical Universiteit Delft. He has published various papers, including one on P2P, blockchain and the energy transition.
Open Source Software and Hardware researcher	Int.OSSHR	Belgium	F	A researcher and strategic director at one of the leading institutions in Europe for open source. She has been working on the topic of open source for 4 years and co-authored an important paper by and for the European Commission on the topic of OSSH.
Renewable energy expert	Int.REE	Netherlands	M	A project manager at a semi-government organisation based in the Netherlands. He previously extensively worked in the field of solar cell technology, and his company is working on accelerating innovation by enabling funding and collaboration between companies and research institutes. The department he leads focuses on the energy transition and renewable electricity.
OSH energy investor	Int.OSHI	US	F	A head of operations at a large investing company based in the GN and investing in

				the GS. The company funds projects working on renewable energy access mainly across Africa.

The interviewees were categorised into the following target groups: academics, entrepreneurs, and individuals in the Renewable Energy field. Individuals could be part of multiple target groups. Academics were considered individuals currently working in academia; entrepreneurs consisted of self-proclaimed entrepreneurs, who were then given a background check to identify entrepreneurial activity (e.g., starting a company, or joining a company at an early-stage to contribute significantly to its development); individuals in the RE field were individuals currently working in the RE field.

These target groups were a result of needing to narrow down the scope of the research. Individuals working in the RE field were included due to the relevance of the energy transition to our society today. They were interviewed to further explore how OSH could benefit the energy transition, if at all. Entrepreneurs were included due to their relevance in instigating and supporting transitions in our society (Schumpeter, 2000). They were interviewed to explore further how they view an OSH transition, beyond a business model/motive discussion. As OSH has largely been studied by academics from a business perspective but little else, it was deemed valuable to include academics in the research. They were interviewed with the purpose of identifying further what their opinions on OSH were, beyond its potential in business.

For the interviews, all questions were posed open-ended, and related questions were posed in the middle of the conversation when interesting points arose. The interviews lasted between 20 – 120 minutes via video conference or in-person meetings, and all interviews were audibly recorded with the permission of the participants. The questions changed slightly for the first three interviews, after which a more set structure was created. The resulting questions can be found in Table 3. Not all questions were asked to each interviewee – the relevant themes and questions for each person were determined pre-interview based on the interviewees' specialisation.

Table 3 Interview questions

Questions	Theme
Tell me about yourself and what you do.	Background information
What are your thoughts on and experiences with OSH and/or P2P?	OSH, P2P
What were some things you would have liked to know when starting to work in the OS sphere, or would still like to know?	OSH
How do you see OSH and/or P2P influencing sustainability, if at all?	OSH, P2P, Sustainability
What do you think the role of OSH and/or P2P is in the energy transition?	OSH, P2P, Energy transition
Do you see any differences in the way that OSH and/or P2P is being applied in the GN and GS? If so, what differences?	GN & GS
Do you have any suggestions or recommendations to people working on OSH and/or P2P projects?	Recommendations

Before each interview, a consent form was sent (Appendix 2), and after each interview, the transcripts were carefully reviewed and pseudo-anonymised. This entailed the removal of any personal information which could lead to identification of the interviewee. Following this pseudo-anonymisation, a technical transcript was created in which only the relevant data to the research themes was included (Appendix 3).

The technical transcripts were then coded according to the following themes: Background, Barrier, Business models, Circularity, Closed Source, Culture, Finance, OS, OSH, OSS, Other, P2P, Circularity, Closed Source, Culture, Energy, Further Research, Global N/S, Open-source, Open-source Software, Open-Source Hardware, Peer-to-Peer, Suggestions, and System Change (Appendix 4). The themes were created according to the information present in the interviews. Following each coding of the transcripts, if it appeared that a new theme needed to be included because the quotes/concepts discussed did not fit in any of the initial themes, then a new theme code was created. The themes were used to structure the analysis and discussion of the results.

Chapter 3. Academic Literature Research

In this chapter, the state of the academic literature regarding OSH is explored with a quantitative approach (RQ1a: What is the current state of knowledge on OSH in academic literature, and RQ1b to what extent is the OSH research in academic literature about both the Global North and Global South?).

However, to first provide a better understanding of OSH and where it lies in the broader OS context, Figure 6 provides an overview of the various terms and concepts used in this field and how they relate to one another. These were concepts recurringly found in the literature review and are sometimes used interchangeably.

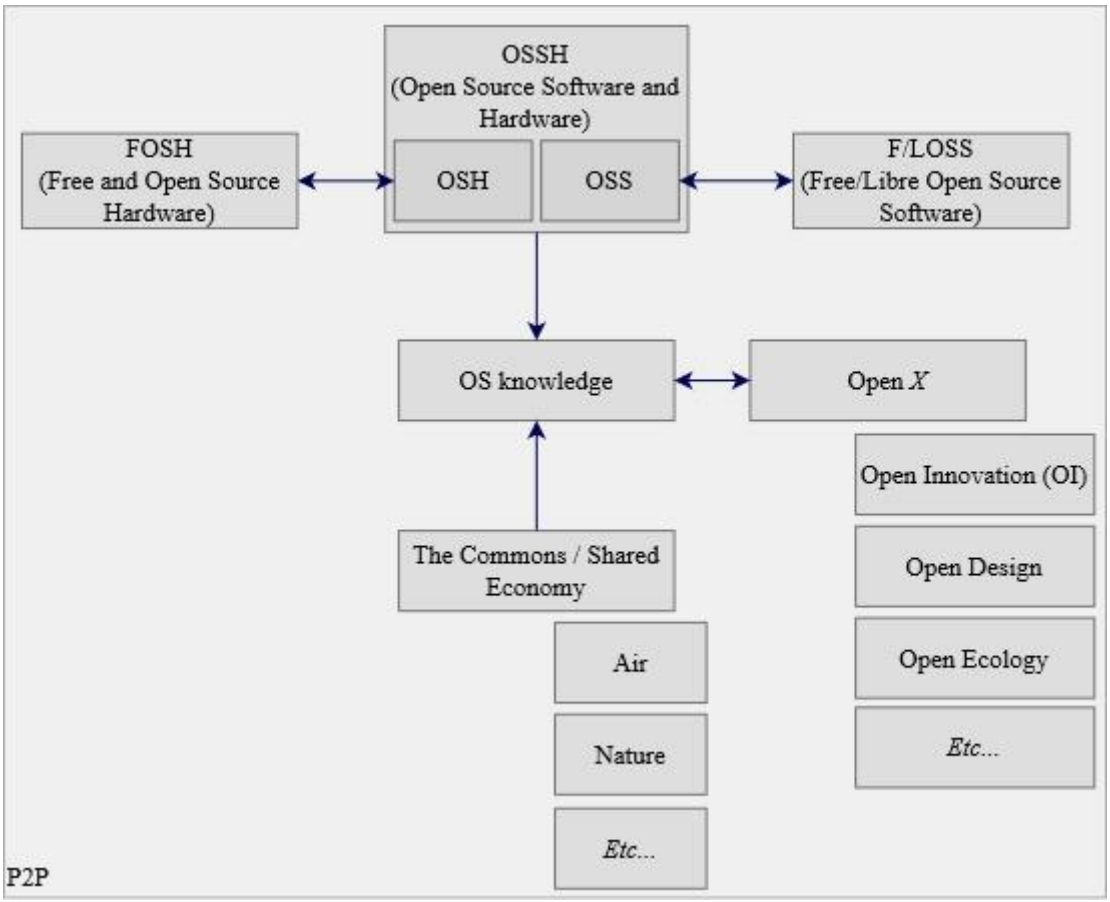

Figure 6 Terminology employed in a P2P paradigm (author's work).

3.1. OSH Publications in Academic Literature

From the literature research done for RQ1a, it became apparent that the past two decades have seen an impressive growth in the attention being paid to OSH: publications statistics found in a trend analysis on WoS using the keyword “open-source hardware” OR “open source hardware” (Figure 7) show a hundred-fold increase over the past 20 years (Web of Science, 2023). An upward non-linear growth in publications is observed from 2010 onwards, with 90% of all publications mentioning OSH being published after 2010. Since 2019, the trend seems to have stabilised at approximately 700-800 publications per year (see Figure 7).

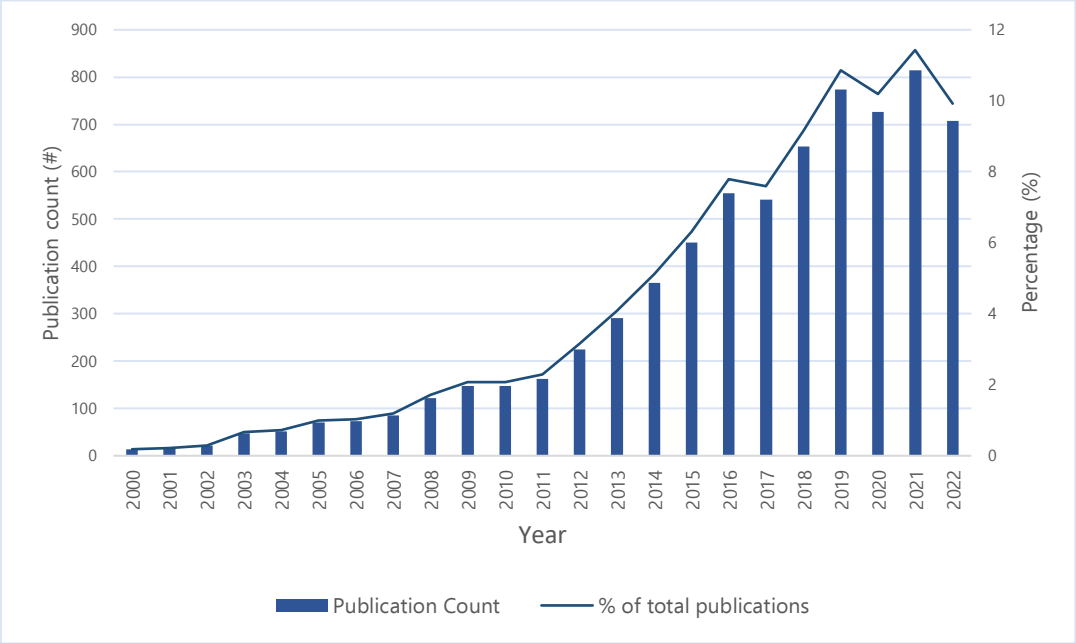

Figure 7 Open-Source Hardware publication trends analysis (total publication count (bars); percentage of total publications (curve)) - RQ1a research results

3.2. OSH Academic Literature for the GN and GS

As explained in section 2.2, exploring RQ1b meant using keywords such as "Global North/South" or "developing/developed country" in combination with "Open-Source Hardware". Comparing this to results found for RQ1a which only searched for "Open-Source Hardware" showed a large difference in publication numbers: OSH & GN/GS searches yielded a total of 140 published papers, whilst the search for OSH yielded a total of 6,412 papers.

An analysis of the papers returned from the searches including GN/GS keywords showed that the majority of the publications included in the results were related to the GS; only one of the papers explicitly used the keyword Global North. This trend is visualised in Figure 8, which depicts the target area mentioned for each paper that was returned from the query search of RQ2.

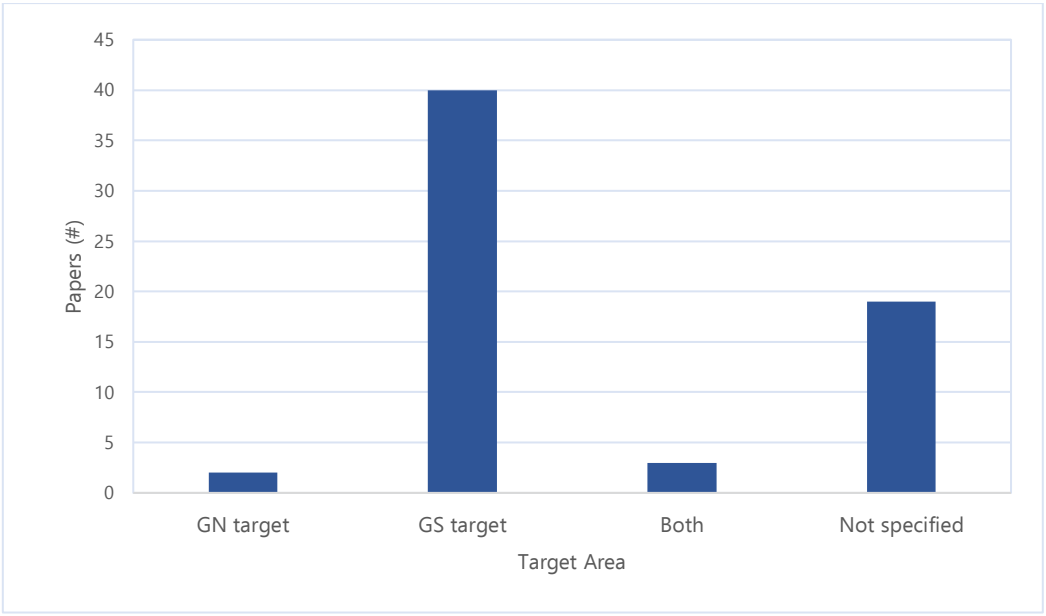

Figure 8 OSH & GN/GS publication trends target area analysis - RQ1b research results

Chapter 4. Interviews

After a thorough desk research, it became apparent that due to the relatively novel concept of OSH in society, there is much left unexplored about OSH and how it is being applied and perceived. By far the most explored subject was found to be how OSH is used in business, particularly by entrepreneurs (Antoniou et al., 2022; Bonvoisin, 2016, 2017; Bonvoisin et al., 2021a; Hellenes, 2016; Li et al., 2017, 2021; Li & Seering, 2019a, 2019b; Nascimento & Pólvora, 2016). In these publications, the main area of research was found to be how to create successful businesses from OSH products, and what motivations hardware entrepreneurs have in utilising OS.

In this master thesis, it therefore became a main point of focus to understand how different groups perceive OSH (RQ2), not only from a business point of view but also from a 'societal implications' point of view. In the following chapter, a summary is given of interviews carried out with entrepreneurs, academics, and individuals in the field of renewable energy. The findings from these interviews are compiled to propose further hypotheses and can be used as a basis from which to further explore OSH and its development in our society.

4.1. Interview Groups

4.1.1. OSH Entrepreneurs

Four OSH entrepreneurs were interviewed for the research. All of them were male, two were based in the US, one in Brazil and one in Germany. The background of each of these individuals varied, with one knowingly saying he lives on "the fringes of system and cultural changes" (Int.OSHE2), and the three others having had a higher education in Science, Technology, Engineering and Mathematics (STEM) and living in more conventional western lifestyles.

Despite their different origins and upbringing, all entrepreneurs had in common **a drive for creating a better world**. One described it as making "products that we really need in the world" (Int.OSHE3); whilst another said that when he had been working in a US-based company as an engineer, he "saw a lot of unmatched needs and […] unused material that could be shared" mentioning that "it felt very stupid. Like this system is highly inefficient" (Int.OSHE1). This resulted in a drive for contributing to a more efficient system, and for working in a way which does not hinder innovation, but rather promotes it.

Two of the entrepreneurs explicitly mentioned that they believe "capitalism is definitely broken" (Int.OSHE4), and that we are living "a very very complex civilisation collapse" (Int.OSHE2). The belief that the system we live in today is dysfunctional was also mirrored by Int.OSHE3, who stated that things should be OS so that "humanity learns something of it. Otherwise, we keep doing the same mistakes again". Overall, the four interviews carried out reflected a desire for an economic and social system beyond the one predominant today. They reflected a desire to establish a more "[OS] and transparent paradigm" (OSH1).

To establish such a paradigm, and for any system change to occur, all emphasised the **role of culture**. A general trend throughout the interviews was that main barriers to adoption of a novel economic or social system are cultural since "the worst enemy that we have in this transition is culture" (Int.OSHE1). This naturally raises the question of: which culture? And as Int.OSHE1 asked: "What are the characteristics of a culture that makes it compatible with [OS]?"

Int.OSHE2 from Brazil stated that there is "a very collaborative and sharing culture" in Brazil, and that people already "create all sorts of machinery in a very open hardware dynamic, but no one calls it open hardware". Int.OSHE1 who has worked in the Middle East and Africa, said that what "is incompatible with peer-to-peer is the tribal mentality and culture". He suggested that the reason for this is that in a "peer-to-peer economy, [roles are] distributed across the network. We talk about the wisdom of network, not the wisdom of the elderly in the village". Regarding the US, Int.OSHE1 said that people who came to his OS company greatly struggled "because they have been moulded within institutions where they have to watch out for competition among employees". In his experience, it took "two or three years" for somebody working in his company to "really get comfortable".

The entrepreneurs did not suggest they have the solution to the cultural requirements that an OS society would need in to thrive. However, various **characteristics to an OS-based system** came up that they suggested would be required for it to prosper. This included *openness*, *decentralisation*, *dealing with complexity in our society*, *collaboration*, and *consumers becoming prosumers*[3] among others. One of the entrepreneurs when asked about the topic of circularity, suggested that although he does not think OS and circularity are linked, he believes that "people in the circular economy usually share the values of openness, transparency, collaboration, so they become easily friends and can work together" (Int.OSHE1).

Additionally, the roles of governments, universities, individuals, communities, and funding bodies as having an important role in a transition were all discussed. Each stakeholder group was said to have a role to play in enabling a transition towards the more OS-oriented society which the entrepreneurs are working on.

The interviews served to highlight the zealous belief that some OSH entrepreneurs have in the paradigm shift towards a more open and collaborative system. It does not seem solely a 'business case' for them, but rather a new way of living and working. As Int.OSHE1 puts it: "I jumped on open-source and I said, this is the future, this is the future if we want to solve world problems".

4.1.2. Academics

Of the three academics interviewed, one was based in the Netherlands, one in Belgium, and one in the US. There was one female and two males, all having carried out higher education (post-doctorate or Master of Science). Two of these individuals have previous experience in the government and industry and are currently active in the academic sphere. All three interviewees had experienced the concepts of OS differently: Int.P2PA was actively working in a research group advocating P2P; Int.RER was working in a national research group which advocated for OS research, but still conformed to the use of Non-Disclosure Agreements (NDAs) and patents; and Int.OSSHR had carried out research for the European Commission on OSSH, and been working on further developing OSSH at a policy-level for four years.

All interviewees believed that **OS could be beneficial**. Some benefits they highlighted included:

- Int.RER said that "for us researchers, it would be great to have more [OS] data", which would result in **better research.**

[3] Prosumers – a term used to describe a customer who wants to contribute to the design and production of the products they use (originating from the words "producer" and "consumer"). *Definition retrieved from the Cambridge Dictionary*

- All three interviewees saw the idealistic aspect of applying OSH to make systems **function better and more efficiently**. They provided a point of view often neglected in the academic discussions on OSH: the idea that OSH, just like OSS is a way of "working for the common good" (Int.P2PA), and that this is a valid reason for developing OSH systems. This was reflected in a quote by Int.P2PA saying: "our lab has a profound focus on the common good. We have this idealistic vision of having things that can be used by anyone, that are free to use".
- Another benefit mentioned was **lower barriers to entry**, and **prevention of lock-ins** (Int.P2PA)

In addition to discussing the benefits of OSH, the interviewees acknowledged that the implementation of OSH still had a long way to go before it could be applied widely. Some barriers that were identified included:

- Int.OSSHR highlighted that the research commissioned by the European Commission in 2022 "was basically the first time that policymakers wanted to know more about open-source hardware". Prior to their research OSH was only thought to be 3D printing by the European Commission indicating a clear **lack of awareness and knowledge in OSH** at a policy level. Meanwhile, Int.P2PA said that a key barrier is that "from an industry perspective [OSH] is not taken seriously at all", and that this lack of awareness and knowledge makes it difficult to push forward OSH in industrial systems.
- Int.RER suggest that **collaboration was lacking** and since "you need more collaboration between companies, which is not necessarily what is happening" OSH would not progress unless change in this realm took place. According to him, developing a system which was collaborative would require "access to information" and "trust", which in his view is not present enough in our society today.
- Concerns about a fully decentralised system which OS often advocates for were mentioned. Int.P2PA expressed doubts about OS functioning as intended, and he suggested that we "would probably need to [have] a sort of hybrid system".
- Other concerns evoked by Int.P2PA also revolved around the potential increase in the challenge of interoperability across systems and products, which he believed would increase if OSH become prevalent.

4.1.3. Individuals in the Renewable Energy Field

Of the individuals interviewed, five were involved in the renewable energy field. Some had more recent experience and their everyday job was in the renewable energy field (Int.OSHI, Int.OSHE3, Int.REE). Others had been involved in the renewable energy sector at one point in the past five years but had now switched to a different field of research (Int.P2PA, Int.RER). Four out of five of them were men, two were based in the Netherlands, two in the US, and one in Germany. No individuals based in the GS were interviewed from this target group, however, the company of Int.OSHI funds innovations working mainly in the GS, in areas with low energy access.

Of the individuals interviewed, none expressed direct opposition to OS and its fundamental values, yet all acknowledged challenges that would hinder its influence in RE. Additionally some expressed scepticism about applying OSH to the (renewable) energy value chain. In Table 4, quotes from some of the interviewees were gathered to highlight the support for and against OSH in the RE industry.

Table 4 Renewable Energy experts' point-of-view on OSH

Quotes supporting OSH in RE	Quotes doubting OSH in RE
"The transition is really depending a lot on the open source, and I think the beauty of open source is collaboration and the community." (Int.OSHI) "Some core innovations being open innovations can really help in expediting [the energy transition]." (Int.OSHI)	"Depending on who's bringing the value or the investing in, you might have to have a close source product. We are very clear about this: we don't say that there is, it's an either-or approach." (Int.OSHI)
"I don't see any fundamental restraints to [open source becoming big]." (Int.REE)	"I think [success] depends on what part of the value chain you're in." (Int.REE)
"It was a success in software engineering, right? If they succeeded, then my first reaction would be like, why wouldn't it work for hardware and like PV." (Int.RER)	

On the one hand, there were specific barriers identified in applying OSH to the RE field. These barriers included finance, and lack of understanding and awareness of what OSH is by anyone not working in OSH:

- Finance consisted of two challenges. First the difficulty in **finding funding for OSH** (Int.OSHE3). The experience of Int.OSHE3 with attempting to develop an OS business with small-scale wind turbines in Germany was a challenging one as they "got a little money here and there", but larger investments from the government did not go through. Over time, this meant people in their company had to stop working on the project and focus on other jobs to receive an income.
- The second challenge in finance for OSH, was the **capital-intensive nature of hardware** which drastically differs from software and leads to different scaling economics (Int.REE). According to Int.REE, "venture capital and open-source business models are poor combination" and so OSH businesses would need to depend on "crowdfunding or philanthropy".
- The barriers of a **lack of understanding and awareness** of what OSH is was highlighted by both the entrepreneur (Int.OSHE3) and the investor (Int.OSHI). According to Int.OSHI, the "biggest challenge is lack of awareness and lack of understanding of what is open innovation". In their company, they experienced this by recurringly encountering the issue of "people only understand[ing] open source as software" (Int.OSHI), and according to them, "most companies and stakeholders or actors in the energy space really don't understand open source" (Int.OSHI). Such a statement emphasises the importance of raising awareness if a society to adapt to new concepts. For Int.OSHE3, he experienced this lack of understanding through funding applications, as "the guy who checked our proposal was a former patent lawyer, so he didn't get the concept at all". This illustrates the intertwined challenging aspect of financing OSH projects when a lack of awareness/understanding is dominant in society, and by extension, industry.

On the other hand, the interviewees highlighted some opportunities that would arise as a result of OSH being implemented in the renewable energy field. These opportunities are as follows:

- When asked about circularity, the interviewees mentioned that due to their focus on placing user experience over profit motives, OSH projects often end up producing products which are "designed in a repairable way" (Int.OSHE3) which then leads to **higher circularity**. As Int.OSHI emphasised, OSH projects focus on designing solutions that prevent the need for "post-fix" approaches. By addressing potential issues during the design process, such as through designing for modularity to facilitate recycling, OSH designs aim to increase product lifetime and eliminate the need for finding solutions after a problem has already occurred.
- Int.RER also mentioned the potential which an OS approach has for pushing forward sustainability by encouraging transparency: knowledge of how to deal with products at their End-of-Life (EoL) is essential to sustainability. When discussing the potential of a material passport[4] Int.RER was found highly enthusiastic, as he suggested that it would enable better recycling strategies to be developed and implemented.
- An additional benefit to employing OSH strategies to the energy space, was suggested to be the prevention of "reinventing the wheel" (Int.OSHI), which referred to the **increased efficiency and effectiveness of innovating,** when innovations are OS. One of the major challenges which Int.OSHI and her company identified when first starting business in the GS (more specifically Tanzania), was that "all of them are doing the same background technology stuff" (Int.OSHI), consequently "spending their limited resources, financial as well as human, in developing these innovations". This, she suggests, could have been avoided if the innovations had been available open source, and the companies would have been able to focus on their unique selling point (USP) instead.
- An additional benefit which Int.RER and Int.OSHI both agree would come about having more OSH strategies in the field of renewable energy, would be the **research quality improvements**. Not only by having more brains working on the same projects (Int.OSHI), but also because of the limitations imposed by closed data when doing research (Int.RER).

Overall, some of the interviewees were quite convinced that OSH would push the renewable energy sector forward and be highly beneficial, whilst others were more sceptical but still acknowledged the potential it could have if its various barriers were overcome.

[4] A material passport is a dataset containing all the information one might need to understand a product. This might include the materials a product contains, technical facts about the product, or information about its upstream supply chain. Research on the potential of material passports in a Circular Economy has shown great potential in increasing circularity of a product (Hoosain et al., 2021)

Chapter 5. Synthesising the Findings

Chapter 3 and 4 have served to explore RQ1 and RQ2 through an academic literature review and analysis, and semi-structured interviews with individuals in the field of entrepreneurship, academia, and the renewable energy sector. In this chapter, the knowledge obtained is brought together to discuss the main findings.

5.1. Growing Academic Literature on OSH

To answer RQ1a (*What is the current state of knowledge on OSH in academic literature?*) the literature research showcases the growing body of literature discussing OSH (Figure 7). Figure 7 adds on to previous literature which has suggested that there is a growing social trend for OSH, but had yet to quantify this (Bonvoisin et al., 2021b; Kostakis & Bauwens, 2014; Li & Seering, 2019b; Pearce, 2018).

According to Hellenes (2016) who studied the growth of Makerspaces, Hackerspaces and Fab labs, this growing trend in OSH since 2010 can be explained by the development of OSH strategies by makers following the financial crises in 2009. Whilst no direct research had been done on the trends of OSH in academic literature, various papers have highlighted the increased release and production of OSH products (Antoniou et al., 2022; Bonvoisin et al., 2018; Pearce, 2015, 2017, 2022). This was mirrored in the discussions held with the Entrepreneurs and Academics (Section 4.1.1 and 4.1.2 respectively), who expressed a growing movement towards OSH.

5.2. Findings of the Global North/South Research

Answering RQ1b (*To what extent is the OSH research in academic literature about both the Global North and Global South?*) yielded two main findings. One, that the majority of research on OSH is being carried out with a GN perspective, and two, that the disparity in GN/GS OSH research may be due to terminology differences.

5.2.1. WEIRD Research

A clear discrepancy can be observed when comparing the results of Figure 7 which depicts the growing trend in OSH publications, and Figure 8 which compiles the research queries of OSH combined with a focus on location (GS/GN). The difference between these figures suggests a significant bias in OSH academic research for the GN. The large differences in returned queries and the analysis of the returned queries showed that there is an implicit assumption for a GN target audience when doing research on OSH. This is not an uncommon practice in research, and one that has even been allocated a term: Western, Educated, Industrialized, Rich and Democratic (WEIRD) research (Henrich et al., 2010).

Research that is carried out using a WEIRD target group is by far most prevalent across academic literature, and has been acknowledged as a trend in psychology, biology and behavioural literature amongst many other fields (Dan, 2010; Henrich et al., 2010; Masuda et al., 2020). To identify this trend in OSH academic literature is therefore not unusual, yet, it has yet to be acknowledged as a limitation in literature. On the contrary, previous research has identified this discrepancy, but circumvented it by suggesting that OSH is a global movement (Hassan et al., 2021).

As this research suggests, although OSH might be a global movement, it has yet to yield balanced input from both the GN and the GS at an academic level.

5.2.2. Terminology Constraints

Through the interviews, it seemed that individuals may not even be aware of a GN/GS divide regarding OSH. Considering acknowledging a limitation is crucial to overcoming it, such a finding suggests that OSH might be far from being explored on an academic level using both the GN and the GS as target areas. However, this discrepancy may be largely rooted in a difference in terminology: in academic literature from the GN, OSH is clearly a term growing in use, but research comparing terminologies of Transition Discourses in the GS and GN has highlighted the divergence in words used as each location adapts concepts to their local culture (Altmann, 2020; Escobar, 2018). In other words, OSH in the GS may have an equivalent term which the GN in its research is not utilising, and vice versa.

This was also a reflection that emerged from one of the interviews, where OSH2 suggested that OSH is a concept that has been 'westernised'. According to the interviewee and some academic literature in many countries of the GS, OSH is seen in everyday objects and ways of work, but is not termed OSH (Altmann, 2020). Acknowledging that OSH is a GN-based concept could greatly shift the discourse on OSH and its role in both the GN and the GS: not only would it be particularly important in overcoming differences in terminologies which can prevent misunderstandings and facilitate effective communication; it would also foster collaboration between the GN-GS and allow the GN to learn a great deal on how/whether to apply OSH. The challenge of aligning on common terminology suggests that further attention on GS/GN applications of OSH needs to be given to ensure OSH academic literature represents the global perspective it currently only implicitly explores.

A parallel to this discrepancy in OSH terminology can be found in work on the 'commons', which is a GN-based term inspired by the GS-based term "buen vivir" (Altmann, 2020). Much of Ostrom's work (a prevalent figure in developing the concept of the commons) is based on the GS, where the principles of the commons are explored and understood based on real-life applications (Ostrom & Gardner, 1993; Poteete et al., 2010). Overall, it may therefore be sound to argue that applying OSH in the GN would greatly benefit from further research on how equivalent concepts and ways of work/life are being used in the GS.

5.3. Common Themes to a Global OSH Ecosystem[5]

Through the research carried out to answer RQ1 and RQ2, various factors influencing the development of a global OSH ecosystem were identified. In this section, the findings are brought together to answer RQ3 (What are the main factors influencing the development of a global OSH ecosystem, and how do these interact with one-another).

In the interviews with academics, entrepreneurs, and individuals in the renewable energy sector, it was found that OSH is considered both a tool to develop and promote solutions, as well as an inherently different way of doing work, which includes increased collaboration and transparency. In other words, OSH is considered a part of what Escobar (2018) terms a Transition Discourse, and is in line with the 'Buen Vivir' and 'Commons' mindset found in the GS and GN respectively. Similar to the

[5] Note that the 'global' aspect of the ecosystem does not suggest that what is to be established is an ecosystem which uses solely the terminology 'OSH'. As established in section 5.2 OSH as a GN-concept could be termed otherwise in the GS. This would by no means suggest less influential and fundamental aspect to the development of such an ecosystem. From here-on however, the terms 'OSH ecosystem' are used for the sake of clarity and consistency.

discourse around Buen Vivir and the Commons, OSH promotes the key aspects of 'collaboration' as opposed to 'competition' (Int.OSHE1, Int.OSHE2, Int.OSHE3, Int.P2PA).

Of the factors influencing the development and thriving of an OSH ecosystem, four central drivers emerged. Although the factors influencing OSH were found to be non-exhaustive, the four factors shown in Figure 9 were the ones found to appear most often and were most apt at incorporating other factors both for the GN, and the GS. In our case the four factors included: Awareness and Knowledge about OSH, Finance, Collaboration, and Culture.

This method of identifying factors influencing a certain ecosystem or innovation is similar to that explored by Ortt and Kamp (2022). In their research, a framework that allows for the development of potential strategies to influence a system is explored, including an exploration of the influencing conditions, and building blocks of the system. The identified barriers to an OSH ecosystem were found to reflect somewhat the Technological Innovation System (TIS) framework of Ortt and Kamp (2022). Awareness and Knowledge about OSH, Finance, Collaboration and Culture can be linked to the influencing conditions which Ortt and Kamp (2022) highlight: Knowledge and awareness of technology, Natural human and financial resources, Competition, and Socio-cultural aspects. Although the framework by Ortt and Kamp (2022) is created to explore specific innovative technologies from the perspective of companies rather than systemic changes from a wider perspective, it is insightful to acknowledge the similarities between the TIS framework and the framework portrayed below.

From the research findings, it was possible to identify a tentative suggestion of the societal groups which most influence these factors. The societal groups identified were **governing bodies** (Blind et al., 2021)– municipalities, national governments, international collaborations, etc; **academics** – individuals carrying out research for private or public institutions; **entrepreneurs** – individuals who start and/or manage an enterprise, usually with high-risk of failure and who tend to be innovators; **investors** – individuals or groups who possess capital and invest in enterprises or projects; **universities** (Signorini, 2019)– a body which carries out education at higher-level; **SMEs** (Blind et al., 2021)– small and medium size enterprises which produce the relevant OSH products; and **OS communities** (Hassan et al., 2021) – usually hackers and makers who come together to work on (individual) projects.

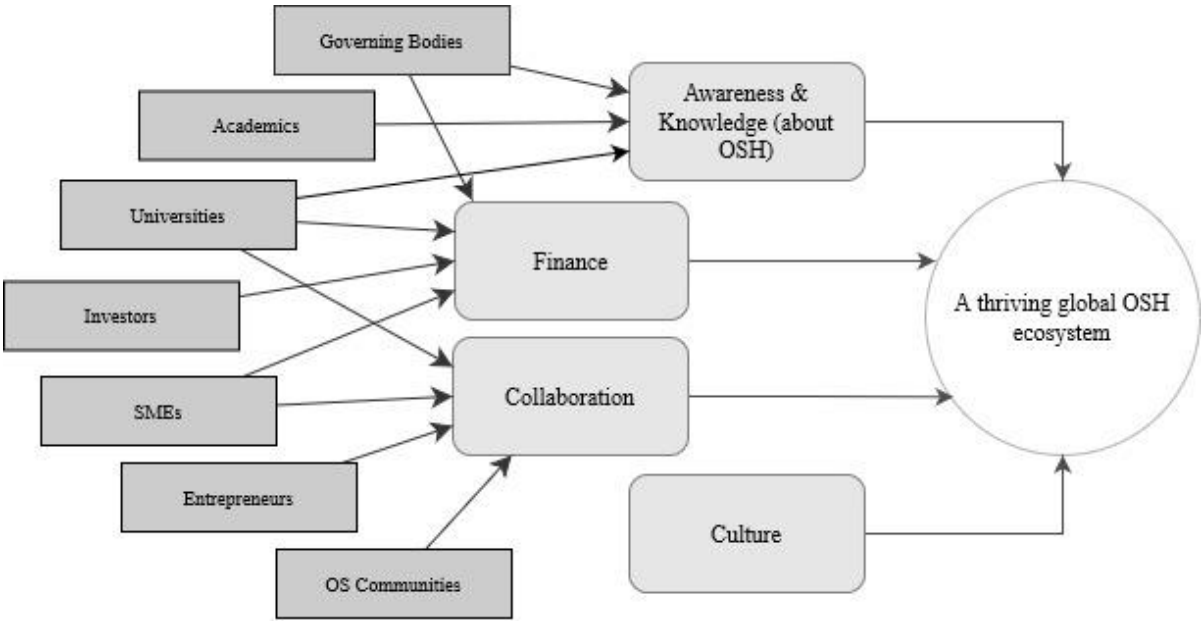

Figure 9 Factors influencing the development of an OSH ecosystem (author's work)

'Awareness and Knowledge (about OSH)' (from here-on referred to as A&K of OSH), here is used to denote the extent to which people are aware of what OSH is, and the technical understanding they have of it. As such, this includes understanding what licenses there are for OSH and the different tools already available for OSH development (for example in 3D printing which is an area of OSH extensively researched) (Gupta et al., 2016).

Following the five stage adoption process used in the diffusion of Innovation theory, A&K of OSH is the first step to adoption (Kaminski, 2011). As such, it can be identified as the largest bottleneck to the development of an OSH thriving ecosystem. Through the interviews and the literature research, it was found to be a hindrance to both organisations and individuals for different reasons. For organisations, lack of knowledge about OSH could result in higher R&D costs, and reduced innovation (Li et al., 2017; Int.OSHI). For individuals:

- Entrepreneurs who could benefit from applying OS by reducing R&D costs and obtaining community support amongst other benefits (Li et al., 2017)
- Individuals in remote communities who could benefit from producing their own OS products locally. This includes (parts of) distributed infrastructures such as solar panel installation racks, mini-wind turbines, or rainwater harvesting systems (Argenton Freire et al., 2022; Bassett & Fleischmann, 2012; Franz et al., 2022)
- Academics in the field of medicine, ecology, energy, electronics, and many others (Chavez & Kovarik, 2017; Gupta et al., 2016; Moritz et al., 2017) who could benefit from increased knowledge sharing
- Policy makers who can utilise OSH to improve security, innovation, and sustainability (Pearce, 2022; OSH Aca.)

When investigating the social groups which most influenced A&K of OSH, it was found that governing bodies, academics, and universities had the most influence. For governing bodies, this originates from their power over the setting of standards and in normalising activities (Blind et al., 2021; Emmy Tsang, OpenForum Europe, personal commmunication, February 2023; Andrew Katz, OpenForum Europe, personal commmunication, February 2023); by advocating for OSH and raising awareness through policymaking, governing bodies have the potential to influence a systemic change (Blind et al., 2021).

For academics and universities, their influence lies in their role in shaping the skillsets and knowledge of future working generations. Providing education on OSH legislations, design, challenges, opportunities, and much more can greatly influence the development of an OSH ecosystem (Arancio et al., 2022; Signorini, 2019).

The hurdle of low A&K of OSH was initially experienced by the OS software movement, and was identified as one of the main challenges it had to overcome before it began to thrive (Feller & Fitzgerald, 2002). As such, it seems evident that a major emphasis on raising awareness about OSH and its potential needs to take place if a global OSH ecosystem is to develop further.

'Finance' in this framework represents available funding for OS projects/businesses, costs of developing a business, and business models for OS projects/businesses. Funding was repeatedly seen in both the desk research and through the interviews as a key enabler to a thriving OSH ecosystem. In the renewable energy field in particular, limited availability of capital for OSH projects was identified as a major barrier (Int.REE).

The funding challenge that OSH projects face is also experienced by most capital-intensive industry. However, it is particularly acute for OSH projects as most investors tend to have little trust in the competitiveness of companies that share their IP, which goes against the predominant paradigm of strong IP protection leading to high profit returns (Int.REE; Int.OSSHR; Dawson, 2022). Such reasoning explains the success of OSH in 3D printing, which requires low capital expenditure (CAPEX) and is easily replicated in a decentralised manner.

Societal groups which were found to influence the finance factor most were SMEs, Universities, Investors, and Governing bodies. SMEs (especially in the hardware sphere) allocate a significant amount of their capital to R&D, which often results in individual silos of innovation per company (Int.OSHI). This lack of collaboration could be avoided through OSH, and lead to more efficient development of innovation. Inspired by the OSS movement, this could take the form of multiple SMEs funding OSH R&D projects, which all of them benefit from.

Large funds are also available from Universities for project developments, Investors for business creation, and Governing bodies through tenders, subsidies, or other financial mechanisms. A recent report by the EU commission highlights the importance of funding from government and investor-related bodies for OSH projects (Blind et al., 2021), whilst Signorini (2019) thoroughly explores the role Universities play in encouraging OSH development.

'Collaboration', as mentioned throughout this research, is one of the key pillars of OSH. To thrive, it is essential that collaboration become a norm, and especially so between businesses. Patents were initially developed with the intention of protecting the commercial interests of innovators and encouraging them to continue innovating and turning their ideas into projects; yet patents today have been found to restrict economic development and hinder innovation, due to the lack of collaboration most patents instigate (Li & Seering, 2019b; Mazzoleni & Nelson, 1998; Osborn et al., 2015). If the financing barrier was overcome, Entrepreneurs and SMEs would be key to increasing collaboration in business. Additionally, Universities and OS communities influence collaboration between individuals due to their role in bringing together diverse individuals with various skills.

Paradoxically, OSH not only increases collaboration, but was also identified as a way of increasing competition within an industry (Int.P2PA; Andrew Katz, OpenForum Europe, personal communication, February 2023). By removing the use of copyright, the barriers to entry into a market are lowered, and as previous research has discussed, monopolies are less likely to arise (Pearce, 2018, 2022). Whether this is something to encourage and support is another question entirely, however there are societal benefits to preventing the rise of monopolies, which suggests further research similar to what Pearce (2022) has done, could greatly benefit our society.

Finally, **Culture** was recurringly found to be one of the key factors enabling the development of an OSH ecosystem. Culture for this research, was the cumulation of intangible aspects of social life which make up the way a society behaves. It is a topic well-researched in Transition Discourses (TDs), and one which plays a large part in enabling systemic changes (Escobar, 2018). The differences in the GN and GS and how OSH is applied in these areas appear most starkly when discussing Culture. Through this research, it became apparent that the differences in TDs of the GN and GS which Escobar (2018) amongst many others highlights, is reflected in the OSH movement. According to some of the interviewees, the use of OSH may be more challenging in GN societies which possess a culture that contrasts starkly with the values of OSH communities.

The factor of collaboration was identified as a trait which is strongly influenced by culture and may drastically impact the development of OSH. It was also found that the zealous aspect of people advocating for OSH may be based in and influenced by culture, and is key to its development (Feller & Fitzgerald, 2002).

As can be seen in Figure 9, **culture as a factor** was not found to be influenced by any one social group. This is because by definition culture is what arises from all the different perspectives of each group. Therefore, all individuals and all societal groups can be assumed to influence culture.

5.3.1. Dependencies of the Factors Influencing an OSH Ecosystem

Each of the factors described in the framework above are key contributors to the creation of a thriving global OSH ecosystem. Through the framework, we can better understand the bottlenecks and points of improvements hindering the promotion of the global OSH ecosystem. In this section, a further analysis is proposed which describes tentatively the interactions between each of the factors, and how these relate to one another (Figure 10).

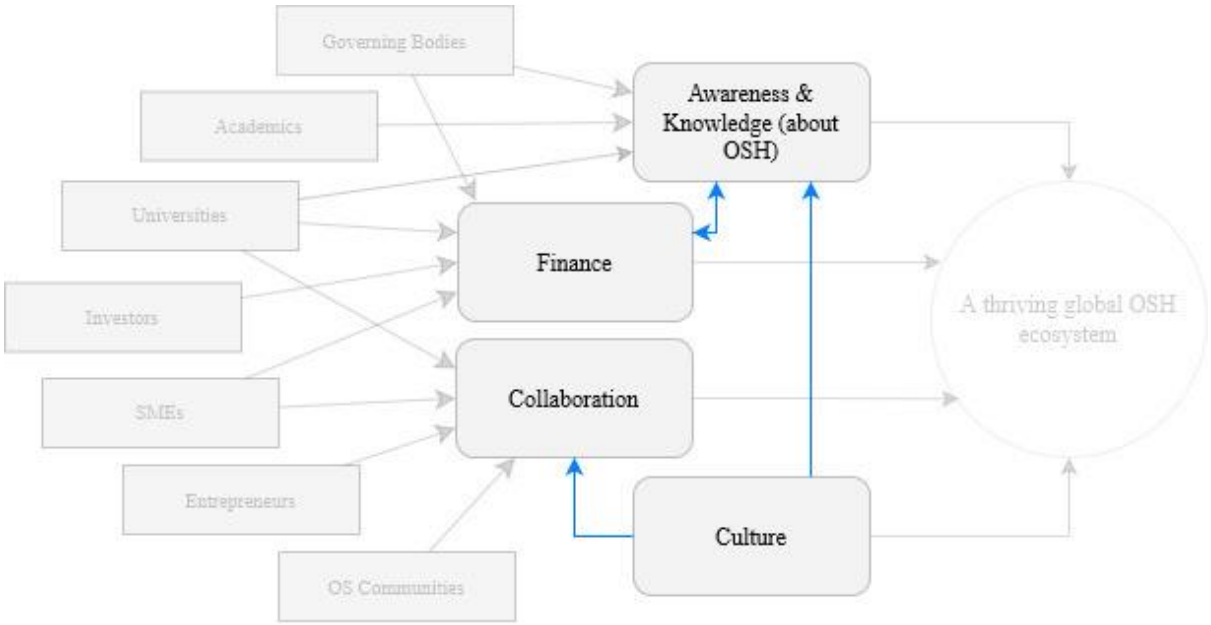

Figure 10 Interdependencies of the factors influencing an OSH ecosystem (author's work)

A&K of OSH was found to closely influence Finance, and vice versa. This is because finance can enable A&K of OSH through education and other strategies, and because of the many aspects of finance which are dependent on OSH being understood by relevant parties. In this research, the relevant parties were identified as:

- governments which can provide funding via subsidies, tenders and other financial mechanisms (Blind et al., 2021; Int.OSHE3; Int.OSHI)
- Funders of various kinds, such as philanthropists and venture capitalists (Li et al., 2022; OSH Aca., Int.REE)
- And finally companies, ranging from SMEs to multinationals, which can invest their R&D capital into OSH, but may not find it in their interest to do so if they are not aware of the benefits which OSH can bring both to them and society (Hassan et al., 2021; Int.OSHI)

The interviews carried out and the desk research repeatedly highlighted the influence which culture can have on A&K of OSH and collaboration. This influence is reflected in various Transition

Discourses, which highlights the key role of culture in social structures (Escobar, 2018). As previously mentioned, future work would therefore do well to explore how the GN and GS might differ in their interpretation of OSH, and whether different cultures can lead to a clearer understanding of how A&K of OSH and collaboration can be encouraged.

Chapter 6. Limitations of the Methodology

Before moving to conclusions and suggestions for further research, we must look at the limitations of the methodology. As with all research, some evident limitations include lack of time and subjective lenses which the author could not help but possess when carrying out the research.

Additionally, the literature research had some clear limitations. When the literature research was designed, the research aimed to emphasise OSH and how it is being developed in the GN and GS. As this (the limitations of how OSH is being applied in the GS) had yet to be explored, the author did not realise until post-literature research that the research queries would yield such biased results. In other words, by placing focus on the OSH side of research, less importance and time was allocated to the GS which is underrepresented in the research and would therefore require much more attention. This presents a limitation in the research, but also an opportunity for future studies.

Additionally, although the literature research attempted to overcome the limitation of terminology when discussing GN/GS, a stronger emphasis could have been placed on including a broader range of terminology. For example, the terms GN and GS were coined in the late 20th century, and as such are slowly gaining representation in academia but may still be underused (Hollington et al., 2015; Pagel et al., 2014). To compensate, the terms “developing country” and “developed country” were used: these were coined in mid-20th century and have been more broadly used than GN/GS. However, other terminology such as “third world” and “first world” could have been employed (Wolf-Phillips, 2007). Further research should therefore dive further into these terminologies and how they are being employed by academia.

Regarding the interviews, there was an inherent GN-bias in the interviewed carried out, as the author is based in the GN, and has a personal network predominantly based in the GN. This meant that reaching out to individuals based in the GS was time-consuming, often yielded no responses, and individuals with a GS-perspective were simply more difficult to find. This was reflected in the interviews carried out, which did not include a balanced representation of individuals originating in the GS and GN. Additionally, a limitation found is the male-dominated interviewee sample. Further research would do well to overcome this by obtaining a more balanced sample of genders, which could provide more diverse responses.

Regrettably, this lack of balance of opinions, notably from GS-/GN-based individuals, means that this master thesis research, like much of the other research carried out today, is done with a biased WEIRD and GN lens. As such, the research does not provide nearly as full a picture of the ‘global’ aspect of the OSH movement and is certain to lack depth when addressing the challenge of different terminologies which the GN and GS apply when discussing OSH-related topics.

The interviews also had a crucial limitation to providing a more holistic vision of how OSH is influencing systems: interviewees were mostly OSH proponents. Identifying and finding OSH opponents was found to be challenging but should most certainly be included in further research exploring the role of OSH in our society.

A final limitation to the methodology which should be highlighted, is the lack of statistical analysis. A statistical analysis could have further quantified the significance of the differences in the GN- and GS- based literature research. To generalise the findings and to draw more concrete conclusions from the research done here, such a limitation must be overcome.

Chapter 7. Conclusion

This thesis was guided by the overarching question of how OSH as a global movement is being perceived and explored. While the research provided some answers, due to its explorative nature it also generated many more questions. By exploring the OSH movement, the author aimed to gain a better understanding of how the global North and global South might use OSH as a tool for systemic change; especially so during critical times that require innovative tools to enable a sustainable system to arise.

The first research question (RQ1a&b) sought to examine the current state of knowledge on OSH in academic literature and the extent to which it is studied in (and by) both the Global North (GN) and the Global South (GS). Through the research, it was possible to see a clear and consistent growing trend in OSH academic research, which has stabilised over the past two years. However, in this trend, a clear implicit bias for the GN in the research was identified. This was seen in the tenfold number of papers which are published (implicitly) discussing OSH in the GN, rather than the GS.

By calling it a 'global movement', we therefore risk obscuring the relevance and actuality of the differences between the GN and GS approach to OSH. Considering OSH is found to be a GN-based term, further research would benefit from exploring how OSH-equivalent terms are being researched in both academic and non-academic settings for the GS.

In the second research question (RQ2), some of the main points of discussion which academics, entrepreneurs and individuals in the renewable energy sector discuss were explored. Combining RQ2 with the research of RQ1 enabled the answering of RQ3, which identified the main factors influencing the development of a global OSH ecosystem. How these factors interact with each other was better understood through the research and allowed the development of a tentative framework (see section 5.3). This framework can be used to evaluate the development of OSH and identify where some of the bottlenecks in its development may be.

Overall, although the relative novelty of applying open source to hardware provides much room for further exploration, the groundwork is being laid out. Considering the critical point at which humanity stands today with regards to the challenges of climate change, scarcity of resources and growing wealth disparity to name a few, exploring tools to systemic change such as OSH can yield valuable insights. For this, the basics of OSH and how it could act as one of the many solutions to some of our most pressing problems is essential, and further research building upon this thesis would do well to explore it.

7.1. Personal Reflections

The most challenging part of this thesis was in knowing and deciding where to stop. After two years of personal experience in developing an OSH start-up, I thought there would be little in the literature that I would encounter that I would get lost in, since I thought I had likely experienced it all first-hand. For the most part, this was true, but I most certainly did not account for the excitement which reading through papers and speaking to individuals about OSH would bring me, making me want to dive ever deeper into the complexity of the topic and how/whether we should be applying it more widely.

There is limited research on OSH and its use as a tool for systemic change, and so I was quickly forced into moving away from papers and into the 'real world' world. The interviews were invaluable in my research, and although no opponents to OSH were interviewed, my personal experience kept me grounded in the reality of the limitations of OSH. Without it, I am almost certain that the

contagious enthusiasm expressed by the interviewees regarding OSH as an essential tool to future systems (both economic and social) would have led me to writing an opinionated piece on OSH rather than a MSc thesis. As it stands, I hope I have provided a somewhat valuable and insightful thesis which can be used to further explore both the future opportunities of OSH, as well as its downfalls.

Paradoxically, because of the limited research in OSH, identifying what to research was a challenge. The immensity of the research gap meant that I was constantly re-evaluating the questions I was attempting to answer, and where they fit into the larger picture. Not only that, but turning the frustration at finding little to no non-male and/or GS-individuals which work on OSH projects into valuable findings was challenging. Only upon writing about necessary further research did I manage to consider my work as having been worthwhile. It is therefore with great hope and enthusiasm that I encourage you to read section 8.2, which might just galvanise you into taking up the baton and starting on a journey towards OSH and all its potential.

Chapter 8. Drawbacks and Further Research

8.1. Drawbacks of the Research

Throughout the research, there was an emphasis on taking a global approach to the OS transition, which meant trying to understand and position both the GN and the GS. However, it quickly became apparent that very little research has been carried out on the differences in an OSH approach when considering cultural and geographic factors. This means that most of the literature and research available on the OSH movement, is employing a GN lens. Previous research has argued that OSH being a global movement means that such an approach to research is generalisable (Hassan et al., 2021). Yet, this thesis uncovered differences in how the OSH movement is seen and used by the GN and GS, as OSH is greatly influenced by culture. This discrepancy in the literature is therefore clearly a cause for concern which may lead to further deepening of the inequality in GN/GS academic research regarding OSH and may even lead to erroneous assumptions about how OSH is being used globally.

In the current context of social and environmental justice, aligning OSH research for the GN and GS, is essential. In the following section, further research highlights how this could be done, as this was a part of this master thesis which did not go in enough depth and comparison. Additionally, the topic of neo-colonialism, although growing in awareness and having been mentioned briefly in one of the interviews, was not explored in this thesis. This was beyond the scope of the research but is clearly lack when discussing topics of inequality between the GN and GS.

A final drawback to mention, is the novelty of OSH research in academia, particularly in exploring the social implications of OSH and cultural influences. Such a drawback meant that an explorative approach was necessary to uncover as far as possible findings which could answer the research questions but could not go further than tentative suggestions and conclusions. However, as the following section will showcase, through this approach a considerable amount further research could be identified.

8.2. Further Research

As mentioned, the explorative nature of this master thesis uncovered many areas in OSH which would benefit from further academic work. In this section, potential avenues are discussed.

8.2.1. GN/GS Differences

The most important finding from the literature research, is that there is a huge research gap to overcome when discussing OSH and the GN/GS. This research gap is reflected in the number of papers published explicitly discussing the GS and becomes evident when attempting to explore how culture can influence OSH and the lack of research in this domain. It became apparent that OSH is a concept drastically more popular in GN-oriented literature, whilst there seems to be a lack of understanding regarding alternative terminologies to 'OSH' which are employed in the GS. Although research on the 'commons' for the GN has been done and how this is rooted in concepts such as 'buen vivir' in the GS, equivalent research for OSH has yet to be done. By doing such research, academia could begin to identify the reason for a low amount of OSH GS-oriented research and could begin to fill the research gap.

Additionally, exploring how the GS utilises OSH (or its equivalent) could provide a better understanding of how OSH is a 'global movement'. This global understanding should be explored taking cultural aspects into consideration. This would enable further research which can provide a

clearer understanding of how different cultures and locations might benefit from utilising OSH as a tool for a systemic change. Such research could take the form of exploring how different cultures understand and apply some of the pillars of OSH, namely: transparency, collaboration, and reciprocity. According to one of the interviewees, applying OSH to the GN is likely to result in more resistance than if applied to cultures which already showcase values of openness, and collaboration. Such a statement could be researched using case studies of OSH projects from both the GN and GS. Learning from societies which already apply to some extent the pillars of OSH could provide invaluable insights to how OSH might grow and benefit or hinder society.

Through a quick analysis of the authors included in the literature research, it became apparent that the majority of papers mentioning the GS were authored by individuals based in the GN or were discussing OSH projects developed by individuals from the GN for the GS. Further comparative and quantitative research should be carried out to determine whether this is a trend, or an erroneous finding by the author. This research could provide a better understanding of the extent to which OSH is being developed by the GN for the GS, and by the GS for the GS. Considering the influence of neo-colonialism in knowledge sharing and its impact on both the GN and GS, such research would be highly relevant. Additionally, no research to date (as far as the author was able to find) addresses the topic of neo-colonialism and OSH. There is therefore much room for research in this field and understanding GN-GS relations in OSH might be essential to potentially preventing the extension of a neo-colonial trend to OSH.

8.2.2. OSH and Systemic Change

This research didn't explore in much depth the benefits which OSH can bring about in meeting human needs. However, as was witnessed during the pandemic when OSH ventilators and other medical devices were developed (Chong et al., 2021; Haque et al., 2021), there is large potential for OSH to be used as a tool to enable rapid humanitarian aid. Further research would therefore do well to identify areas in which OSH would best benefit our society, for example in aiding in humanitarian crises, or in addressing the social and planetary boundaries (Raworth, 2017).

Additionally, exploring how capitalism, the free-market, and ownership influence OSH and are influenced by OSH, was not done in this research but would provide an interesting topic of further research. Especially so if considering the GN and GS which have drastically different approaches to these concepts (Escobar, 2018). Jeremy Rifkin in his book "the Zero Marginal Cost Society" explores the topics of capitalism, free-market, OS, and others, but it has yet to be researched from a more 'scientific' perspective. Indeed, exploring Rifkin's theory of capitalism and the commons having a parent-child relationship (respectively) could be valuable, and may lead to insights on the social and cultural trends taking place today.

The discussions with entrepreneurs suggested that a drive for working in the sphere of OSH was a desire to work for a better world and to overcome the 'failures' of capitalism. According, to them, OSH was the future of business, as it has been with OSS. The motivation of entrepreneurs to contribute to OSH on moral grounds has been studied in literature (Li et al., 2017, 2021). However, studying the role of a somewhat pious or spiritual approach to OSH has yet to be explored.

8.2.3. Gender in OSH

Although the scope of this research did not extend to identifying gender (in)equalities in the field of OSH, the challenge of identifying non-male OSH entrepreneurs and participants to the interviews suggests an area for further research. Through a rapid web of science search using the keywords

'gender' and 'Open-source hardware', the lack of relevant results returned suggests that gender (in)equality in the field of OSH is an area that has yet to be explored.

Considering entrepreneurship tends to be a male-dominated field (GaweŁ & KrstiĆ, 2021; Rietveld & Patel, 2022), doing research on whether OSH entrepreneurship is male-dominated and comparing it to closed source entrepreneurship could be an interesting area of research. Additionally, through such research an understanding of whether gender is a factor which influences the open aspect of start-ups could be understood. As a side project beyond the scope of this research and with the purpose of exploring OSH and gender in start-ups, a survey was created (Appendix 5 – analysis provided upon request). A further exploration of the results of this survey and a higher response rate could provide insights into whether gender influences IP protection.

8.2.4. OSH in Academia

The interviews highlighted a difference between the motivations of individuals in academia vs entrepreneurship or RE sector individuals when discussing OSH. For individuals in academia, OSH was seen as a very practical decision – collaboration and sharing means better research and better science. As Open Access is growing in the academic sphere, further research would be valuable to explore to what extent such a movement towards OSH is representative of academia at large, and whether this movement can be leveraged to develop an OSH ecosystem in academia. An example of such a growing movement is found at the Technical University of Delft, where OSH is being pushed forward by the Delft Open Hardware group (TU Delft, n.d., 2022; de Vos, Personal Communications, March 2023).

Additionally, what was noticeably absent from the interviews with the academics was the lack of a business perspective or 'finance oriented' discussions. This was surprising, as most academic research today on OSH is around business models and the motivations of developing OSH businesses. This suggests that further research by academics would do well to explore how OS is understood from a cultural or as a social movement point of view, rather than solely from a business point of view.

8.2.5. Dealing with Complexity

A topic briefly mentioned in some of the interviews with the entrepreneurs but not further elaborated upon in this thesis, was the potential which OS and P2P have for dealing with complexity, and therefore wicked problems. Wicked problems have been described as having clear properties, including being understood as problems which are ambiguous, complex and whose solutions are multiple (Rittel & Webber, 1973). The hyper-connectedness of our world, and growing global society has resulted in a growing body of wicked problems, including sustainability, and climate change (Pryshlakivsky & Searcy, 2013).

By advocating for decentralisation OSH provides an alternative to standardized solutions, which may be a valuable tool for seeking solutions to wicked problems. However, there has been little to no research done on the use of OSH for addressing wicked problems. As such, future research would benefit from researching these topics and how they interlink.

8.2.6. OSH for an Energy Transition

Although the thesis initially aimed to focus on how the OSH movement can contribute to the energy transition, new insights arose which altered the focus – instead, the discrepancy in how OSH is being understood in the GN and the GS, and what factors hinder the development of a global OSH ecosystem were given focus. However, this meant that OSH and how it can contribute to the energy transition is still yet to be researched on various fronts. Through the literature research, it became clear that there

are various academics already exploring how OSH could promote the energy transition (Buitenhuis & Pearce, 2012; Giotitsas et al., 2015); however, there is still much to explore in this field. Some areas of potential research which emerged in the research include: where OSH can be used most effectively in a RE supply chain to accelerate the transition; how OSH RE projects can overcome the barrier of funding which tends to be particularly high due to high CAPEX requirements; and to what extent is OSH a tool for inclusivity in the RE transition.

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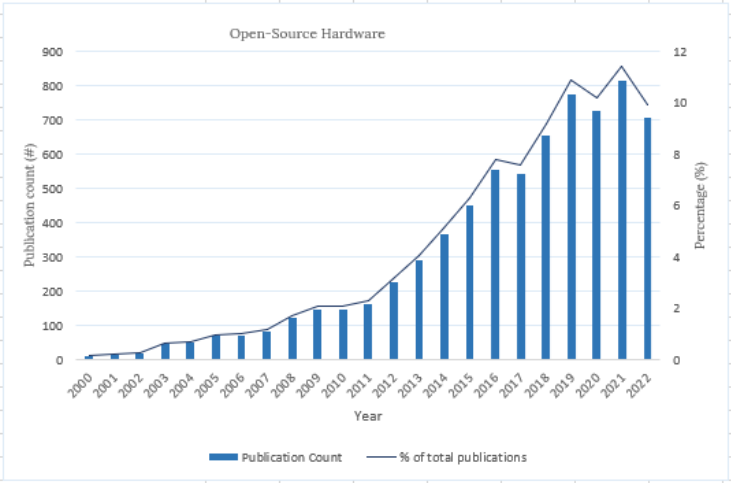
Appendices

Appendix 1 Trends Analysis (RQ1)

"open-source hardware" OR "open source hardware"				
Publication year	Count	% of all-time publications	Trends	
2000	13	0.183	2010-2022 total publications	6412
2001	15	0.211	% published after 2009	90.018
2002	21	0.295		
2003	48	0.674		
2004	52	0.73		
2005	71	0.997		
2006	73	1.025		
2007	85	1.193		
2008	122	1.713		
2009	148	2.078		
2010	148	2.078		
2011	163	2.288		
2012	225	3.159		
2013	291	4.085		
2014	365	5.124		
2015	450	6.318		
2016	555	7.792		
2017	541	7.595		
2018	653	9.167		
2019	774	10.866		
2020	726	10.192		
2021	814	11.428		
2022	707	9.926		



	Authors	Article Title	Abstract	GN target	GS target	Both	ot specifi	Medicine	Electronic	Education	Energy	Design	griculture	Industry	Other
2	Chavez, A; Kovarik, C	Open Source Technology for Medical Practice in	The purpose of this chapter is to provide an overview of the role of open source technologies within medical practice in developing countries. Fi	x				x							
3	Hosha, V; Shah, I; Shah, M; H	Cost-Oriented Open Source Automation Potential	One of the most cost effective ways to make system control (automation) is by using open source hardware and software, in order to be cost oriented besides the price t	x										x	
4	Moritz, M; Redlich, T; Grunz	Value Creation in Open-Source Hardware	Technical progress in production technology, the advancement and spread of information and communication technologies (ICT) as well as the spill-over of the highly eff	x									x		
5	Bravo-Martinez, J	Open source 3D-printed 1000 mL micropump	Scientific innovation goes hand in hand with technological innovation, as scientific work depends to a great extent on the hardware available in th	x				x							
6	Kazala, R; Straczynski, P	The Most Important Open Technologies for Design of	Nowadays, industrial automation systems are mostly used with proprietary hardware and software. Creating such systems requires relatively large costs. This is a proble	x										x	
7	Pearce, JM	Strategic Investment in Open Hardware for National	Free and open-source hardware (FOSH) development has been shown to increase innovation and reduce economic costs. This article reviews the opportunity to use FOSI	x								x			
8	Zualkernan, IA	Design and implementation of a low-cost classroom	Economic considerations and lack of adequate infrastructure impose unique design constraints on future classrooms of the developing world. Tl	x						x					
9	Amaxilatis, D; Akrivopoulos,	An IoT-Based Solution for Monitoring a Fleet of	Raising awareness among young people and changing their behaviour and habits concerning energy usage is key to achieving sustained energy saving. Additionally, youn	x						x					
10	Ahlawalia, A; Atwine, D; De K	Open Biomedical Engineering Education in Africa	Despite the virtual revolution, the mainstream academic community in most countries remains largely ignorant of the potential of web-based teacl	x						x					
11	Pandian, SR	Playful STEAM Learning Using Robots	In developing countries like India, the school and college education systems are mired in the passive, teacher-centric pedagogy based on rote lea	x						x					
12	Gomez, EA; Evans, K	A Practical Application of TrimCloud: Using	The current educational technologies in developing countries are not always successfully implemented and utilized due to infrastructure limitation	x						x					
13	Park, MH; Zhe, YJ; Wang, Hu	From hardware store to hospital: a COVID-19-	Resource-scarce regions with serious COVID-19 outbreaks do not have enough ventilators to support critically ill patients, and these shortages	x				x							
14	Lopez-Vargas, A; Fuentes, M	Open-source technologies and IoT as a tool for	Solar Home Systems have been widely introduced in developing regions, usually in poor and isolated locations with lack of access to electricity,	x							x				
15	Martin-Somer, M; Moreno-S	High-performance low-cost solar collectors for water	Solar technologies constitute an excellent alternative for water treatment in low-income countries where the poverty of a large part of the popula	x							x				
16	Yon Chong, A; Garcia, A; Du	Low-cost, rapidly deployable emergency mechanical	The COVID-19 pandemic disrupted the world by interrupting most supply chains, including that of the medical supply industry. The threat impose	x				x							
17	Lopez-Vargas, A; Fuentes, M	Low-Cost Datalogger Intended for Remote	A low-cost datalogger intended for standalone photovoltaic (PV) systems in developing countries was designed by employing open source soft	x							x				
18	Yang, XK; Yang, LY; Zhang,	A WiFi-enabled Indoor Air Quality Monitoring and	Particulate matter pollution becomes an increasingly important problem in developing countries and poses a hazard to human health especially in	x		x									
19	Fathima, K; Shilpa, VJ; Mahm	Design and Implementation of Three-Axis Cost	The need for Fabricating a circuit is enormously increasing in day to day electronics. Many resource poor countries in the Developing world are t	x						x					
20	Harini, VS; Dharani, M; Bshji	Robots for the Bottom of the Pyramid: Mobile Robot	Innovative and quality education for all is a major precondition for smart nations. Children and youth are fascinated by mechanisms, machines and	x						x					
21	Murzotti, S; Payonnet, PA; E	Low Cost Artificial Ventilator Embedding	In this paper, a less than $200 artificial ventilator that can be used against COVID-19 pandemic is presented. Using low-cost easy-to-find materi	x				x							
22	Caceres, M; Firman, A; Mone	Low-Cost I-V Tracer for PV Modules under Real	Solar photovoltaic technologies have undergone significant scientific development. To ensure the transfer of knowledge through the training of qualified personnel, didac	x							x				
23	Zhong, QC; Wang, YQ; Amir,	Smart Grid Research and Educational Kit to Enable the	Control and power electronics are two major enablers for the paradigm shift of power systems from centralized generation to distributed gener	x			x								
24	Betancur-Vasquez, D; Mejia-	Open source and open hardware mobile robot for	Nowadays, additive manufacturing, rapid prototyping and assembly modules represent a market that has invaded the entire world, especially in developing countries whe	x			x								
25	Lopez-Vargas, A; Fuentes, M	Current challenges for the advanced maar scale	Millions of Solar Home Systems (SHSs) have been progressively installed in rural areas of developing regions, usually in isolated locations that li	x							x				
26	Sivarajani, S; Sumathi, S	A Review on Implementation of Bimodal Newborn	In developing countries the newborn swapping and abduction in hospitals are challenging issues and occurs all over the world. Traditional methoc	x			x								
27	Hoque, SR; Saha, SS; Chowd	A Cost-Effective Solution for Real Time Remote	The outbreak of COVID-19 hit the world with an incomparable magnitude and introduced new challenges in the diagnosis and treatment of patien	x				x							
28	Ilyas, MU; Khan, MM; Laghar	CODI Bot: An Accessible Robot for New Coders	College students in low and middle-income countries enter undergraduate STEM programs under-prepared, with little or no prior knowledge ab	x								x			
29	Saini, M; Garbo, AA; Bjekin	Design and Implementation of an Internet of Things	Applying the capabilities of the Internet of Things holds particular promise for advancing certain of the United Nations Sustainable Development Goals. For instance, citi	x			x								
30	Bruno, F; De Marchis, M; Mi	A Pressure Monitoring System for Water Distribution	Efficient management of water distribution networks (WDNs) is currently a focal point, especially in countries where water scarcity conditions are more and more amplific	x			x								
31	Whitehead, T; Evans, M; Bing	Local or Global? Approaches for New Product	To increase opportunity and quality of life for people living in poverty, governments and non-government organizations (NGOs) sell products to c	x								x			
32	Malkin, R; Beer, KV	Diffusion of Novel Healthcare Technologies to	A new product has completed clinical trials in a distant, resource poor hospital using a few dozen prototypes. The data looks great. The novel m	x				x							
33	Freire, RA; Lorenzo, J; Bosvc	Challenges of open design in low-income communities:	Open design (OD) is a promising approach to address global sustainability challenges. At the same time, however, the increased use of OD brings new challenges. To unc	x								x			

	Authors	Article Title	Abstract	GN target	GS target	Both	ot specifi	Medicine	Electronic	Education	Energy	Design	griculture	Industry	Other
34	Bhawsar, P	Clusters: semantically different yet a panacea for	Purpose The paper aims to relook at the notion of competitiveness in the challenging times of pandemic. The failure of global value chains caused many nations despite th	x										x	
35	Ben Rejeb, H; Rousseil, B	Perspectives on the evolution of a fabrication	Purpose The purpose of this paper is to help in the establishment of the first fabrication laboratory (FabLab) in Tunisia. The FabLab movement c	x								x			
36	Butchers, J; Benzon, S; Willia	A Rationalised CFD Design Methodology for Targe	In the Global South, pico- and micro-hydropower turbines are often made by local workshops. Despite several advantageous features, e.g., a hig	x							x				
37	Abbasoli, W; Harmel, A; Bulka	Maker movement contribution to fighting COVID-19	COVID-19 is an unexpected and brutal pandemic that requires new innovation models to overcome the constraints of this crisis and address its multiple challenges. Open	x				x							
38	Henriquez, JJ; Bojarski, B; Bo	Crowd-sourcing Urban Air-quality in Developing	Outdoor air pollution now contributes annually to over 3.2 million premature deaths worldwide and is among the top health risk factors. Urban	x			x								
39	Mtshe, Y; Sathyakumar, N; P	A Build Your Own Robot Manipulator for	Robotics is one of the major disruptive technologies of our time, and offers significant opportunities for innovation and competitiveness in the c	x						x					
40	Pattanashetty, K; Balaji, KP; P	Educational Outdoor Mobile Robot for Trash Pickup	Machines in general and robots in particular, appeal greatly to children and youth. With the widespread availability of low-cost open source hare	x						x					
41	Kim, K; Kim, HK; Lim, H; Myun	A Low Cost/Low Power Open Source Sensor System	In this research an open source, low power sensor node was developed to check the growth of mycobacteria in a culture bottle with a nitrate red	x				x							
42	Dotson, AD; Cenek, M; Mich	Open-Source IoT Framework for Mobile Household	Humanitarian responses often addresses the basic human needs which include safe, sanitary, hazard free environment. From the war torn countries to remote communities,	x											x
43	Salido, J; Bueno, G; Ruiz-Sun	A review on low-cost microscopes for Open Science	This article presents a review after an exhaustive search that yielded 23 works carried out in the last decade for the availability of optical microscopes with open hardwar	x				x							
44	Medina, LE; Villalobos-Cid, F	Design of a low-cost neuromuscular blockade	The increasing number of hospitalizations due to the ongoing pandemic has brought medical devices to the forefront of clinical management. For instance, mechanical ven	x				x							
45	Valencia-Redrovan, D; Gonz	SA(3)M: An Interactive Robot to Provide Support for	The number of the elderly worldwide has risen to 600 million in recent years, however, not all of them have the opportunity to receive adequate care. This situation is more	x				x							
46	Rodriguez-Sanchez, MC; Ch	International collaborative projects on digital	Collaborative projects allow engineering students to learn from one another and improve the skills necessary for working in a team. We conducted a study in	x						x					
47	Calderon, A; Griffin, J; Zagal	Beamfolder: an open hardware high-resolution digital	Purpose - The democratization of invention is a long lasting desire for the advancement of society. Having access to education and the means of	x			x								
48	Fernandez, FJV; Segovia, JS;	Rov(UAv)Rgc: A Low Cost and Fully Functional	Although the cure for the SARS-CoV-2 virus (COVID-19) will come in the form of pharmaceutical solutions and/or a vaccine, one of	x				x							
49	Sathyakumar, N; Balaji, KP; Q	A Build-Your-Own Three Axis CNC PCB Milling	The need for fabricating a prototype circuit arises frequently in electronics, including education and research laboratories. In resource-poor coun	x			x								
50	Aditha, E; Matthews, VO; J	NomadicBTS: Evolving cellular communication	Utilization of software-defined radio (SDR) and open-source technologies in the next evolution of cellular communication networks may significc	x			x								
51	Coppes, A; Monaco, G; Cal	A low-cost, open-source autonomous surface vehicle	Although waste stabilization ponds (WSPs) are widely used in developing countries, monitoring data on their operational performance are scarc	x			x								
52	Karoki, K; Yan, K; Iwata, H; Sa	Development of a high-throughput field phenotyping	Phenotyping is a critical process in plant breeding, especially when there is an increasing demand for streamlining a selection process in a breeding program.	x								x			
53	Aymerich, C; Rodriguez-Lazo	Low-Cost Open-Source Device to Measure Maximal	The measurement of maximal inspiratory (MIP) and maximal expiratory (MEP) pressures is a widely used technique to non-invasively evaluate resp	x				x							
54	Gyllinsky, JV; Gannon, J; Ako	Patient Self-assessment of 3D Printed Upper-	With 40 million amputees living in poor countries with limited access to health care, there is a significant need for novel prosthetic solutions. This	x				x							
55	Hobbs, SW; Paull, DJ; Huythc	Developing a spectral pipeline using open source	The ability to access, design and create low cost sensors capable of returning scientifically useful data has led to an exponential increase in citizen science, education and	x			x								
56	Rodriguez, DRC; Loguardia,	Architecture Based on Open Source Hardware and	The usage of real-time tracking systems for vehicles has demonstrated to be a viable and economical option, entailing in more control and manag	x											x
57	Focke-Perez, I; Ramirez-Psyc	An open real-time tele-stethoscopy system	Background: Acute respiratory infections are the leading cause of childhood mortality. The lack of physicians in rural areas of developing countr	x				x							
58	Aydin, L; Kucuk, S	Design and Construction of Ankle Foot Orthosis By	Three dimensional (3d) printer technologies are rapidly developing and increasingly being used in several fields. In this study, as a first step a 3d	x				x							
59	Ertugrul, S; Kaya, O; Turkman	Humanoid robot arm design, simulation, kinesthetic	Robot technology is constantly developing and the studies in this field are also increasing in our country. Universities, machine-manufacturing an	x				x							
60	Rybynok, VO; Kyriacou, PA;	Development of a personal electronic health record	In most emergency situations, health professionals rely on patients to provide information about their medical history. However, in sit	x				x							
61	Aidukas, T; Eckert, R; Harvey	Low-cost, sub-micron resolution, wide-field	The revolution in low-cost consumer photography and computation provides fertile opportunity for a disruptive reduction in the cost of biomedical imaging. Conventior	x				x							
62	Valladares, LDC; Laman, J; Pa	Towards Customized Medicine with Open-source	Alterations in the normal gait can be enhanced to improve patients' quality of life. Although several devices improve these conditions, the techno	x				x							
63	Andra, FD; Sritha, G; Enoch,	Air Quality Monitoring and Control System for a	The authors developed a system that allows air quality monitoring and controlling within a hospital room. The system based on temperature and humidity sen	x				x							
64	Shen, XY; Li, ZQ; Ma, L; Bian,	Design and implementation of low-cost portable	The potentiostat is critical in the development of electrochemical systems; however, its cumbersome detection and high cost considerably limit it	x				x							
65	Myers, FB; Henriksen, RH; Bi	A Handheld Point-of-Care Genomic Diagnostic System	The rapid detection and identification of infectious disease pathogens is a critical need for healthcare in both developed and developing countri	x				x							

64	Shen, XY; Li, ZQ; Ma, L; Bian,	Design and implementation of low-cost portable	The potentiostat is critical in the development of electrochemical systems; however, its cumbersome detection and high cost considerably limit it	x				x							
65	Myers, FB; Henrikson, RH; B	A Handheld Point-of-Care Genomic Diagnostic System	The rapid detection and identification of infectious disease pathogens is a critical need for healthcare in both developed and developing countri	x				x							
66				GN target	GS target	Both	Not specified	Medicine	Electronics	Education	Energy	Design	Agriculture	Industry	Other
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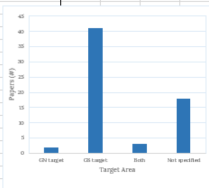

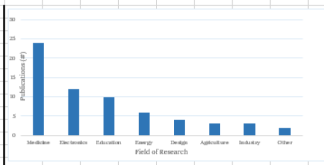

Appendix 2 Consent Form

Opening Statement

You are being invited to participate in a research study carried out by myself, Perine Fleury - a Master student of Industrial Ecology from TU Delft and Leiden University, in the Netherlands.

The purpose of this research study is to explore the extent to which utilising an open-source approach can facilitate the energy transition, and push forward circularity in the solar industry.

The interview will take up to 30 minutes to complete. The data collected will be used for completing a Master thesis, potential publication, and recommendations for the Open-Source world, entrepreneurs, policy makers, and other institutes. I will be asking you to answer some questions regarding topics such as open-source, solar energy, circularity, the energy transition, and policy making.

As with any online activity the risk of a breach is always possible. To the best of my ability your answers in this study will remain confidential. I will minimize any risks by storing all recordings, transcripts and personal data on the private platform TU Delft OneDrive; additionally, upon completion of the project, all personal data (such as recordings, email addresses and names) will be destroyed. Note that technical summaries of the data collected from the interview will be produced and be made available with the Master thesis.

Your participation in this study is entirely voluntary and you can withdraw at any time. You are free to omit answering any questions.

Thank you for your time, and if you have any questions reach out to me via email: p.l.fleury@student.tudelft.nl

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		
1. I have read and understood the study information dated [*DD/MM/YYYY*], or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time, without having to give a reason.	☐	☐
3. I understand that taking part in the study involves using either video recording (if online) or audio recording (if physical).	☐	☐
4. I understand that recordings will be destroyed after completion of the thesis research; which will end around April 2023.	☐	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
6. I understand that taking part in the study involves the following risks: - Mental discomfort - Emotional discomfort I understand that these will be mitigated by - The ability to end the interview at any given moment, without explanation required	☐	☐
7. I understand that the following steps will be taken to minimize the threat of a data breach, and protect my identity in the event of such a breach: - Pseudo-anonymization of interview transcripts - Data storage on the TU Delft One Drive - Deletion of name and contact address after completion of research	☐	☐
7. I understand that taking part in the study also involves collecting specific personally identifiable information (PII) [a recording will be taken of the interviews] and associated personally identifiable research data (PIRD) [job position within your project] with the potential risk of my identity being revealed.	☐	☐
10. I understand that personal information collected about me that can identify me, such as my name and contact email, will not be shared beyond the study team.	☐	☐
11. I understand that the (identifiable) personal data I provide will be destroyed upon completion of the project (approx. April 2023).	☐	☐
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
12. I understand that after the research study the de-identified information I provide will be used for a Master Thesis, and potential publication.	☐	☐
13. I agree that my responses, views or other input can be quoted anonymously in research outputs, with the Master project and/or publication being used as a source.	☐	☐
D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE		
16. I give permission for the technical summary containing de-identified quotes that I provide to be archived in TU Delft OneDrive repository so it can be used for future research and learning.	☐	☐
17. I understand that access to this repository is open to TU Delft employees and students.	☐	☐

Signatures

Name of participant [printed]	Signature	Date

I, as researcher, have provided the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

Researcher name [printed]	Signature	Date
Perine Fleury		07.11.2022

Study contact details for further information: Perine Fleury; P.L.Fleury@student.tudelft.nl

Appendix 3 Technical Transcripts

OSHE1 Technical Transcript

What has brought you to open source and also specifically maybe to open source hardware.

After I finished my studies, I went to work in California for a laser Manufacturer. So my background is in physics. And this was an unusual laser company, because they were working on a specific type of laser that was very new and there were no applications for it.

So it's like you invent the light bulb, but there is no flashlights for it.

Although people might know about possible applications that were no applications developed, so my role in this company was a laser applications engineer, so I had to work with a bunch of Entrepreneurs. Companies, and Academic labs at different universities, to help them learn how to use this to help them discover what it is good for.

And what they [developers and entrepreneurs] all had in common is that they all wanted to use this laser. So for example, some people were in dentists. So they wanted to see if this laser can clean teeth. Other people were like eye surgeons and they wanted to see if they can use this laser to do eye surgery.

So they wanted to see if this laser, this new laser brings new, new features. OK, where new possibilities we were working with people doing photovoltaic cells and they wanted to use the laser to cut the glass.

So what happens here in the ecosystem is that you know it's private. It's business as usual. It's based on NDA and patenting.

And I knew about everybody else but nobody else knew what other people were doing. So I understood from the center of this ecosystem that if I could share information, I could accelerate their research and development. Maybe 10 fold, sometimes even 100 fold, because I knew that these other guys had some information that these guys were trying to develop or they had some expensive equipment that that these other guys need.

I saw a lot of unmatched needs and offers and some unused material that could be shared. It felt very stupid. Like I thought that this system is highly inefficient. I felt like I was purposefully slowing it down by not telling people what I knew.

And then the financial crisis hit in 2008. So I came back to Canada working for a university and this is where I started to become radicalized, meaning that you know, I started to think and develop these ideas of open source and open source hardware back in 2008 was like, you know, was like starting and developing. With the 3D thing coming in.

Open source software was well developed with good licenses, but in 2008 open source hardware didn't even have a license. People were talking about possible license, so it was kind of the beginning. I jumped on this and I said, you know, this is the future, this is the future because you know, if we do want to solve world problems, we have to put aside the profit motive. But then I understood that it is economically possible too, to do open source development.

And that was the beginning of all these things like Arduino was the beginning of, you know, Adafruit, you know, so you understand that even in the current economy there is a niche market for open source stuff.

Even in a competitive market, if your market strategy is speed of innovation, then you don't have to [patent]. I mean, you know, there's always a compromise to do right.

So you can go full open source, no shield, no defense. But you have to go fast. So how do you turn that Openness and transparency into your advantage?

Instead of being a weakness because you're open and transparent so your competitors know what you do. How can you turn that into advantage to grow your innovation speed even further and leave them in the dust.

So that's my path into this. And then and then from that jump to peer-to-peer to say wait a second, I'm thinking about how to feed open source business model within this economy. But this economy is changing to something else, this economy is probably dead, it's just a matter of time, right it's on life support and maybe what's coming is a sort of a peer-to-peer economy.

That that runs on very different principles. So, all this talk about competitive competition and you know this is so there is a case for today. You know you could have profitable open source, you can perform a business based on open source models.

But if you think that this economy is on life support and something else is coming, well then the whole thing changed. The whole paradigm, changing changes and you can put open space at the core of that economy. So then you say, OK, open source is what will be the mainstream innovation model and everything else would be would be based on that and the world would be a network and it's based on transparency and sharing and this is how you see all the blockchain and Web 3 development right.

Everything is based on open source and on transparency.

If you think about a peer-to-peer society and open source is the mode of innovation meaning we innovate together in a collaborative way. A lot of things get shared, or everything gets shared and remixed. So you have a free flow of ideas and technology right.

Do you think some industries or economies find it easier to adapt to peer-to-peer and open-source?

So it happens first where it's easiest. OK, so it happens in the technology space in the information space and the media. And then the financial system, because it's [peer-to-peer] easy because it's cheap because it's low cost because it can be easily adapted.

This peer-to-peer society was made possible by information technology, by digital technology and so the first ones that understood the power [of peer-to-peer] were programmers. So they started with the free software movement.

I think that they're all getting now touched and what makes it accelerating is the doll is the creation of these organizations based on blockchain.

Software, hardware, pharmaceutical, energy.

Do you think circularity and the closure of loops is inherent in a peer-to-peer economy, and how do you see those two things influencing each other.

I don't think they are linked. I think it's just a coincidence and, well, not actually a coincidence, but… There is nothing in the principles of peer-to-peer that talk about circularity.

Networks are better at capturing new opportunities and translating them into something real, and also networks are better than firms at allocation of resources. Meaning if you have some materials they will be put into good use. If you have some people with certain skills, they will be put into good use. There's no waste or misallocation of resources, which happens a lot in corporations because there is one manager that decides which project to fund and how many people to put on it and who you put on that project and who do you put on another project.

So in an open source development there is better allocation because you have mostly self allocation. And because everything is shared, you can combine things to make new things. But even if you know that you can combine X&Y to do something new, you cannot do it because you don't have access to it because you don't have the intellectual property or because you don't have the know-how.

But there's an environmentalist movement, a movement of scarcity and says we are on a very small finite planet and we have to learn how to do more with less.
That is an external constraint put on the on the peer-to-peer economy to say, OK, you figure out how to do stuff with networks.

You know people that are in the circular economy usually share these values of openness, transparency, collaboration with people in the economy so they become easily friends and they can work together and put these principles into the same organization but there is nothing fundamental. Peer-to-peer can run without the circular.

And in fact if you look at it from an expansionistic economy point of view that is saying you think the world is small and we're dying? Well, let's just get out of here. Let's just create new worlds, right?

So we don't know how peer-to-peer is gonna go. Is it gonna follow expansionism where we're not thinking in terms of scarcity anymore. But we're thinking about in terms of abundance in the universe. Or are we gonna stay with the environmentalist logic of scarcity.

So they either come closer together or peer-to-peer will not care about circularity. If we get into this expansionist abundance meat.

There is growing interest towards open source and the number of places which are adopting peer-to-peer concepts such as transparency, openness, etc. Where do you think we are right now [in terms of growing interest]?

I think the economics is on the side of peer-to-peer. And open-source is part of that. It's a more complex economy that can deal with complexity. We see complexity really manifesting itself.

OK. Because when we leave in a small country, we can actually organize it mechanically, like a machine with the government in bureaucracies and all that, right?

Fast and fast so. So this is a very complex problem and what they tried to do during the COVID it's again mechanical or shut the valve here. Open the valve there. You know I'm saying it's like no that's not how you deal with the complex problem. You know it's not by shutting off here and because you because by shutting off here and closing here yes you're beds in hospitals. But you're creating, but people are suiciding at home, you know. And people, people with cancer cannot go to the doctor and so on and so forth. So we create so many other problems that. So you try to save 100 lives and you create 1000 deaths.
These are examples of complex problems that do not have bureaucratic or mechanical solutions. OK, and what happens is that peer-to-peer is a more complex system that is able to deal with complexity.

This is what we see today: the tendency to recentralization and oversimplification of society because they've got more complex and the and the and the bureaucracy is just losing it. So the natural reaction to sale save itself is to is to go back to a simplified social state which goes to centralization and control. So this is what opposes the peer-to-peer

We can all live in a small bubble, using less and living in harmony. OK, but we can also leave, but we can also use peer-to-peer to colonize other planets. it's good. And it's complex. It's dealing with complexity.

Peer-to-peer still doesn't possess the resources. Because the majority of the existing resources are locked into traditional institutions.

We are right in the middle of a chaotic period. It's a critical moment in a transition. This is it and we're in the thick of it. This is probably gonna take another five years.

But peer-to-peer is more than just an idea. It's more than just a prototype, it has 10 years of solid implementation and development

So if everybody would play good and nobody would be anti human, let's say it would happen for sure. It would happen for sure. In my opinion we see all the signs for that.

With Sensorica with the community the main barrier to adoption is cultural. It's not even economical. Yeah, people are coming to the lab and they don't understand the peer-to-peer open and transparent paradigm.

Because they have been moulded within institutions where they have to watch out for competition among employees. So you're the guy in the next cubicle wants your job. Once your salary, once a higher salary and you wants to make you look bad so they look good so you know. So so people that come within this environment of sensorial where we say you're not open it up.

Share as soon as you start writing, don't worry about your grammar mistakes. Don't worry about your poor ideas. Other people were gonna write on top of you and it's gonna be nice. And you're gonna experience some nice communion with people, and it's gonna be amazing. But no, people, people are shy to do that. People are afraid to do that. That's cultural. That's a cultural imprint of capitalism in them. It's in their system, it's fear. They feel shy. They feel, they feel insecure. They feel that to get naked in front of everybody, so to speak, when you expose your vulnerabilities, when you share your document early, right. You know you have to be open to constructive criticism. Constructive criticism doesn't mean to say oohh you're stupid.

And how do you become prosperous as an individual in an open environment? Is not by coming out on top and working on people's head, it's on the country where she people in front of you so they can pull you with them.

So I think you know the worst enemy that that we have in this transition is culture. It is to have people experience something new and it takes two to three years for somebody that comes to Sensorica to really get comfortable and not make the awkward mistakes.

So what we do have experience in Africa, we have projects and also in Middle East

They haven't soaked. They haven't marinated a lot too much in in the capital is the economy because they have the rural life, let's say.

Well, they do have, which is incompatible with peer-to-peer is the tribal mentality and culture. The blind respect to authority which is very good in that environment. But in peer-to-peer economy, [that role is]distributed across the network through some individuals that share that role of vision, leadership and all that. We talk about the wisdom of network, not the wisdom of the elderly in the village.

So culture is a biggie. One is a big one and it, you know, people have to soak in this environment and understand the logic, the grammar of that and the why. Why are we seeing you guys work? Why are you guys using these tools? Well because these tools enable us to share by default

But what are the characteristics of a culture that makes it compatible with peer-to-peer, right?

You cannot go faster than the culture and the pace of adoption of peer-to-peer is cultural. It's cultural adaptation.

OK. And I would, I would even say that it goes, it goes with generational change, so, so there is. So there is a there's a demographic component there, OK we need we need the generation of 2020 20 years olds and less we need the we need the young ones of today to kind of come to the age of responsibility and power in order to have full transition. OK, because they are more native over digital world.

Uh and then? Then people in my generation, right, that that have to jump from capitalism to peer-to-peer and they need they. They need years to get accustomed. It's like you migrating, you have that experience when you immigrate. You don't even know how to buy a public transportation ticket. And you have to read the local signalization and you make these awkward mistakes; like when you go to a house you are going to kiss people on the cheek or look at me in the eyes, or what are you gonna? So people know you're a stranger. Even after three years in my OSH company I know people who are strangers to this culture.

OSHE2 Technical Transcript

Background

I don't see myself as a typical Brazilian. I was always travelling in my childhood, I have a very nomadic vein from my childhood.

My life has been so that I'm always on the fringes of system changes. I try hard to have a conventional life, but it just hasn't happened.

I was never a technology-driven guy, but I was and still am very attracted by it. So even when the term nerd didn't exist… [I was a part of the nerds].

In a country that was coming out of a dictatorship, thinking of a whole process of redemocratising it. Privacy was not an issue. Brazil was, and it still is, in various ways, a huge favela. A slum. Everybody lives with everybody. So you have a very collaborative and sharing culture, in a sense.

[Over time and through experiences] I really became someone that was very aware of not only technology, but cultural differences between different social worlds and different realities. And how technology can relate to it.

I live in the fringes of system and cultural changes.

In the 2000s I discovered the peer2peer paradigm, with Michel Bouwens. I discovered complexity studies, from Santa Fe institute. And I didn't know I was a net-weaver, or a commoner. But with time I saw myself as those.

But in the 80s and 90s I tried to live a very conventional life. I spent maybe 14 years of my life trying to be a marketing consultant.

Question about how OS links to P2P, how they influence each other, and how we can enable system changes

Since we became sedentary species, and more sedentary species. Because we still have this migrates movement going all over the planet, but basically, we became a sedentary species. We had the time to create things that didn't exist when we were nomads. Like time. Time didn't exist as nomads.

And in these 2 million years of our existence, we really didn't have the concept of time. And we discovered things like fire. And when you look at anthropological research and archeological research it's amazing to see how collaborative we were with fire.

When we were living with Neanderthals, there was all sorts of collaborations. Interspecies. This is peer2peer.

When it came to sustaining the fire. We knew that fire was vital, not only to cook things, but at night, we are very fragile, and we needed the fire to not be eaten by animals. And this itself gives you a hint, of how to think peer2peer.

Cause when you look at the peer2peer paradigm, how it's being conceived, it's very related to the organisational paradigm.

And the organisational paradigm is very related to see our species as a sedentary species. Because as a sedentary species we became territorialists. We started to invent imaginary lines saying this is mine this is yours. As a sedentary species, we started to perceive as more important to regulate our relationships, rather than flowing interactively. That's why we came up with social contracts. Well first of all we invented time. And with the invention of time, we invented the measure of time, and then with this we invented how to do best for our survival.

When we didn't have this thing we call time, we were going with the flow of the stations, with the daylight, the moonlight. We were entangled with this type of 'time'. And we weren't really worried about being productive. Because we were in this land, and we needed to explore the land, where we lived, where we had our culture, our roots.

Time, with this dynamics of being territorial, created the necessity to automise, or to be productive. The concept of production, is a derivation, is a consequence of us inventing this thing called time.

And when we were nomads, we were observed by other species. But when we started looking around, when we started observing other species. We created mythologies, we created religions, something that didn't exist for us as nomads. We start to create our own world. And when we start to create our own world, and not in conjunction with the natural world, is when we have the basic toolkit of what we call civilisation. And that basic toolkit, that we call civilisation, has some aspects of peer2peer, but it's not peer2peer in its complexity.

When we created this time, we started to systematise our relationship with others, with the land, and with nature. And when we started to systematise it, we lost totally the connection with complexity itself. We became our own thing.

The very concept of something private, in historical terms is very recent.

When we conceptualise with these sedentary civilisations, what we call society, what we called initially a tribe, a community and then we called it a society. We were already thriving through the "organisational paradigm". We created hierarchies, we created centers of power, through religion, we created economy; we created everything that is still the basics of our society as we know it. So in this peer2peer itself was captured by this organisational paradigm, and systematised as co-ops.

When you come to this peer2peer paradigms, you inevitably come to talking about coops, or webplatforms. Always talking about something that is systematised. Something that is bottom up or top down dynamics, but once more, it's related to the organisational paradigm.

At the end of the 2000s, starting of the 2010s, I was very critical about that. Like, did we really forget how complex we are. How P2P is so related to complexity? How complexity is an emergent phenomenon?

So I started to do a lot of exploration, and not research, because I was living this, to see if we still have this intrinsic, very imbedded instinctive or intuitive peer2peer dynamic within us and inbetween us. Where you don't predesign, or preorder, in a participatory because participation is a social peer2peer technology, but participation is pre-desgined. You pre-design when you can speak, when you can vote, when you can sing, so participation is very organisational, and interaction is very emergent, very complex. So when we are interacting we are becoming mutually speaking, in terms of empathy, we are becoming pregnant. We are going to conceive a child, and we are going to conceive something that is going to alter you and going to alter me. And this dynamic, is complex driven, and it's not systematised. It has emergent properties. And this emergence, is the real peer2peer dynamic.

Because when you look at nature, nature is at its essence, p2p and emergent. It's complex, interdependent. All sorts of phenomenon emerges here and dies there. And it's always making a regenerative move. And life itself is regenerative in its p2p, and its always giving birth to new possibilities, to new potentials. It's in a constant change.

When I look at the works that David Boyler has been doing, Michel Bouwer, Silke from the commons transition, etc. they are still extremely based on the organisational paradigm. And it's like you don't have the possibility to think P2P if you're not setting up a co=op let's say, or a web p2p platform. So even when you look at the Fediverse (federation verse of p2p), they still have this very organisational layer to it – who is going to do this, who is going to do that. You're treating the fediverse as a group of enterprises or endeavours, p2p endeavours, not as something co-created, emergent.

The relationship between open source and patents is not a symbiotic one. It's a parasite one. It's a very extractive relationship. It doesn't nurture. It only extracts what it needs.

I feel like we are living a very very complex civilisation collapse like we've never had before. And the pandemic, gave us a taste of it. That was sufficient for tens of millions of people to be bothered. But not in the scale of the billions.

Going back to normal became something that everybody was seeking to do. Huge amounts of people were seeking to do accelerated network DAO.

When we talk about the way that we're going to still exist as societies in 10 yrs, 15y rs, 20 yrs, or even 5 yrs. I never put it in the macro scale. I never work in the macro scale. Why? Because we had a whole century dedicated to it. The 20th century was dedicated by, where the future was dictated by the nation state.

In the 19th century 18th century, the monarchies and all sorts of imperial kingdoms, they were not really concerned about the future. Yes, the king or theemperor was concerned about his future or his legacy, but there was never really the concern of people as a whole. So this is a trait from the 20th century, when nation states are very preoccupied by its own nation state future, and the geopolitical chessboard of cold war and hot war…

So we had a whole century to play with this nation state futurism, where this very fragile, what people call bureaucracy, made some impression. Made some stance to the nation state logic.

The nationstates need the constant fabrications of enemy. Where the war is its natural state. I'm saying this because where is peer2peer in this dynamic, where is open source? Well, it's kind of a mixed bag. First of all, it's captured by the organisational paradigm as we talked about earlier. The second thing, is that open source was not really something that was open-source per se, because the concept itself was created in the academy, in the university realm. It was not created by the people, for the people, with the people. If you talk to any common folk around you, if you ask them what is open source, they won't have a clue about it. It's not something that was culturally appropriated by social worlds at large. But historically speaking if you critically look at how the open source occurs in different social worlds, in different societies, you're going to see that it comes out of this natural way for us to collaborate and adapt in a very interactive way. Everything that we collaborate and interact on to satisfy whatever needs or challenges we have, you can collaborate open-source.

So you see it's not only related to technology itself, like software, or hardware.

Here in brazil for instance, you have sugar cane. And you don't have a market for the machinery to extract the liquid of the sugarcane. Folks here, they create all sorts of machinery in a very open hardware dynamic, but no one calls it open hardware. And you still don't have a machine that you can go to the market and buy it, to extract the sugar from the sugarcane. So I'm saying this for you to understand that in this whole collapse that we're living in, we're rediscovering a lot of things. We're rediscovering how we're able to collaborate and adapt, and to come up with creative solutions that doesn't depend on hiperconsumerist market where you need the money to buy things.

We're rediscovering ourselves as prosumers, not only as consumer. And this rediscovering of ourselves as prosumers, is very peer2peer. Even where I live here, it've very P2P.

I'll give you a very concrete example from the village I live in. People here are very private, they have their own cars, their own life, things like that. But when it comes to something that happens to the whole village, let's say the water supply for example. If there is a problem with the water supply here, in this village, people just offer themselves to collaborate.

If it was in the United States or Europe, they would see if there is a plummer to do the job and contract. But what is happening here, and this happened just last week; people come out and look at each other, and ask "what is happening", and "oh I think there is a problem with the water supply", "ah okay let's take a look at it" , and someone says "I have something I can put here", and "I have something I can put there". And in less than

an hour, it was done deal, it was resolved. With the resources that people had, in their houses, or as idle resources that they don't use. And it was resolved. And this is P2P, this is collaborative, and it happens in a very micro dynamic.

So, what I'm saying is, when it comes to thinking ourselves in the midst of this huge complex collapse that we're living, we're rediscovering peer2peer in a very trivial and complex way. Without the need of activists talking about peer2peer, or talking about the commons. Because people are naturally peer2peer.

It's millennials talking, and living by hierarchies. Not only talking about monarchies, or empires, but also republics, so-called democratic republics, I'm talking about nation states, where hierarchy is also. And in a way, it's become "natural" for us to deal with hierarchies.

Yes, nature has its natural hierarchies, but it's not something that is systematised, that is power driven, like you want to control it. It's different, it's an emergent characteristic of nature. When it comes to nature, you have these patterns of organisation. And you have these modes of regulations. When you talk about patterns of organisation we're talking about centralised, decentralised and distributed. When you talk about modes of regulation, we're talking about horizontal modes, vertical modes and transitional modes. And nature does all of that at the same time.

The underlying characteristic of nature is distribution.

For nature, centralisation is not a constant thing. It occurs here and there. That's the difference.

We have the very wrong understanding of nature. I'm not only talking about the understanding that Francis bacon and Descartes did 300 yrs ago that nature is mechanical, it's linear. Yea it's about that too, but it's not about that only. I'm saying that we tend to think that nature is peaceful, but it's not. We tend to think that nature is constant, but it's not. And it's a paradox. Because we put it on the horizon as something to reach out to, to become. Oh we want to become this very constant thing, this very peaceful thing that nature is. But nature's nothing of that.

The way that we conceived our existence as a society, that needs the constant of infrastructures, of even superstructures, to make the society as we are function. Like a mechanical being, like something very mechanical. A closed-source system. The problem with the societies that we became, is that we thought these societies could be closed-source. But it can't. It's not a motor. When you study cybernetics, you understand the difference between a closed source system and an open-source system.

A closed-source nation state cannot exist.

When I'm thinking about peer2peer, when I'm thinking about opensource, when I'm thinking of this nation satet logicv that we live within, we're not talking about revolution. We're not talking about the left rising to power, or the right. I'm not talking about this binary ridiculous thing that we call politics nowadays. I'm talking about something that is related to one of the scientists I most respect, who was very critisised in academy in her days. I'm talking about lynn margulis. For her life doesn't evolve by itself. Life coevolutes. She came out of the concept of symbiosis. Which is very peer2peer.

As we are rediscovering that we can generate in a very network way micro narratives that has the power as little hyphas to generate different kinds of outcomes. We can deal with the evolution of life itself.

This might sound ridiculous because we are so conditioned to think of the future, and thinking of resources for the future, and maintaining the status-quo of what we call life. But for me, we are already changing, the future is already happening right now.

We can feel it in our guts that the way we conceived society as a whole, is not functioning, it's not working. We are already going to our roots, to our nomadic roots, and we are already seeing ourselves as adaptive, aggregative, collaborative. And we're doing what life itself does: we are regenerating ourselves, but we're not aware of it. We're not aware that we are already doing this, because we are still captured by the macronarrative

of this nation state. We're still captured by here and when. Still captured by this endless war, by this bipolar society, this binary thing of left and right. But when you look at the potential of the intrinsic, complex, analogue driven dynamic dynamic that is ingrained in all of us, we are already cocreating, and living the future in our present, without being aware of it. And when we realise, it gives us a sense of 'beingness', a sense of 'beingness' that we lost. And we are literally making these connections without being aware of it. And that's the crazy part of it.

For me, the possibility for us to feel or to be more aware of what is happening to us right now as a species, is through this micronarrative. But it's not a broadcasting micronarrative. It's an intertwined micronarrative. It's a mutual micronarrative, so what you and me are cocreating right now. Like the double helix of DNA, we are cocreating a double helix of micronarrative that is going to be sufficient to sustain the energy between you and me, even if we're no longer connected, we're going to revisit it.

What I'm saying is I opened some fissures in me, and you open some fissures in you, and we're not aware of it. But this mutual interactive, even via this screen here, zoom, we were able to generate something together; this double helix micronarrative. And that double helix, like a hypha within a huge fungi, it has the power to entangle with another micronarrative, with a different type of narrative. And for me, it's this complexity doing P2P dynamic that generates mutual double helix micronarratives that intertwines with others, that is literally the machinery of our coevolution happening right here, right now. And that's crazy I know.

We are storytellers. I wouldn't say that we're homosapiens, we're homo narrativus. Something like that. So we need to cocreate stories together. So the relationship you have with your partner is a story that you and him are cocreating, a micronarrative that you and him are cocreating. And something of that is more intimate, that is between you and him, but something is more open-source, so it can intertwine with other micronarratives that are coming from other places, other people, other social worlds. So, this is the way that we are already co-evoluting. We are already reconnecting with complex nature, without the need to manifest for it, or to generate a huge planning to change the micronarrative of the huge country, and things like that.

Becoming aware of that is an incommensurable sensation. I deal with it each day. Because it's literally the source of life itself. And we are connecting with it, without being aware that we are reconnecting. Because the way we conceive reality is collapsing, it's not sustainable.

OSHE3 Technical Transcript

BACKGROUND RESEARCH THEY DID

We applied blockchain technology to build a peer2peer energy trading market.

We were thinking how can we apply blockchain and smart contracts specifically to this domain. And I realised after a lot of discussion that the problem we have is not really on the blockchain layer, or the peer2peer layer. It's more on the market layer. In the sense that we have different households that consume energy with different patterns; during the night they require more, or less, depending on their needs. So the biggest part of this paper we worked on is this market mechanism. Where we are using a decentralised algorithm, it proceeds in rounds; every 15 min households involved in this particular neighborhood all have a smart-meter, and then we compute the allocation of energy and resources, that would lead to the highest social welfare. Everyone is as satisfied as possible.

End-colony optimisation – distributed algorithm for automisation, inspired by ants and how they collaborate in nature.

We use blockchain to store the results of the computation.

ENERGY

Energy doesn't work that way [like cryptocurrency], you only contribute to the grid. You put energy on the grid, and no-one knows where it ends up. That's one thing that makes this domain much different from traditional blockchain. And I think this is also a pitfall to many people trying to apply blockchain to energy.

Fully decentralised means there is no single centralised party involved.

Smart-grids are, by definition, a grid, they're decentralised. They rely less on these centralised producers of energy.

The energy grid is not ready, we're still relying on traditional infrastructure.

I've always worked on lightweight systems. It means that not much research usage is required to make sure the system is operational and works.

I see that a lot actually with blockchain for example (Ethereum, bitcoin), they're very wasteful, very heavy. But that kind of heaviness is not required for a system to operate. With much more lightweight ledgers.

OPEN SOURCE

We've been developing our own software called tribler, and we've been developing it for 15-17 years now. And it's peer-to-peer and you can use it to download torrents. And it's always been open-source.

From a personal background, I've always been very interested in reverse engineering, not necessarily on the hardware side but on the software side.

If we don't use open hardware, what will happen is the hardware stack will be taken over by a Chinese or American vendor, as you see right now, and we will all be locked in into their ecosystem. And if we want to move away from that, it will be very very difficult.

We're in academia. The partners you're talking to are more aligned in industry.

Our lab has a profound focus on the common good. We have this idealistic vision of having things that can be used by anyone, that are free to use. And that's the root of our lab.

Working for the common good is basically where we are working on.

We're getting back to that era in the sense that we're seeing a large fragmentation of all these streaming services, and videos.

Things with energy trading are very much aligned with this idea too [common good].

The master switch – explains how decentralisation and centralisation works. And what you usually see, is there is a new technology, and it starts out as an open infrastructure, that everyone can use [gave the example of the radio], and then people start capitalising and centralising the technology, and then it's monopolised, and then people start to complain, so it's broken open, and the cycle starts again.

And I think the internet is heading to a centralised closed, walled garden idea, that apple and google. It is in the process of closing up. Peer-to-peer is the counter force. Is it successful? I don't know.

Peer2peer always needs to have benefits: people want convenience. And big tech companies like apple and google bring convenience. That's why people keep using them.

There needs to be an intrinsic benefit of using these kinds of technologies. And I think that dependence on centralised parties, people are more aware now that this is a dangerous assumption to make, with the privacy scandals that we see, and other developments.

I believe that open software should go alongside open hardware. It brings convenience [open hardware]. It reduces the barriers to entry. If you have one party that says what you should do it's easier to avoid mistakes, and to be fair, I believe the whole open hardware ocosystem is a bit of a mess right now.

BARRIERS

I think interoperability, is a very challenging thing, and something that has a lot of focus from the research community.

The more different types of open hardware there is, the more interoperability is going to be an issue.

The more choices does not always mean better. Best example is the power outlet – you need a different kind of adapter everyone.

It's a bit of a double-edged sword – big tech companies being the first to capitalise on new innovations and being the ones building new standards.

Do you want the people to decide on your protocols? I'm not sure if you would fully democratise this decision process, I'm not sure it would work either. It would probably need to be a sort of hybrid system.

You have to start a movement with these kinds of things, and we're trying a little bit with peer2peer. And I would say that from an industry perspective it's not taken seriously at all.

Autonomy should always be with the end-user.

OSHE4 Technical Transcript

Background

I studied renewable energies and started working in the field of wind turbines. At first a small wind turbines with a capacity of 15 kilowatts and then also that was my professional work too, in Germany it's like called income work or the translation that gives me money and on the site since 2016 I'm a member of the Ernie Wind Turbine Collective.

And we are focusing on education, specifically on small wind turbines and off grid systems. And the site also renewable energies in general.

And for this purpose, we use small wind turbine manual, which is written by XXX. And he started to design this small wind turbines in 1970s -80s.

He created this manual and sold it on the Internet and you can buy it for a couple of EUR. I think 7 euro's or something.

And with our initiative we always of course try to focus on open source. We try to use 100% just open source tools for our software, for our back office, for our communication, for everything we do.

After I finished university, I also realised that all the software that I was using before now cost a lot of money per year, so I also there switched from Matlab, first to Octave and from Octave now to Python, and from inventor to free CAD. And yeah, which is also like. It's difficult at the beginning, but I think it's definitely worth it you can share with everybody and just send a link for the software and the file and they can open with the software.

We tried with the small wind turbine and got a little funding from university where they funded us for six months and they offered like we could use one office and they paid three people. This time we used to look for bigger funding like in Germany, it's called exist. It's like a funding from the government for two years for three people and you get like mainly the cost for the people and little money for hardware that is always a problem with like prototyping and hardware that you also need money to have a workshop to have to buy tools to buy hardware.

The guy who checked our proposal was a patent lawyer or a former patent lawyer, so he didn't really get the concept at all, and so we didn't get any further. Then we tried some proposals to other accelerators and stuff and got a little money here and there.

But then yeah, we just stopped and just did it like on the site, and everybody just focused more on their jobs to have an income.

Now in Germany, there's an open knowledge foundation and they have an open prototype fund for software since several years, which is regularly funded by the government and is a success. And they have this year for the first time a prototype fund for hardware as well and we applied there and got the funding for the documentation of our wind turbine that we developed so far, and that's what we are currently doing.

We are with a two-person team now on it working one to two days per week. We are using our own GitLab on our server and have a git repository there.

Documentation on an open source licence online, quite often you can't access it; if you want to change it further, develop it. It's sometimes difficult because the files themselves used will need the property software.

So, no one of us is working full time on that. We all have our jobs in different fields of renewable energy from wind turbine, solar to like energy efficient housing.

Next week in Germany there's a kick off meeting for the open-source Alliance for everybody who's in open source hardware unites there. Then there's a new project started which is called open Tool Chain Foundation, which is reviewing what people need via a survey.

It takes the idea of every open source hardware and what they need. Most of it needs open source software to produce the hardware so they are focusing on open source tool chains. Software for one specific type of work, but looks like if someone wants to produce a certain kind of hardware, what tool do they need and can this tools already talk to the others? Can I import it from this format to this format?

I think it’s super important because in an industry they always have the number of software for what they use.

There’s a lot of movement in Dublin and open source ecology, and Germany. I’m hoping to just be paid to work in this field so that it's not just like meetings at night and all that stuff. That’d be really cool.

About the documentation they are doing

And their aim [another OSH project] is to have a written PDF because they are not familiar with Git and all the techie stuff. So they will have the PDF in Word and some pictures, or some sketches on how to build it.

Back then with Ernie, we didn't focus that much on open source, it was more on the small wind turbine and the plants that already existed and of course, because it is an educational project. When we went to universities and teach like that as our normal way of making money that the university books us. We give one week course on how to build a wind turbine. So that wasn't so much focus on open source back then, although we just used always open-source tools because we wanted, but the hardware and the plans we used for our work weren't open source.

But now I'm also like there's a head. There's a roof Organisation for all the DY small wind turbine which is called wind empowerment.

Challenges in OSH you have experienced or know about

Not being able to participate like seeing an error but not knowing how to how to post an issue or how to take part in further developing it so this is something that I really see as a big challenge and which would need to be overcome. And we as the open source community would need to have like regular Git courses once a month so that you don't need to wait for an opportunity to Start learning it.

Just to make it simpler and so people are not frustrated. Because Git is a quite big tool and we all have our projects and we are already tired with our projects and we can't afford to put like hours and hours of work extra work into just like side tools.

So that is, I think, a really big challenge I guess. Also, for a lot of people that was also in the meetings we had with the other groups from the Open Prototype fund hardware that I think we are maybe the only team, or there's one more team that really uses Git.

And any other software, like any other open source software, when it's not like immature software yet. I think Blender for example is a good example for being very well developed and having matured and a lot of videos online. A lot of people using it, but a lot of open source software is not there yet, and then for free CAD. For example it was tiring, it was a tough process to enter.

I think compared to software projects where you don't need extra things, like a workshop and tools to build something you have, you need. You need the laptop and a person and a house and an Internet connection. And the Internet connection is already there most of the time. The house is already there, the laptop's already there. The person just needs to put time in.

So I think that's why it's there are much, much more open software projects.

And I yeah, make good money with my knowledge already in my normal working life. Then of course if I also have fun with my job, I just sit down for a weekend and do something and then create something. And I think with hardware the difference is that it’s just a much more complex product. You need the software to design the hardware, then you need to create the hardware you are often also dependent on other companies, and whatever buying bearings, buying whatever? And you yeah then need to test whether this works for you. Not everything can be simulated.

I guess for the software code you can like run it. If it doesn't work, you cheque something, if it still doesn't work. You still have some bugs, but you can fix it at the place you don't need to buy hardware. Build a prototype, test it, realise okay. This is not working by new hardware. Do a new iteration cycle and so I think yeah we or for us saying.

Like the decision of more or less stopping was because it was clear that it’s just too big project. Like we can't just do it like one day a week because in one day a week I just managed at the evening to be at the same point where it was last week because I need to be to commit time and for testing for buying different types and different Hardware items to check.

The thing that I think are beneficial of open source hardware is that it can be further developed by a community and customised for certain sites or if like a certain in this area, this material is more common or easier to get than this can be adjusted and documented. And the second part is of course repairing things.

Which if, the part gets broken, and you, it's spurned, but you can still read its R1, or even you just know the position, then you just cheque the documentation and know just need to know by this little part, which is of course with other companies not possible or with proprietary hardware.

And the third part is recyclability that you have if you have a good documentation online, you know okay this is made out of this glass and this would. And this metal and so you know how to disassemble it.

The fourth is, and it's not directly linked to open source, but most open source projects also focus on a thing. How thing is designed, and that is designed in a repairable way.

The thing with the energy transition is like with our product with the small wind turbine. I don't really see a big impact I see it as a niche and because it is a niche, I think it's much more important that it is open source and that it is developed to become the very best wind turbine in the community and that failures and errors are shared and that currently like small one turbine manufacturers come and go. A person who buys one this year and who wants to have a spare part next year, but the company might not be there anymore.

How do you see OS influencing the energy transition?

Open source could have a really big impact on the energy transition if open source. The meta anymore or I see a lot of projects or how you how you mentioned at the beginning that we all do it because of idealism and sometimes through this big motivation by pure idealism, we forget the aims or the needs in the real world. And for example, that's why when I first saw your product, I thought that is awesome. If this works and if they really manage to, it's a product that is needed worldwide.

And it's not like wind turbine are difficult to deploy.

And that's the thing with Open Source, we can create more products that we really need in the world. That would be my dream, and specifically to energy transition.

Yeah, also fought of looking for that doesn't have to do anything with energy transition, but I thought of looking for the most used hardware item and just building it open source like a cattle or something like a kitchen device. Something that just everybody buys every year or every two years and just yeah.

Any suggestions for OSH to further grow?

I think that has like various layers as I'm an engineer and more working in like the small. World or not, like the big big picture policy world.

This software tools that took me in the last years a lot of time to try like I don't know how many. Mathematical little software tools and little cut tools or electrical documentation tools. I try it and I was at some time so tired of looking another YouTube video or reading another documentation on how this tool works. So I just from this really practical side so I'm super happy now that I.

Have free CAD as a tool and I think that won't change in the future. I think that is the most mature open source software tool when it comes to cut software and this will like it.

And then when it comes to electrical documentation, I would recommend QElectroTech. Which is for like not PC's like, not the little boards. But if you want to have like solar arrays off grid system, how cables run in electric, how electric cables run in the house. All this stuff like bigger electrical installations.

So and when it comes to calculating stuff or combining text and mathematical stuff, I use Python and Jupiter notebook.

When it comes to then for core, of course for PC's and staff key cut, but I'm not that much of an electronics guy so I'm not using that much. If you want to get funding and have nice rendered images, Blender of course.

So that you don't run around downloading things wasting time with trying different softwares and that would be my recommendation. Like if you're really in the engineering on the small level. And yeah of course like I mean big level we policymakers.

Whereas not supported anymore or stuff like this or everything which is not supported anymore, or where the companies don't exist anymore. That all this stuff need to go open source and then you can like society and humanity learns something of it. Otherwise we keep on doing the same mistakes again, because maybe next time.

Another company comes around and thinks it's a good idea and invests, thinking yes let's try and it was done.

Five years ago, but never put never published because it didn't work.

Yeah, that would be on the small scale and bigger scale.

OSHI Technical Transcript

BACKGROUND

[company] was started by a gentleman named Fabio de Pascale. OK. So Fabio is a space engineer by background and has been working in energy access for more than 10 to 15 years, right. I think he started his journey sometime in 2009 or 2010 and he has been one of the culprits as well. Right? So when and when he started his journey and the energy access space, you know, he actually started his company and named Evergy in Tanzania, where they were, where they were giving access to clean energy, using the lightweight mini grids or DC based mini grids.

At that time, you know, there were many companies in the sector, you know, in the solar space, not particularly the mini grid, but a lot of the other solar home systems company. They were all trying to do a lot of the background technology stuff.

All of them are doing the same background technology stuff and at one point, you know, they realize that all of them are actually trying to reinvent the wheel of something which is not really a USP of them, right. It is required for their business, but it is not these background infrastructure technologies that they are not defining their core business right. But they're important they are.

And result of which all of them were actually spending their limited resources, financial and as well as human capital resources in developing these technologies innovations.

And had I had these innovations been available open source, they would have actually, you know, saved those. You know, those investments in these technologies and instead would have invested in in the spaces which are more relevant to them because one thing is for sure, which is, you know, in the energy access phase, the companies are always struggling with the financial resources, right. They're both financial and as well as human capital.

Sometimes we'll lot of most of them were creating this not because they wanted to create it, but also nobody knew that somebody else is using the same thing, that there wasn't any knowledge sharing happening, result of which everybody was just creating all these solutions for themselves, which are replication and result of which you know the.

Be a Fabio decided as he got further down the line and he was engaging with the one of the donors and they were talking about the key challenges which are faced in this and this was that you know how often many of the actors end up reinventing the wheel purely sometimes not knowing.

Right. And that was the genesis of creating an access. Is that OK? How can we save companies I can? How can we help companies in investing their resources in the places which will make more sense like which gives them the more return instead of in the R&D which it can be created by one company and being available to the others. We'll have a more returns that was the genesis of next coming in right. So Fabio having.

Being in that place, done that live, that that OK, if we really want the sector to move forward, what are the some As some of the specific things where we can make that done and the reality is you will always have this.

Comment coming in: Ohh there aren't enough funding or financial excesses and all those are limited, so I hope I answered your question.

OK, the global S is a largely focusing while depending on the whether you're in the low income country or middle income country or high income country, right, the high income countries are now focusing on energy transition, wherein low and middle income countries are focusing on energy access because large part of their population is still without energy.

Right. They don't have access to the basic energy services, right? So we have always worked in the energy access space because we focus on low and middle income countries where this is. So instead of having that energy services being available through the coal or through you know the fossil fuel focus you know.

And often there is a limitation right, the low and middle income countries cannot have the energy services same way as the global N got it.

Yeah, and decentralized and urge decentralize or renewable energy has a huge role to play in providing basic energy access right. And that's why that's the reason we focus on energy access. So our work focuses largely on low and middle income countries in low and middle income countries are large population do not have the access to the energy and that's why we focus on an energy access and we do see that how some core innovations being open innovations can really help in expediting that work. So we the way we look at it is that OK.

Yeah. So often that's why these are some core technologies which are required to bring together the overall product and may not be the core product.

The rest the reciprocate or you will say the acceptance of open source. First of all open source is highly linked to only software. So people only understand open source as software. Most companies and stakeholders or actors in the energy access space really don't understand how open source.

How open innovation I it fits in the energy access space and I think their biggest one, so lack of awareness and lack of understanding what is open innovation. That's a bigger thing. And the second question that they often understand is how can you how can you be? They really don't have any understanding on the commercial. Can you be still be commercially viable and being an open innovation?

Reception of OS Funding

We are doing a lot of the work on in terms of awareness and the advocacy and how open information can fit in easily, fits in the current scheme of things, and how it is still possible for commerce companies to be commercially viable with the open innovation.

So well, as I said that open innovation open source is often taken as a free or associated only with the software. So that's the that's the work that we are doing beyond just funding, right?

The thing is that again it depends on the product that they are open sourcing. If it is let's say one can open when we say an open source. You largely open source that design of it, right?

But then companies can still come to you for manufacturing of that, depending on what. So I don't think it's possible for me to have a one fit answer for this kind of a thing. You know people can always open source a base design and then some additionality aspect of it can always be delivered as premium services.

And this is the model that most companies you know [do]. This is what Spotify did. Spotify said their core mission was always to provide access.

Freedom to access of for any music anywhere for what they in order to have a viable, sustainable business model. What they did is they allowed people to actually start creating their own personal list, or they have their access to the other people's list. Now these kind of additional services then they premiumize it.

The open source design is a part of it, but it's not possible for every small company to do the production side of it. If you are a large enough company, you could take the manufacturing side of it.

Right. You could provide the consulting services for people who want to adopt this kind of a solution, right? So there are lots of potential possibilities for anyone to look at the commercial aspect, how to commercialize your open innovation.

Additional services, yeah, because depending on look, The thing is, this is the thing. If you as a company has all the in-house resources and you can like many companies, there are many software, they say we give you the base access, you can develop on anything of that because reality is.

Any development that you create it needs a resources, so somebody has to feed on. Somebody has to cover for those resources to development, right?

So and hence in order to cover that, you put a a bill to it, right? I have seen, you know, many companies actually provide access to the data so that the challenge is often not on the access to the data, but it can be. It is about what you inference from there. So if you are a company which had the really in-house resource, you could do with whatever, but often the realities and many of the smaller companies don't have.

Many, many of the smaller companies don't have the access to everything, right? They don't have a in house resource and that's where they would actually, you know, they would actually go for the premium services, right. Whether the analytics side of it or rather the consulting side of it, right. So when I say a premiumize it where you can add the premium version for the analytics side of it, right.

The Energy Transition

The Linux Foundation energy, is actually playing a key role in stakeholder mobilization.

The reality is the energy transition is a massive and a mammoth task. If each company is going to try to do it themselves at their level, it's not gonna be possible. And that's where they are really pulling together the resources. By bringing people together, because in the energy transition space, a lot of the work which is going in making the grid smart.

And that's where you know the software has a big role to play.

Now making it open source you are able to actually pull together the resources of different nature of different strength, right? And it's that's why I said you should really check out the work on the allergy page where they are working together with different companies who bring a different strengths in in leveraging the role of a software open source softwares in building smart grids in moving the utilities to the smart grid space.

And especially in the energy transition, it's the same which is being leveraged now in the immobility space, right? So instead of just creating that, can we have a smart TV infrastructure by instead of 1 company which is gonna be trying to create it, it's gonna take forever and will take a lot of resources, right? But instead, you know, different companies are pulling together and creating these open source infrastructures which can then be leveraged by different companies.

And then can be continuously being updated by these companies, right? One of the one of the strength of open sources that you have, you don't have a one brain, but you have one hundreds of brain working together in continuously improving that.

Like every day somebody is challenging the other person for the betterment and for the improvement.

The transition is really depending a lot on the open source and I think the beauty of open source is collaboration and the community.

Circularity

Well, before open source hardware comes in. I think these things need to be looked at the design level because that's where you are able to actually really bring the circularity aspect right, because otherwise you are really looking at post- fix.

And I think it's definitely one should look at again, it has to be, I would say simply, it has to be looked from a product-to-product point of view. And I wouldn't say a simple blanket approach will be possible at some times you know.

Depending on who's bringing the value or the investing in and, they would have to have an A close source product. We are very clear about this that we don't say that there is, it's an either-or approach. No, there is a role for both kind of innovations, open source and closed source. So depending on you know what is a strength you as a company bring in in that through that product that decides whether you are able to do open source or you know a close source.

And you can see that actually dope in Union is and European Commission is now investing heavily on open source, open data you know.

There are a couple of organizations which are in the forefront of making sure that even on the policy side, how it is an open.

These policies, the that the public has an access to these policies and all that. So what all I kind of struggling to remember the exact name of the those organization for all I can say that is that.

Even at the EU level, there is a lot of focus in bringing this transparency to the open source approach.

A background to the role of open source in the overall ways of working at a different aspects of the you know our day-to-day life, our business and the way we engage in the in the society.

OSSHR Technical Transcript

Umm, can I ask what? What faculty or what program are you are studying? Because we have this program that is called open firm Academy and we work a lot with academics and I have to say like I was just very excited when you reached out. To me there's a lot of PHD's, a lot of master students that work on the topic of open source and open technologies in the US not that many in Europe that we know of. So I'm very happy that you reached out to us and yeah, I'm just curious who you are doing it with. Like what programmer.

In Europe, I don't know how long it's been going on, but because I did most of the research for this study like in 2020, 2020 was basically the year when we were doing this stuff. And I see that there is a rise in these things happening.

Do you do anything on standardization in your work?

I mean we do a lot of work on standardization. Like throughout the years and we've been around for over 20 years and the little changed and also just like.

It seems like a lot of standardization is moving to the open source space and then we just have to factory standards. I actually had the chat last week with a lady who's working on open EV chargers.

It's open charger alliance. They're working on standardizing because they have this open standard for every chargers and they have problems with actually mandating it in Europe. But this is the most used standard in the US and South Korea, and in a couple of other countries, and they have problems with implementing in Europe because the European Commission wants an ISO standard.

And they can't get it done so far.

I've been at work for like 4 years now. I'm not a technical person. And funnily enough, I'm not a political science person. I did my masters in new Media and communications. Uh, so we were basically researching the impact of social media and technologies on peoples lives, which is very nice, which I do at alpha as well, but very much from the from the openness angle. And as I said on open hardware like, I'm just very interested in it. Personally. We haven't had a chance to work on this much more than in the study for the European Commission.

Umm, I got quite in touch with uh, with many open source hardware researchers and now I'm working on open silicon, which is a bit different.

Basically, chip production. It's a very complicated ecosystem, especially during COVID resource supply chains shortages and like a lot of issues, a lot of money at stake. The European Commission put a lot of money now into implementing, just like having European chips and strengthening the European chips industry.

And there is something called open silicon, which is basically an open infrastructure instruction set for creating these chips. So kind of an open design for a chip.

And there is a lot of governance, a lot of projects that are around it. The most common one is risk 5.

Umm, they have a foundation so they kind of work like open source software. They have a foundation for the project, kind of like. Umm, I could compare it to Linux for open silicon.

So yeah, I'm working on this now and the more hardware space, but this is, I would say it's in between open source software and hardware and very much a separate topic on of its own and on open source hardware. Yeah, I worked mostly for the on this study. What is interesting is even the fact that the European Commission requested to have open hardware included there because it was basically the first time that policymakers wanted to know more about open source hardware.

So the European Commission first thought that open hardware is mostly 3D printing. That's a pity. But over the course of the study, we worked with them quite closely. We invited many researchers, we had a working group on open source hardware and we quite established that this is not true. And of course, it's especially interesting for research.

Before our call I took a look at the kind of recent things that I received, so here I sent you a policy position, equitable research capacity towards the sustainable development goals. The case for open size hardware and this Julietta she's leading this. There are these monthly meetups on open science hardware.

In this group there is also this really cool researcher, Joshua Pierce.

He’s doing a really, really good job. And from my more policy perspective, we usually need numbers, and he has very good numbers.

Question: When you were doing the research for the European Commission, you mentioned a lack of awareness/understanding even about open source. Apart from with policymakers, did you identify this as a hurdle anywhere else?

Umm, so I would very much make a distinction between hardware and software.

We are based in Brussels. We work a lot with the Commission a lot through the Parliament. There is much more awareness on the open source software.

Uh, but there is also very much dedicated initiatives in the European Commission - so an open source program office. It’s quite a small one, but they do have one.

Umm there's, you know, there is the open source observatory. There's there's a lot of initiatives that are explicitly talking about open source software, which also is more relevant to an institution such as the European Commission, but also in the Member States. As such, if you talk about the government, open source software is much more relevant.

When you talk about hardware, it's much more relevant for research for academia, but indeed there was this very much, I would say, archaic notion that open source hardware is 3D printing. Umm, I think 3D printing is great, but it's not going to change the world in the broader sense, in my opinion.

Umm it can help many people, many companies.

But it's not as vital, especially for digital infrastructure. Is that the that our governments, the largest companies, cloud providers are using.

When it comes to what should we do? There is a lot to be done and what I discovered was that there was basically no research, no papers that included open source hardware and policy in the same paper.

So that was a very big challenge for us and we identified only a couple of people who were able to speak about it with us. It's basically only a couple of people.

And then silicon is a very separate area where there is quite some experts on that, but they specialize on this. So, I would say there are these like 3 separate divisions.

And recommendations for those are very different because in software we are very much more advanced. It's much easier for us to propose recommendations such as I know tax breaks for open source software development.

Such as favoring open source software in public procurement. Governments are huge buyers of software. It really worked in France. There is a lot of research on that. So no, these are like much more operational things, especially on the wave of the whole digital serenity motif that has been going on for, I would say the last three years.

We are very much fans of technological independence. I feel that this term is much more grounded in what we actually mean, and this can be used for diverse purposes by different political parties and political actors.

Umm. And we are very much as an organization and as individuals more towards the vendor neutrality and more principle- based procurement and just you know choosing how to develop your digital infrastructure when it comes to open-source hardware.

What I think is the most crucial is just more research, and especially like if we want policymakers to realize.

That this is actually important and yeah, there is startups like you startup. We we had some contacts with startups that are doing open hardware, but not that much. The European Commission loves Assamese and there is no open source hardware SMEs in the same alliance. There is no Horizon projects that are talking about open source hardware.

So this is something that from my very much Brussels-based perspective I can say when it comes to science and research. There are people who can say more about it and you know from the more pragmatic perspective.

Umm, but I believe it just like also about the explicit saying that open-source hardware is for example part of open science policies.

And this is something that Julieta wrote in this paper and I very much agree on this because we worked, you know, here and there and like generally open science. And it's rare that open hardware is a part of it, like explicitly.

Question: I want to know how you think open source hardware might influence or be used also for the global S because we're you focus on a lot on the global north and that's really European.

Point of view, in my research I see that there is very little that talks about the global South and how it can enable the transition in the global South and and I'd be curious to see if you have any experiences with that or any thoughts on that.

Yep, that's very interesting because when I was doing research on hardware, I saw that, uh, open source hardware was just like is very useful in many applications that in Europe we don't necessarily need. So like you just buy a product, right? And I remember there was this workshop at the European Commission got three years ago on open source software and hardware and there was this researcher who was talking about users of open hardware for researchers in Central Africa, I don't remember the details right now, but like it was, it was fascinating. Just, you know, like having these open designs allow them to conduct research, on a much tighter budget and with the same effectiveness. So like that, that was, that was really cool.

What is interesting, we are a very European very global North organization, but we have been working with the US for a long time like just different organizations from the US.

Umm, of course on software, but in the last year or two there is a big, big uptake of initiatives on open source software and digital public goods and digital Commons globally.

It's very much driven by many foundations, charities, so, you know, like think of a billionaire found, founded foundations and they are doing these global initiatives on connecting people in different countries, especially in the global South.

To use the same open source projects and designs and designs now projects, mostly software and this is something that I'm always asking them guys. Are you thinking of hardware as well?

They're not at this step, just like any kind of like, more high level, more policy, more, you know, broad strokes initiative.

Umm, but I hope it's going to to join in there. This is something that I would that I would like to see. I haven't necessarily seen the the results of this more global cooperation on open source software because it's happening right now, especially for example in the in the space of digital payments of open wallets and stuff like that.

Umm, but this is like very much a machine that is already running and I feel like it could be it could be a blueprint for open hardware.

Question: The movement is very much coming from an approach of the global North.

Like digital colonisation?

Question: [laugh] I wasn't sure how to phrase it. So I'm just curious what your thoughts are on that?

Yeah, there are different initiatives. I'm quite critical of the whole, you know, like we we've seen that a lot that especially European and American companies had these, you know, charitable initiatives that were theoretically open and nice. And actually it was just a way of hijacking the market.

But in the initiatives that are happening right now, I see two types. One is this more that I'm a bit careful about.

Umm, but for example there is this initiative called code develop and they're working on connecting different governments from the global South on digital payments, but it's mostly run by the Government of India and by Indian companies with the solutions that are actually using that they're actually implementing. Umm, so it's led by them and supported with the with the American money.

But the project is very much under the governance of India.

Umm, there is some initiatives that are very much European and American companies led and I'm very critical of them like I've I think it could have some short term positive impact, but as such it's not fully ethical to me.

But that's very much a personal opinion.

Now it's also the reason why we focus so much on Europe, to be honest, because we are happy to work with people from outside of Europe, but we just we know about Europe, we, you know like this is this is you know like we come from different European countries on Polish for example. So you know we still have different perspectives and we still share them and create something and we are very much open to the people from outside of Europe and in the last year it has been happening more and more but yeah.

I don't want to go to African countries and tell them what to do, like that's not OK.

Explanation of interviewer's work in OSH (beyond thesis)

I have a lot of ideas but they are very long term ideas. You know, it's more like for example, setting up an open source hardware Business Association, however stupid it sounds. But in Brussels everybody's represented like there is a kidney association here, like there's there is a potato Europe. It's a big organization, when you think about it. And we actually have to set up open source software Business Association. And now, even though it's not a big association, it's not super active. But there is a stakeholder.

The European Commission is always like we have to ask these people, they know what they are talking about.

Umm, so you know that's a very long term thing that I believe should be found funded by some kind of a foundation or something.

Umm. And you know, bring some just like, cool companies, not even like, the biggest success stories, but like people who are actually working on this and to speak, to speak up on this research and open source hardware business models.

I don't like I'm. I'm curious about like a lot of materials that you're probably using both in your work and in your in your thesis.

Because I see that just having a well stamped piece of research is very helpful, and having a number a couple of numbers that are speaking.

Like: Going open source for this company allowed them to speed up their developments, allow them to exchange information with this Research Institute on the other side of the world.

What you're doing, and you know, like that's a that's a good thing and all the good luck in staying open. And from many, many conversations, I know it's not that easy always. And we are, as I said like we are not purists on open source but it's it's nice to feel open source literally for the innovation sake which I care about as a person working for not-for-profit.

[goodbye and thanks comments]

P2PA Technical Transcript

Background research

We applied blockchain technology to build a peer2peer energy trading market.

We were thinking how can we apply blockchain and smart contracts specifically to this domain. And I realised after a lot of discussion that the problem we have is not really on the blockchain layer, or the peer2peer layer. It's more on the market layer. In the sense that we have different households that consume energy with different patterns; during the night they require more, or less, depending on their needs. So the biggest part of this paper we worked on is this market mechanism. Where we are using a decentralised algorithm, it proceeds in rounds; every 15 min households involved in this particular neighborhood all have a smart-meter, and then we compute the allocation of energy and resources, that would lead to the highest social welfare. Everyone is as satisfied as possible.

End-colony optimisation – distributed algorithm for automisation, inspired by ants and how they collaborate in nature.

We use blockchain to store the results of the computation.

Energy

Energy doesn't work that way [like cryptocurrency], you only contribute to the grid. You put energy on the grid, and no-one knows where it ends up. That's one thing that makes this domain much different from traditional blockchain. And I think this is also a pitfall to many people trying to apply blockchain to energy.

Fully decentralised means there is no single centralised party involved.

Smart-grids are, by definition, a grid, they're decentralised. They rely less on these centralised producers of energy.

The energy grid is not ready, we're still relying on traditional infrastructure.

I've always worked on lightweight systems. It means that not much research usage is required to make sure the system is operational and works.

I see that a lot actually with blockchain for example (Ethereum, bitcoin), they're very wasteful, very heavy. But that kind of heaviness is not required for a system to operate. With much more lightweight ledgers.

Open-Source

We've been developing our own software called tribler, and we've been developing it for 15-17 years now. And it's peer-to-peer and you can use it to download torrents. And it's always been open-source.

From a personal background, I've always been very interested in reverse engineering, not necessarily on the hardware side but on the software side.

If we don't use open hardware, what will happen is the hardware stack will be taken over by a Chinese or American vendor, as you see right now, and we will all be locked in into their ecosystem. And if we want to move away from that, it will be very very difficult.

We're in academia. The partners you're talking to are more aligned in industry.

Our lab has a profound focus on the common good. We have this idealistic vision of having things that can be used by anyone, that are free to use. And that's the root of our lab.

Working for the common good is basically where we are working on.

We're getting back to that era in the sense that we're seeing a large fragmentation of all these streaming services, and videos.

Things with energy trading are very much aligned with this idea too [common good].

The master switch – explains how decentralisation and centralisation works. And what you usually see, is there is a new technology, and it starts out as an open infrastructure, that everyone can use [gave the example of the radio], and then people start capitalising and centralising the technology, and then it's monopolised, and then people start to complain, so it's broken open, and the cycle starts again.

And I think the internet is heading to a centralised closed, walled garden idea, that apple and google. It is in the process of closing up. Peer-to-peer is the counter force. Is it successful? I don't know.

Peer2peer always needs to have benefits: people want convenience. And big tech companies like apple and google bring convenience. That's why people keep using them.

There needs to be an intrinsic benefit of using these kinds of technologies. And I think that dependence on centralised parties, people are more aware now that this is a dangerous assumption to make, with the privacy scandals that we see, and other developments.

I believe that open software should go alongside open hardware. It brings convenience [open hardware]. It reduces the barriers to entry. If you have one party that says what you should do it's easier to avoid mistakes, and to be fair, I believe the whole open hardware ocosystem is a bit of a mess right now.

Barriers

I think interoperability, is a very challenging thing, and something that has a lot of focus from the research community.

The more different types of open hardware there is, the more interoperability is going to be an issue.

The more choices does not always mean better. Best example is the power outlet – you need a different kind of adapter everyone.

It's a bit of a double-edged sword – big tech companies being the first to capitalise on new innovations and being the ones building new standards.

Do you want the people to decide on your protocols? I'm not sure if you would fully democratise this decision process, I'm not sure it would work either. It would probably need to be a sort of hybrid system.

You have to start a movement with these kinds of things, and we're trying a little bit with peer2peer. And I would say that from an industry perspective it's not taken seriously at all.

Autonomy should always be with the end-user.

REE Technical Transcript

Background

We are a semi government organisation. So, we are a foundation but we are funded by this government. And our purpose is to accelerate innovation in the Netherlands. We do that by increasing the collaboration between companies or universities.

My function is programme manager. And that means specifically that I'm responsible for the innovation programme that focuses on renewable electricity, which is consisting of solar energy and wind energy, and specifically inland.

Question: How do you see future developments in solar?

I would break that down in three parts. I would break it down in technology development; In implementation; and in production, so if I shortly focus on the on the three, starting with technology development; I see there are a few robust trends from the past that I think will continue. The trends are lower cost and higher efficiency, so it's the basic trends that we have seen so far and there are still some room for efficiency improvement in the current generation modules. But we, the world is nearing the limits, so I expect shift to tender modules within the next couple of years. A lot of companies are trying to do this.

I think that the silicon perovskite tandem module will be the next breakthrough in the market. Though it's guesswork, because there are still challenges regarding lifetime reliability and stuff, so it's not a given that it what will happen, but there's so much money and like thought power, being spent on it. I think it will happen.

And I think at the same time, cost reductions will take place. There's a lot of room for improvement there still.

And then a new trend that's coming up is… How do you say? See you could call it circularity. Or you could call it CO2 footprint or there are a number of ways to call it, but I think we will see a trend and lowering of the environmental impact of of the production and I think that development will we be strongest in Europe.

I think because Europe has the most strongly developed framework for Environmental Protection and impact. So those are the trends that I've foreseen in the near future.

Then second, on implementation. I think in every country in the world, we are going to see a big boom of solar. It's already happening in many countries and it will continue.

There will be places where solar will not be the biggest source of energy. For example, in Western Europe, wind energy is very favourable, but I think the prediction that solar energy will be the biggest source of energy in the world. I think it's going to be true. So we will see increasing solar implementation everywhere.

And then on production. Production is now centred in Asia, mainly China, and it is very recently that it is being regarded as a strategically risk. So, you see that the power blocks of this world. So the United States, the European Union, but also India for example. They are all setting up programmes to have a new or renewed PV industry.

I think that it's terrible that forced labour is in this production chain. However, I do not think that's the biggest contribution to reduction costs. Because the cost dropped by 90%, so a factor of 10 in the last 10 years. So the major breakthroughs in cost reduction is upscaling. It's reduced losses.

That being said, the same technology production in US or Europe will be more expensive. Very recently, there was a report from McKinsey on the global PV or the other at the European reshoring, and I think they say if we do exactly the same, what they're doing in China, we will be 25% more expensive.

So that's a fact. So, there are a couple of ways Europe, or the US could have support mechanisms. For example, this inflation reduction act in the United States is doing exactly this. It's big support for producing in the United States. So, I think in the United States they now have the framework to overcome this cost difference already. Europe is still working on that.

But it could also be innovation. So if Europe is first in this new generation of products, then you could have this competitive edge. I don't think we should be too naive that we will outpace the Chinese, or once it's done in Europe, that it will not be copied to China.

I think yeah, the main solution for this reshoring will be support mechanisms.

So at this moment solar is, in for example Western Europe not yet so cheap that it's the cheapest source of energy.

I mean there are still subsidy mechanisms in place, for Netherlands you have this large as the scheme.

And so that means you are competing with all sources of energy. And there are parts of the world where solar is cheapest, so you could wonder why it should be lower cost, because we are the cheapest source of energy. In fact, it has become cheaper than it ever was. So, let's focus on other product characteristics like sustainability.

I think in the end you have this competition with other sources of energy.

As long as it's there, I think cost reduction is favourable for the uptake of solar and on the long run. I mean it doesn't have to be. That becomes cheaper and cheaper so.

I mean, the Western world has been paying for years and years, around 50euros per MW hour of electricity. Solar can definitely beat that.

If you want to go further in sustainability, so if you want to phase out oil, for example, a feedstocks. Then you have your green electricity as a source, then you have all kinds of commercial losses.

There will be harder to push this for the future of the market. But in the end we can.

Maybe we are now spending 3 or 4% of global GDP on energy and can we have a sustainable society where we spend 6% of GDP on energy? Probably we can. So, it's not a big deal. In fact, I think I've read a report of XX. It's this large consulting company where they said that when we have done the transition properly, probably our GDP part we spend on energy is probably lower than before the transition, so that is an interesting thought. So we are going to a cheaper system and yet we have to take this one hurdle.

APPLYING OPEN SOURCE TO THE ENERGY TRANSITION

I think [success] depends on what part of the value chain you're in. If you can be successful or not because the production part and mainly the start of the production part, so it's the silicon mining. It's the furnaces, there you have huge economy of scale. I mean, even if you are open source these this has to be done by big. Well, I call them companies, but by big organisations.

You get this working, so I think open source there. I think it will be very hard to have an open source model for that kind of development.

Further down the value chain, if you are in the integration or installation parts. I think it's very applicable, so do it yourself solar installation is already being done. Many parts there is a [possibility]

And so there I think it can be applicable and I know where that you are looking to recycling or reuse, refurbishing, and I think it can be applicable there. The hard thing there is that if something is recyclable or refurbishable depends on how it was produced in the 1st place. So, if you don't have this open source model there, it's going to be hard to have it in the end of life stage also.

These are some of the hurdles I see in this industry. And economies of scales they matter a lot and so getting big does make the production more efficient.

I don't see any fundamental restraints to [open source becoming big]. However the startup-scaleup phase will be hard because you start small and you have to become big.

And in general that happens with capital that happens with venture capital. I think venture capital and open source business models are poor combination. So I think there you need to look to do crowdfunding or philanthropy, and for scaling up I wonder if that can happen.

That's why software start-ups are so interesting for investors: your CapEx, your capital expenditures are low. So you need a team of smart people to get something working and so you can keep everything for yourself and then you get rich or you share it. It's open source and the world profits.

With a hardware production, you need to start with, a lot of equipment, machinery, stuff. So, you need to invest a lot of money before you can start profiting, so there's a very different economic model. Like I think there are only a few sources of funding that can make this work.

I think the funding needs to come from investors that share this ideal. So either you find one that's very rich, so like it's philanthropist, or you find many that support this or that. That will be crowdfunding.

So that will be my main question: where is this open source model applied successfully? On hardware products?

Yeah, so then let me so these producers of Arduino are companies in general.

You are talking about open source, but many technology developing companies for solar are trying or already doing a licence model so they've developed the technology and they licence this to other factories. This seems to work, so I think the licence model where in fact you have revenues flowing back to the technology owner. So then I wonder why Open source.

You have the challenge too. First you need to develop this technology so you have to spend money but the licence model can alleviate this high CapEx expenditure on these machinery.

So maybe that could be an interesting comparison. If you look at successful companies that successful licence their technology in in solar industry and I think there have been examples.
And then you could see how to and what is the difference between a licence model and an open source model. I think it's not even that big, in fact.

The thing is still the idea of this: licencing companies. OK with the revenue from the licence firstly that is why investors in the modern company or fund the company are interested, because they think that with this licence, I can earn back my investment.

But let's say you don't have an investor that wants his investment back in manifold. And then the revenues also enabled the original company to keep innovating. And that's also a risk. So if your funds dry up then maybe you have lunch at technology but you run the risk of like of that you have like it's a dying technology because you are not providing innovation anymore.

So I think those are two reasons why differences between the licencing model and an open source I think.

It's not impossible [open source innovation]. Because I know one disadvantage of the licencing model is that the daughter companies that are using the technology, they don't really have an incentive to innovate themselves because they basically get: this is how to produce. And in fact probably they are not allowed to add to the technology. So that's something, that's a force that you could use in an open source approach.

RER Technical Transcript

Background
I Did my PhD in Canada. And I joined NREL three years ago first as a postdoc.

And I worked on, and still am working on a lot with modeling human behaviors, but little bit less.

Question: what research are you asking funding for?

At first, doing some literature review about recycling processes. And then trying to figure out which would be the best recycling process to kind of push in the US.

And then optimization models. That would look at where we should put those recycling facilities, accounting for transportation costs and things like that because. The US is huge in as soon as you start transporting things, it can drive up your costs a lot and then it might be a barrier for PV owners to opt for recycling PV at the end of life.

And the third part would be to improve the spatial resolution of the PV model we have because we had some assumptions we used that were not really great.

That would be the first phase, and in the second phase, it would be about implementing a pilot scale recycling process somewhere.

Open-Source and availability of information you produce

Most of the codes that we're developing are publicly available. I don't know if they are open source, but anybody can use them most of the time.

Question: By public you mean it's on the internet?

It's on the GitHub.

We publish most of what we write. It's in a journal article and when we have the money we make it Open Access. If we don't, you know, it's still available for like libraries and stuff.

Most of the output from this potential research would be made public. The only thing is that for phase two [of the research we might be doing], if there is a pilot scale recycling process that is developed, I'm sure that at first it's going to be kept private, and maybe there's a patent that's going to be signed.

And I don't know exactly how much information will be made public.

I have a senior researcher in the PV EIA and he works in collaboration with researchers in Australia, in Europe all about PV recycling. So there is like a big Research Center in France, and some of the folks there are studying recycling as well, so he's working with them.

But a lot of the research regarding PV recycling in Europe is actually not made public. And when we try to find data [it's not possible].

Regarding suggestions for overcoming barriers to circularity and the energy transition

I would say trust, if you want to have circular systems. A very simple example is industrial symbiosis. You cannot do any industrial symbiosis if you're not gonna trust your partners. And if you're not gonna exchange, you know, some information, some data.

And even like right from the get go, if you want, if you want to use some byproduct from a company, you need to know how uch they're gonna, how much they're gonna produce, right. So you need to have access to that information. Uh, you need to trust that.

Umm. And also for us researcher. Like when you try to model recycling like end of life in general it's very hard to find data. So we don't even know how much PVs we use right now. We don't really know how much spin recycle. We just try to guess from whatever we can gather. So yeah, that's pretty important.

Suggestions for a more sustainable/circular system

At least for us researcher, there would be great to have more data on end of life.

And if you want a circular economy to actually work, you have to rethink how companies are gonna work together. I guess my suggestion would be, you know start from scratch.

You need more collaboration between companies, which is not necessarily what is happening.

Thoughts on open-source hardware:

It was a success in software engineering, right? If they succeeded, then my first reaction would be like, why wouldn't it work for hardware and like PV.

I guess you have to look at the conditions, the context, how it happened and tried to recreate those condition. I mean not exactly the same but like trying to identify what would be the the right condition for PV.

So probably some of those conditions will be the same, but maybe some will be different.

Recycling in the industry

I really like the idea of a Bill of material. If the recycler would have like a little card, I think they would help them tremendously.
That's what some of the recyclers that we interviewed that was one of the biggest problems that they have like different PV model that don't contain the same materials so they sometimes can't really apply this in processes.

They can't really do that anymore [repair solar panels] because the PV's are there was back in the time the quality of the panels were pretty good. They could do some basic repairs and it would still function. But now, panels are pretty cheap quality and so usually when it's broken, you can't really do anything with it anymore.

So, they have like 3 separate bins. One goes to landfill; one they recycle. But the recycling process is very, very basic: they take out the aluminium frame and then they just burn the whole thing in an incinerator to give some energy.

And the third bin is whatever they can sell back on the on secondary market.

The problem is it's too expensive, so they could actually repair if they wanted to, but it just too expensive compared to the value that they they would sell it on secondary markets

But they have the techniques, they have the knowledge for a lot of repairs. But it doesn't make sense economically.

Appendix 4 Coded Transcripts

	Interviewee	Abbreviated representation name	Location	Gender	Expertise description
Entrepreneurs	OSH Entrepreneur 1	*OSHE1*	*US*	M	An entrepreneur living and originating from the US, who has been working in the field of OSH for three decades. He has developed his own OSH company that is considered highly successful due to its financial stability, project developments, and social work.
	OSH Entrepreneur 2	*OSHE2*	*Brasil*	M	An entrepreneur living and originating from Brazil. He has been working in the field of OSH for two decades. He is passionately involved in many active projects including OSH product developments and OSH-related teaching.
	OSH entrepreneur and Renewable Energy Engineer	*OSHE3*	*Germany*	M	A renewable energy engineer that has been working in the field of wind energy for nearly a decade, and joined an OSH project turned cooperative, developing wind turbines in Germany. He is currently one of two heads for the cooperative and is working on it part-time.
	OSH entrepreneur 4	*OSH4.*	*US*	M	An OSH enthusiast who experienced a change in career path in the past few years and became an entrepreneur after being exposed to a large OSH company in the US. Since then, he has been working on various OSH projects and on doing research to help guide an OSH transition.
Academics	Renewable Energy Researcher	*RER*	*US*	M	A French researcher working at the National Renewable Energy Lab in the US. He has published papers on solar recycling, LCA and circular economy.
	Open Source Software and Hardware researcher	*Int.OSSHR*	*Belgium*	F	A researcher and strategic director at one of the leading institutions in Europe for open source. She has been working on the topic of open source for 4 years and co-authored an important paper by and for the European Commission on the topic of OSSH.
	Peer-to-peer academic	*P2P Aca.*	*Netherlands*	M	An academic from the Netherlands who has been working on P2P and blockchain technology for a decade at the Technical Universiteit Delft. He has published various
Aca					OSSH.
	Peer-to-peer academic	*P2P Aca.*	*Netherlands*	M	An academic from the Netherlands who has been working on P2P and blockchain technology for a decade at the Technical Universiteit Delft. He has published various papers, including one on P2P, blockchain and the energy transition.
Renewable Energy Field	Renewable Energy Expert	*REE*	*Netherlands*	M	A project manager at a semi-government organisation based in the Netherlands. He previously extensively worked in the field of solar cell technology, and his company is working on accelerating innovation by enabling funding and collaboration between companies and research institutes. The department he leads focuses on the energy transition and renewable electricity.
	Renewable Energy Researcher	*RER*	*US*	M	A French researcher working at the National Renewable Energy Lab in the US. He has published papers on solar recycling, LCA and circular economy.
	Peer-to-peer academic	*P2P Aca.*	*Netherlands*	M	An academic from the Netherlands who has been working on P2P and blockchain technology for a decade at the Technical Universiteit Delft. He has published various papers, including one on P2P, blockchain and the energy transition.
	OSH entrepreneur and Renewable Energy Engineer	*OSHE3*	*Germany*	M	A renewable energy engineer that has been working in the field of wind energy for nearly a decade, and joined an OSH project turned cooperative, developing wind turbines in Germany. He is currently one of two heads for the cooperative and is working on it part-time.
	OSH energy investor	*OSHI*	*US*	F	A head of operations at a large investing company based in the GN and investing in the GS. The company funds projects working on renewable energy access mainly across Africa.

Legend	Meaning
Colours	*Use in the thesis as quote*

	Tag		Who	Quote
2	Background		OSH4	I'm involved in a whole bunch of stuff. I have been involved with Sensorica since 2015.
3	Background		OSH4	And I started to fool around in the open-source movement business structures even before sensorica.
4	Background		OSH4	In 2014, I was helping this lady. She was a great salesman. She had this great business idea to to sell kombucha. But what she did was go and tell the clients how to make it themselves.
5	Background		OSHE1	After I finished my studies, I went to work in California for a laser Manufacturer. So my background is in physics. And this was an unusual laser company, because they were working on a specific type of laser that was very new and there were no applications for it. So it's like you invent the light bulb, but there is no flashlights for it.
6	Background		OSHE1	Although people might know about possible applications that were no applications developed, so my role in this company was a laser applications engineer, so I had to work with a bunch of Entrepreneurs. Companies, and Academic labs at different universities, to help them learn how to use this to help them discover what it is good for. And what they [developers and entrepreneurs] all had in common is that they all wanted to use this laser. So for example, some people were in dentists. So they wanted to see if this laser can clean teeth. Other people were like eye surgeons and they wanted to see if they can use this laser to do eye surgery. So they wanted to see if this laser, this new laser brings new, new features. OK, where new possibilities we were working with people doing photovoltaic cells and they wanted to use the laser to cut the glass.
7	Background		OSHE2	I don't see myself as a typical Brazilian. I was always travelling in my childhood, I have a very nomadic vein from my childhood.
8	Background		OSHE2	My life has been so that I'm always on the fringes of system changes. I try hard to have a conventional life, but it just hasn't happened.
9	Background		OSHE2	I was never a technology-driven guy, but I was and still am very attracted by it. So even when the term nerd didn't exist... [I was a part of the nerds].
10	Background		OSHE2	[Over time and through experiences] I really became someone that was very aware of not only technology, but cultural differences between different social worlds and different realities. And how technology can relate to it.
11	Background		OSHE2	I live in the fringes of system and cultural changes.
12	Background		OSHE2	In the 2000s I discovered the peer2peer paradigm, with Michel Bouwens. I discovered complexity studies, from Santa Fe institute. And I didn't know I was a net-weaver, or a commoner. But with time I saw myself as those.
13	Background		OSHE2	But in the 80s and 90s I tried to live a very conventional life. I spent maybe 14 years of my life trying to be a marketing consultant.
14	Background		OSHE3	I studied renewable energies and started working in the field of wind turbines. At first a small wind turbines with a capacity of 15 kilowatts and then also that was my professional work to, in Germany it's like called income work or the translation that gives me money and on the site since 2016 I'm a member of the Ernie Wind Turbine Collective.
15	Background		OSHE3	And we are focusing on education, specifically on small wind turbines and off grid systems. And the site also renewable energies in general.
16	Background		OSHE3	We are with a two-person team now on it working one to two days per week. We are using our own GitLab on our server and have a git repository there.

17		Background		OSHE3	So, no one of us is working full time on that. We all have our jobs in different fields of renewable energy from wind turbine, solar to like energy efficient housing.
18		Background		OSHE3	And for this purpose we use small wind turbine manual, which is written by you, Pickett. And he started to design this small wind turbines in 1970s -80s.
19		barrier		OSH4	I remember, I started to term the phrase social engineering and hackathons. And people were like: you guys are committing fraud.
20		barrier		OSH4	We all know the language among ourselves, but have to kind of step out [and see it from their perspective]. Well, collaboration is good and everybody collaborates at some level.
21		**barrier**		**OSH4**	**If you look at a Venn diagram, there's really no intersection between the open source community, the innovators, and the creators. And the people that have resources like financial resources and labs.**
22		barrier		OSH4	It's hard to mobilize people around the the same project, like how do you get people with the technical skills, and how do you get them compensated for their work.
23		barrier		OSH4	Like we got a grant from a professor. But he wants to see a continual process.
24		barrier		OSH4	So now like if you have a cooperative of solidarity, you have the clients that are part of it. Do you have the employees that are part of it and then you have the administrators that are in part of it so. That's the problem with open-source community, between partnerships and just like a client supplier. Sometimes you need a solid structure that people are going understand
25		Barrier		OSHE3	But then yeah, we just stopped and just did it like on the site, and everybody just focused more on their jobs to have an income.
26		Business Models		OSH4	And like she'd make it in their own kitchen, she'd supply the Scobie and everything. And so the customer knew exactly what went into the product.
27		Business Models		OSH4	And then she could offer to sell the kombucha to the customer. So Kombucha takes a couple weeks, and not everybody's gonna be able to do it on a regular basis. So sometimes it's best to actually buy it if you really like it. So I thought this was a great business idea. Very open, transparent people know exactly what they're getting and they could actually be involved. They could interact with you to change recipes.
28		Business Models		OSH4	I've met other people. Like this one man, he had a security company and he said pay me $100 an hour and I can set up your house. Or, I could give you the plans and sell you the parts and you could do it yourself.
29		Business Models		OSH4	[OS] opens up many avenues for customer interactions. And people can actually come back to you. It's hyper innovation. You get more eyes on the project.
30		Business Models		OSH4	I'm gonna share this technology with you because it'll help you clean up your organization, because the government is watching us. See, we have to get together to go through this.
31		Business Models		OSH4	It's very hard to have business models, but I think if we could change the language sometime to make somebody understand it, this could work.
32		Business Models		OSH4	And it's about [business]. Like, installing solar panels. They're good for 25 years, but that's a bad business.
33		Business Models		OSHE1	Even in a competitive market, if your market strategy is speed of innovation, then you don't have to [patent]. I mean, you know, there's always a compromise to do right.
34		Business Models		OSHE1	Instead of being a weakness because you're open and transparent so your competitors know what you do. How can you turn that into advantage to grow your innovation speed even further and leave them in the dust.
35		Business	P2P	OSHE1	That [peer-to-peer] runs on very different principles. So, all this talk about competitive competition and you know this is so there is a case for today. You know you could have profitable open source, you can perform a business based on open source models.
36		Business Models		OSHE3	He created this manual and sold it on the Internet and you can buy it for a couple of EUR. I think 7 euro's or something.
37		Business Models		OSHE3	And they have this year for the first time a prototype fund for hardware as well and we applied there and got the funding for the documentation of our wind turbine that we developed so far, and that's what we are currently doing.
38		Business Models		OSHE3	The thing with the energy transition is like with our product with the small wind turbine. I don't really see a big impact I see it as a niche and because it is a niche, I think it's much more important that it is open source and that it is developed to become the very best wind turbine in the community and that failures and errors are shared and that currently like small one turbine manufacturers come and go. A person who buys one this year and who wants to have a spare part next year, but the company might not be there anymore.
39		Circularity	P2P	OSHE1	I don't think they [circularity & P2P] are linked. I think it's just a coincidence and, well, not actually a coincidence, but... There is nothing in the principles of peer-to-peer that talk about circularity.
40		Circularity	P2P	OSHE1	Networks are better at capturing new opportunities and translating them into something real, and also networks are better than firms at allocation of resources. Meaning if you have some materials they will be put into good use. If you have some people with certain skills, they will be put into good use. There's no waste or misallocation of resources, which happens a lot in corporations because there is one manager that decides which project to fund and how many people to put on it and who you put on that project and who do you put on another project.
41		Circularity		OSHE1	You know people that are in the circular economy usually share these values of openness, transparency, collaboration with people in the economy so they become easily friends and they can work together and put these principles into the same organization but there is nothing fundamental. Peer-to-peer can run without the circular.
42		Circularity		OSHE3	Most open source projects also focus on how something is designed, and that it is designed in a repairable way.
43		Closed Source		OSHE1	So what happens here in the ecosystem is that you know it's private. It's business as usual. It's based on NDA and patenting.
44		Closed Source		OSHE1	And I knew about everybody else but nobody else knew what other people were doing. So I understood from the center of this ecosystem that if I could share information, I could accelerate their research and development. Maybe 10 fold, sometimes even 100 fold, because I knew that these other guys had some information that these guys were trying to develop or they had some expensive equipment that that these other guys need.
45		Closed Source		OSHE1	I saw a lot of unmatched needs and offers and some unused material that could be shared.
46		Closed Source		OSHE1	It felt very stupid. Like I thought that this system is highly inefficient. I felt like I was purposefully slowing it down by not telling people what I knew.
47		Closed Source		OSHE3	Documentation on an open source licence online, quite often you can't access it; if you want to change it further, develop it. It's sometimes difficult because the files themselves used will need the property software.
48		Culture		OSHE1	With Sensorica with the community the main barrier to adoption is cultural. It's not even economical. Yeah, people are coming to the lab and they don't understand the the peer-to-peer open and transparent paradigm.
49		Culture	Closed Source	OSHE1	Because they have been molded within institutions where they have to watch out for competition among employees. So you're the guy in the next cubicle wants your job. Once your salary, once a higher salary and you wants to make you look bad so they look good so you know. So so people that come within this environment of sensorial where we say you're not open it up.
50		Culture		OSHE1	So I think you know the worst enemy that we have in this transition is culture. It is to have people experience something new and it takes two to three years for somebody that comes to Sensorica to really get comfortable and not make the awkward mistakes.
51		Culture		OSHE1	They [individuals in Africa and Middle East] haven't soaked. They haven't marinated too much in the capitalism in the economy because they have the rural life, let's say.
52		Culture		OSHE1	Well, what they do have, which is incompatible with peer-to-peer is the tribal mentality and culture. The blind respect to authority which is very good in that environment. But in peer-to-peer economy, [that role is]distributed across the network through some individuals that share that role of vision, leadership and all that. We talk about the wisdom of network, not the wisdom of the elderly in the village.
53		Culture		OSHE1	So culture is a biggie. One is a big one and it, you know, people have to soak in this environment and understand the logic, the grammar of that and the why. Why are we seeing you guys work? Why are you guys using these tools? Well because these tools enable us to share by default
54		Culture		OSHE1	You cannot go faster than the culture and the pace of adoption of peer-to-peer is cultural. It's cultural adaptation.
55		Culture		OSHE1	OK. And I would, I would even say that it it goes, it goes with generational change. So there is a there's a demographic component there, we need the generation of the 2000s, the 20 years olds and less, we need the the young ones of today to come to the age of responsibility and power in order to have full transition. OK, because because they are more native over digital world.</n>
56		Culture		OSHE2	In a country that was coming out of a dictatorship, thinking of a whole process of redemocratising it. Privacy was not an issue. Brazil was, and it still is, in various ways, a huge favela. A slum. Everybody lives with everybody. So you have a very collaborative and sharing culture, in a sense.
57		Culture		OSHE2	Since we became sedentary species, and more sedentary species. Because we still have this migrates movement going all over the planet, but basically, we became a sedentary species. We had the time to create things that didn't exist when we were nomads. Like time. Time didn't exist as nomads.
58		Culture		OSHE2	And in these 2 million years of our existence, we really didn't have the concept of time. And we discovered things like fire. And when you look at anthropological research and archeological research it's amazing to see how collaborative we were with fire. When we were living with Neanderthals, there was all sorts of collaborations. Interspecies. This is peer2peer.

59		Culture		OSHE2	And the organisational paradigm is very related to see our species as a sedentary species. Because as a sedentary species we became territorialists. We started to invent imaginary lines saying this is mine this is yours. As a sedentary species, we started to perceive as more important to regulate our relationships, rather than flowing interactively. That's why we came up with social contracts. Well first of all we invented time. And with the invention of time, we invented the measure of time, and then with this we invented how to do best for our survival.
60		Culture		OSHE2	Time, with this dynamics of being territorial, created the necessity to automise, or to be productive. The concept of production, is a derivation, is a consequence of us inventing this thing called time.
61		Culture		OSHE2	So you see it's not only related to technology itself, like software, or hardware. Everything that we collaborate and interact on to satisfy whatever needs or challenges we have, you can collaborate open-source.
62		Culture		OSHE2	Here in brazil for instance, you have sugar cane. And you don't have a market for the machinery to extract the liquid of the sugarcane. Folks here, they create all sorts of machinery in a very open hardware dynamic, but no one calls it open hardware. And you still don't have a machine that you can go to the market and buy it, to extract the sugar from the sugarcane. So I'm saying this for you to understand that in this whole collapse that we're living in, we're rediscovering a lot of things. We're rediscovering how we're able to collaborat and adapt, and to come up with creative solutions that doesn't depend on hiperconsumerist market where you need the money to buy things.
63		Culture		OSHE2	It's millennials talking, and living by hierarchies. Not only talking about monarchies, or empires, but also republics, so-called democratic republics, I'm talking about nation states, where hierarchy is also. And in a way, it's become "natural" for us to deal with hierarchies. Yes, nature has its natural hierarchies, but it's not something that is systematised, that is power driven, like you want to control it. It's different, it's an emergent characteristic of nature. When it comes to nature, you have these patterns of organisation. And you have these modes of regulations. When you talk about patterns of organisation we're talking about centralised, decentralised and distributed. When you talk about modes of regulation, we're talking about horizontal modes, vertical modes and transitional modes. And nature does all of that at the same time.
64		Culture		OSHE2	We have the very wrong understanding of nature. I'm not only talking about the understanding that Francis bacon and Descartes did 300 yrs ago that nature is mechanical, it's linear. Yea it's about that too, but it's not about that only. I'm saying that we tend to think that nature is peaceful, but it's not. We tend to think that nature is constant, but it's not. And it's a paradox. Because we put it on the horizon as something to reach out to, to become. Oh we want to become this very constant thing, this very peaceful thing that nature is. But nature's nothing of that.
65		Culture		OSHE2	For me, the possibility for us to feel or to be more aware of what is happening to us right now as a species, is through this micronarrative. But it's not a broadcasting micronarrative. It's an intertwined micronarrative. It's a mutual micronarrative, so what you and me are cocreating right now. Like the double helix of DNA, we are cocreating a double helix of micronarrative that is going to be sufficient to sustain the energy between you and me, even if we're no longer connected, we're going to revisit it.
66		Culture		OSHE2	Even where I live here, it've very P2P. I'll give you a very concrete example from the village I live in. People here are very private, they have their own cars, their own life, things like that. But when it comes to something that happens to the whole village, let's say the water supply for example. If there is a problem with the water supply here, in this village, people just offer themselves to collaborate. If it was in the United States or Europe, they would see if there is a plummer to do the job and contract. But what is happening here, and this happened just last week; people come out and look at each other, and ask "what is happening", and "oh I think there is a problem with the water supply", "ah okay let's take a look at it" , and someone says "I have something I can put here", and "I have something I can put there". And in less than an hour, it was done deal, it was resolved. With the resources that people had, in their houses, or as idle resources that they don't use. And it was resolved. And this is P2P, this is collaborative, and it happens in a very micro dynamic.
67		Culture		OSHE3	Not being able to participate like seeing an error but not knowing how to how to post an issue or how to take part in further developing it so this is something that I really see as a big challenge and which would need to be overcome. And we as the open source community would need to have like regular Git courses once a month so that you don't need to wait for an opportunity to Start learning it.
68		Culture		OSHE3	Just to make it simpler and so people are not frustrated. Because Git is a quite big tool and we all have our projects and we are already tired with our projects and we can't afford to put like hours and hours of work extra work into just like side tools.
69		Culture		OSHE3	The meta anymore or I see a lot of projects or how you how you mentioned at the beginning that we all do it because of idealism and sometimes through this big motivation by pure idealism, we forget the aims or the needs in the real world. And for example, that's why when I first saw your product, I thought that is awesome. If this works and if they really manage to, it's a product that is needed worldwide.
70		Energy		OSHE3	Open source could have a really big impact on the energy transition.
71		Energy		OSHE3	And it's not like wind turbine is difficult to deploy.
72		Finance		OSHE3	We tried with the small wind turbine and got a little funding from university where they funded us for six months and they offered like we could use one office and they paid three people. This time we used to look for bigger funding like in Germany, it's called exist. It's like a funding from the government for two years for three people and you get like mainly the cost for the people and little money for hardware that is always a problem with like prototyping and hardware that you also need money to have a workshop to have to buy tools to buy hardware.
73		Finance		OSHE3	The guy who checked our proposal was a patent lawyer or a former patent lawyer, so he didn't really get the concept at all, and so we didn't get any further. Then we tried some proposals to other accelerators and stuff and got a little money here and there.
74		Finance		OSHE3	I'm hoping to just be paid to work in this field so that it's not just like meetings at night and all that stuff. That'd be really cool.
75		Finance		OSHE3	I think compared to software projects where you don't need extra things, like a workshop and tools to build something you have, you need. You need the laptop and a person and a house and an Internet connection. And the Internet connection is already there most of the time. The house is already there, the laptop's already there. The person just needs to put time in. So I think that's why it's there are much, much more open software projects.
76		OS		OSH4	That's my interest. And even with machines, back in 2014, 2013, I went to my [computer] and it was updating. It took me half an hour. I was late to a client because I didn't get the address I needed on my [computer]. So I don't control the machine, that's why I went into Linux.
77		OS	P2P	OSHE1	But if you think that this economy is on life support and something else is coming, well then the whole thing changed. The whole paradigm, changing changes and you can put open space at the core of that economy. So then you say, OK, open source is what will be the mainstream innovation model and everything else would be would be based on that and the world would be a network and it's based on transparency and sharing and this is how you see all the blockchain and Web 3 development right.
78		OS		OSHE1	Software, hardware, pharmaceutical, energy.
79		OS	P2P	OSHE1	So in an open source development there is better allocation because you have mostly self allocation. And because everything is shared, you can combine things to make new things. But even if you know that you can combine X&Y to do something new, you cannot do it because you don't have access to it because you don't have the intellectual property or because you don't have the know-how.
80		OS		OSHE1	I jumped on this and I said, you know, this is the future, this is the future because you know, if we do want to solve world problems, we have to put aside the profit motive. But then I understood that it is economically possible too, to do open source development.
81		OS	Closed Source	OSHE2	The relationship between open source and patents is not a symbiotic one. It's a parasite one. It's a very extractive relationship. It doesn't nurture. It only extracts what it needs.
82		OS		OSHE3	And with our initiative we always of course try to focus on open source. We try to use 100% just open source tools for our software, for our back office, for our communication, for everything we do.
83		OS		OSHE3	After I finished university, I also realised that all the software that I was using before now cost a lot of money per year, so I also there switched from Matlab, first to Octave and from Octave now to Python, and from inventor to free CAD. And yeah, which is also like. It's difficult at the beginning, but I think it's definitely worth it you can share with everybody and just send a link for the software and the file and they can open with the software.
84		OS		OSHE3	Next week in Germany there's a kick off meeting for the open-source Alliance for everybody who's in open source hardware unites there. Then there's a new project started which is called open Tool Chain Foundation, which is reviewing what people need via a survey.
85		OS		OSHE3	It takes the idea of every open source hardware and what they need. Most of it needs open source software to produce the hardware so they are focusing on open source tool chains.
86		OS		OSHE3	There's a lot of movement in Dublin and open source ecology, and Germany.
87		OS		OSHE3	The thing that I think are beneficial of open source hardware is that it can be further developed by a community and customised for certain sites or if like a certain in this area, this material is more common or easier to get than this can be adjusted and documented. And the second part is of course repairing things.

88		OS		OSHE3	And there's the part about recyclability that you have if you have a good documentation online; because you know this is made out of this glass and this wood, and this metal, and so you know how to disassemble it.
89		OSH	OSS	OSHE1	Open source software was well developed with good licenses, but in 2008 open source hardware didn't even have a license. People were talking about possible license, so it was kind of the beginning.
90		OSH		OSHE1	And that was the beginning of all these things like Arduino was the beginning of, you know, Adafruit, you know, so you understand that even in the current economy there is a niche market for open source stuff.
91		OSS	Business Model	OSHE1	So you can go full open source, no shield, no defense. But but you have to go fast. So how do you turn that Openness and transparency into your advantage?
92		Other		OSH4	I'm writing a book about how we could mitigate climate change and it all comes down to preserving natural habitats.
93		other		OSHE2	And when we were nomads, we were observed by other species. But when we started looking around, when we started observing other species. We created mythologies, we created religions, something that didn't exist for us as nomads. We start to create our own world. And when we start to create our own world, and not in conjunction with the natural world, is when we have the basic toolkit of what we call civilisation. And that basic toolkit, that we call civilisation, has some aspects of peer2peer, but it's not peer2peer in its complexity.
94		other		OSHE2	When we created this time, we started to systematise our relationship with others, with the land, and with nature. And when we started to systematise it, we lost totally the connection with complexity itself. We became our own thing.
95		P2P		OSHE1	So that's my path into this. And then and then from that jump to peer-to-peer to say wait a second, I'm thinking about how to feed open source business model within this economy. But this economy is changing to something else, this economy is probably dead, it's just a matter of time, right it's on life support and maybe what's coming is a sort of a peer-to-peer economy.
96		P2P	OS	OSHE1	so it happens first where it's easiest. OK, so it happens in the technology space in the information space and the media. And then the financial system, because it's [peer-to-peer] easy because it's cheap because it's low cost because it can be easily adapted.
97		P2P	OSS	OSHE1	This peer-to-peer society was made possible by information technology, by digital technology and so the first ones that understood the power [of peer-to-peer] were programmers. So they started with the free software movement.
98		P2P		OSHE1	I think that they're [industries] all getting now touched and and what makes it accelerating is the DAO is the creation of these organizations based on blockchain.
99		P2P		OSHE1	That [the environmentalist movement] is an external constraint put on the on the peer-to-peer economy to say, OK, you figure out how to do stuff with networks.
100		P2P		OSHE1	So we don't know how peer-to-peer is gonna go. Is it gonna follow expansionism where we're not thinking in terms of scarcity anymore. But we're thinking about in terms of abundance in the universe. Or are we gonna stay with the environmentalist logic of scarcity.
101		P2P	OS	OSHE1	I think the economics is on the side of peer-to-peer. And open-source is part of that. It's a more complex economy that can deal with complexity. We see complexity really manifesting itself.</v>
102		P2P		OSHE1	These are examples of complex problems that do not have bureaucratic or mechanical solutions. OK, and what happens is that peer-to-peer is a more complex system that is able to deal with complexity.</v>
103		P2P		OSHE1	This is what we see today: the tendency to recentralization and oversimplification of society because they've got more complex and the and the bureaucracy is just losing it. So, so, so the the the natural reaction to sale save itself is to go back to a simplified social state which goes to centralization and control. So this is what opposes the peer-to-peer.
104		P2P		OSHE1	But peer-to-peer is more than just an idea. It's more than just a prototype, it has 10 years of solid implementation and development
105		P2P		OSHE2	Cause when you look at the peer2peer paradigm, how it's being conceived, it's very related to the organisational paradigm.
106		P2P		OSHE2	When we conceptualise with these sedentary civilisations, what we call society, what we called initially a tribe, a community and then we called it a society. We were already thriving through the "organisational paradigm". We created hierarchies, we created centers of power, through religion, we created economy; we created everything that is still the basics of our society as we know it. So in this peer2peer itself was captured by this organisational paradigm, and systematised as co-ops.
107		P2P		OSHE2	When you look at nature, nature is at its essence, p2p and emergent. It's complex, interdependent. All sorts of phenomenon emerges here and dies there. And it's always making a regenerative move. And life itself is regenerative in its p2p, and its always giving birth to new possibilities, to new potentials. It's in a constant change.
108		P2P		OSHE2	When I look at the works that David Bogler has been doing, Michel Bouwer, Silke from the commons transition, etc. they are still extremely based on the organisational paradigm. And it's like you don't have the possibility to think P2P if you're not setting up a co=op let's say, or a web p2p platform. So even when you look at the Fediverse (federation verse of p2p), they still have this very organisational layer to it – who is going to do this, who is going to do that. You're treating the fediverse as a group of enterprises or endeavours, p2p endeavours, not as something co-created, emergent.
109		P2P		OSHE2	So I started to do a lot of exploration, and not research, because I was living this, to see if we still have this intrinsic, very imbedded instinctive or intuitive peer2peer dynamic within us and inbetween us. Where you don't predesign, or preorder, in a participatory because participation is a social peer2peer technology, but participation is pre-designed. You pre-design when you can speak, when you can vote, when you can sing, so participation is very organisational, and interaction is very emergent, very complex. So when we are interacting we are becoming mutually speaking, in terms of empathy, we are becoming pregnant. We are going to conceive a child, and we are going to conceive something that is going to alter you and going to alter me. And this dynamic, is complex driven, and it's not systematised. It has emergent properties. And this emergence, is the real peer2peer dynamic.
110		P2P		OSHE2	When I'm thinking about peer2peer, when I'm thinking about opensource, when I'm thinking of this nation satet logicv that we live within, we're not talking about revolution. We're not talking about the left rising to power, or the right. I'm not talking about this binary ridiculous thing that we call politics nowadays. I'm talking about something that is related to one of the scientists I most respect, who was very critisised in academy in her days. I'm talking about lynn margulis. For her life doesn't evolve by itself. Life coevolutes. She came out of the concept of symbiosis. Which is very peer2peer.
111		P2P		OSHE2	What I'm saying is I opened some fissures in me, and you open some fissures in you, and we're not aware of it. But this mutual interactive, even via this screen here, zoom, we were able to generate something together; this double helix micronarrative. And that double helix, like a hypha within a huge fungi, it has the power to entangle with another micronarrative, with a different type of narrative. And for me, it's this complexity doing P2P dynamic that generates mutual double helix micronarratives that intertwines with others, that is literally the machinery of our coevolution happening right here, right now. And that's crazy I know.
112		P2P		OSHE2	So the relationship you have with your partner is a story that you and him are cocreating, a micronarrative that you and him are cocreating. And something of that is more intimate, that is between you and him, but something is more open-source, so it can intertwine with other micronarratives that are coming from other places, other people, other social worlds. So, this is the way that we are already co-evoluting. We are already reconnecting with complex nature, without the need to manifest for it, or to generate a huge planning to change the micronarrative of the huge country, and things like that. Becoming aware of that is an incommensurable sensation. I deal with it each day. Because it's literally the source of life itself. And we are connecting with it, without being aware that we are reconnecting. Because the way we conceive reality is collapsing, it's not sustainable.
113		Culture		OSHE1	But what are the characteristics of a culture that makes it compatible with peer-to-peer?
114		System change		OSHE1	What they tried to do during the COVID it's again mechanical or shut the valve here, Open the valve there. You know I'm saying it's like no that's not how you deal with the complex problem. You know it's not by shutting off here and because by shutting off here and closing here yes you've got beds in hospitals, but you're creating, but people are suiciding at home, you know. And people, people with cancer cannot go to the doctor and so on and so forth. So we create so many other problems that. So you try to save 100 lives and and you create 1000 deaths.</v>
115		Suggestion		OSHE1	Peer-to-peer still doesn't possess the resources. Because the majority of the existing resources are locked into traditional institutions.
116		Suggestio	Culture	OSHE1	Share as soon as you start writing, don't worry about your grammar mistakes. Don't worry about your poor ideas. Other people were gonna write on top of you and it's gonna be nice. And you're gonna experience some nice communion with people, and it's gonna be amazing. But no, people, people are shy to do that. People are afraid to do that. That's cultural. That's a cultural imprint of capitalism in them. It's in their system, it's fear. They feel shy. They feel, they feel insecure. They feel that to get naked in front of everybody, so to speak, when you expose your vulnerabilities, when you share your document early, right. You know you have to be open to constructive criticism. Constructive criticism doesn't mean to say ohh you're stupid.
117		Suggestio	Culture	OSHE1	And how do you become prosperous as an individual in an open environment? Is not by coming out on top and working on people's head, it's on the country where she people in front of you so they can pull you with them.
118		Suggestion		OSHE1	And then people in my generation that have to jump from capitalism to peer-to-peer and they need years to get accustomed.
119		Suggestion		OSHE2	We are storytellers. I wouldn't say that we're homosapiens, we're homo narrativus. Something like that. So we need to cocreate stories together.
120		System change		OSH4	In the business, like in the oil industry, they don't say open source. When you send technology, they only accept "non confidential".

121		System change	OSH4	So we could use the term non confidential information to somebody that's regularly into the business field. To understand it more. Instead of training somebody about open source methodologies.
122		System change	OSH4	I believe capitalism is definitely broken. Even from its fundamental tenants. Like you're supposed to be competitive. But trying to participate in capitalism for the small guys is like playing soccer at the bottom of the hill.
123		System change	OSH4	It's like you have all these oligopolies and like all the resources. But like, it's not competitive, you can't come out and share technology and really compete with your competitor, like better prices, better sales. And that's what really makes a business run. It's not like just holding technology.
124		System change	OSHE2	At the end of the 2000s, starting of the 2010s, I was very critical about that. Like, did we really forget how complex we are. How P2P is so related to complexity? How complexity is an emergent phenomenon?
125		System change	OSHE2	The way that we conceived our existence as a society, that needs the constant of infrastructures, of even superstructures, to make the society as we are function. Like a mechanical being, like something very mechanical. A closed-source system. The problem with the societies that we became, is that we thought these societies could be closed-source. But it can't. It's not a motor. When you study cybernetics, you understand the difference between a closed source system and an open-source system. A closed-source nation state cannot exist.
126		System change	OSHE2	As we are rediscovering that we can generate in a very network way micro narratives that has the power as little hyphas to generate different kinds of outcomes. We can deal with the evolution of life itself.
127		System change	OSHE2	This might sound ridiculous because we are so conditioned to think of the future, and thinking of resources for the future, and maintaining the status-quo of what we call life. But for me, we are already changing, the future is already happening right now.
128		System change	OSHE2	We can feel it in our guts that the way we conceived society as a whole, is not functioning, it's not working. We are already going to our roots, to our nomadic roots, and we are already seeing ourselves as adaptive, aggregative, collaborative. And we're doing what life itself does: we are regenerating ourselves, but we're not aware of it. We're not aware that we are already doing this, because we are still captured by the macronarrative of this nation state. We're still captured by here and when. Still captured by this endless war, by this bipolar society, this binary thing of left and right. But when you look at the potential of the intrinsic, complex, analogue driven dynamic dynamic that is ingrained in all of us, we are already cocreating, and living the future in our present, without being aware of it. And when we realise, it gives us a sense of "beingness", a sense of "beingness" that we lost. And we are literally making these connections without being aware of it. And that's the crazy part of it.
129		System change	OSHE2	When it came to sustaining the fire. We knew that fire was vital, not only to cook things, but at night, we are very fragile, and we needed the fire to not be eaten by animals. And this itself gives you a hint, of how to think peer2peer.
130		System change	OSHE2	The very concept of something private, in historical terms is very recent.
131		System change	OSHE2	So, what I'm saying is, when it comes to thinking ourselves in the midst of this huge complex collapse that we're living, we're rediscovering peer2peer in a very trivial and complex way. Without the need of activists talking about peer2peer, or talking about the commons. Because people are naturally peer2peer.
132		System change	OSHE2	When you come to this peer2peer paradigms, you inevitably come to talking about coops, or webplatforms. Always talking about something that is systematised. Something that is bottom up or top down dynamics, but once more, it's related to the organisational paradigm.
133		System change	OSHE2	I feel like we are living a very very complex civilisation collapse like we've never had before. And the pandemic, gave us a taste of it. That was sufficient for tens of millions of people to be bothered. But not in the scale of the billions.
134		System change	OSHE2	Going back to normal became something that everybody was seeking to do. Huge amounts of people were seeking to do accelerated network DAO.
135		System change	OSHE2	When we talk about the way that we're going to still exist as societies in 10 yrs, 15y rs, 20 yrs, or even 5 yrs. I never put it in the macro scale. I never work in the macro scale. Why? Because we had a whole century dedicated to it. The 20th century was dedicated by, where the future was dictated by the nation state.
136		System change	OSHE2	In the 19th century 18th century, the monarchies and all sorts of imperial kingdoms, they were not really concerned about the future. Yes, the king or theemperor was concerned about his future or his legacy, but there was never really the concern of people as a whole. So this is a trait from the 20th century, when nation states are very preoccupied by its own nation state future, and the geopolitical chessboard of cold war and hot war...
137		System change	OSHE2	The nationstates need the constant fabrications of enemy. Where the war is its natural state. I'm saying this because where is peer2peer in this dynamic, where is open source? Well, it's kind of a mixed bag. First of all, it's captured by the organisational paradigm as we talked about earlier. The second thing, is that open source was not really something that was open-source per se, because the concept itself was created in the academy, in the university realm. It was not created by the people, for the people, with the people. If you talk to any common folk around you, if you ask them what is open source, they won't have a clue about it. It's not something that was culturally appropriated by social worlds at large. But historically speaking if you critically look at how the open source occurs in different social worlds, in different societies, you're going to see that it comes out of this natural way for us to collaborate and adapt in a very interactive way. Everything that we collaborate and interact on to satisfy whatever needs or challenges we have, you can collaborate open-source.
138		System change	OSHE2	We're rediscovering ourselves as prosumers, not only as consumer. And this rediscovering of ourselves as prosumers, is very peer2peer.
139		System change	OSHE2	The underlying characteristic of nature is distribution. For nature, centralisation is not a constant thing. It occurs here and there. That's the difference.
140		System change	OSHE2	When we didn't have this thing we call time, we were going with the flow of the stations, with the daylight, the moonlight. We were entangled with this type of "time". And we weren't really worried about being productive. Because we were in this land, and we needed to explore the land, where we lived, where we had our culture, our roots.
141		System change	OSHE3	Now in Germany, there's an open knowledge foundation and they have an open prototype fund for software since several years, which is regularly funded by the government and is a success.
142		System change	OSHE3	And that's the thing with Open Source, we can create more products that we really need in the world. That would be my dream, and specifically to energy transition.
143		System change	OSHE3	On the big policylevel side of things, I think that when companies don't exist anymore, all this stuff needs to go open source and then society and humanity learns something of it. Otherwise we keep on doing the same mistakes again, because maybe next time another company comes around and thinks it's a good idea and and invests, thinking yes let's try. But it was done five years ago, but never published.
144				
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Legend | **Entrepreneurs** | Academics | Renewable Energy

	A	B	C	D	E
1		Tag		Who	Quote
2		Background		NRER	I Did my PhD in Canada. And I joined NREL three years ago first as a postdoc. And I worked on, and still am working on a lot with modeling human behaviors, but little bit less.
3		Background		NRER	At first, doing some literature review about recycling processes. And then trying to figure out which would be the best recycling process to kind of push in the US. And then optimization models. That would look at where we should put those recycling facilities, accounting for transportation costs and things like that because. The US is huge in as soon as you start transporting things, it can drive up your costs a lot and then it might be a barrier for PV owners to opt for recycling PV at the end of life. And the third part would be to improve the spatial resolution of the PV model we have because we had some assumptions we used that were not really great. That would be the first phase, and in the second phase, it would be about implementing a pilot scale recycling process somewhere.
4		Barrier	Challenge	NRER	At least for us researcher, it would be great to have more data on end of life.
5		Barrier	Challenge	NRER	And if you want a circular economy to actually work, you have to rethink how companies are gonna work together. I guess my suggestion would be, you know start from scratch. You need more collaboration between companies, which is not necessarily what is happening.
6		Barrier		NRER	And even like right from the get go, if you want, if you want to use some byproduct from a company, you need to know how uch they're gonna, how much they're gonna produce, right. So you need to have access to that information. Uh, you need to trust that.
					And also for us researcher. Like when you try to model recycling like end of life in general it's very hard to find data. So we don't even know how much PVs we use right now. We don't really know how much spin recycle. We just try to guess from

7		Barrier		NRER	don't even know how much PVs we use right now. We don't really know how much spin recycle. We just try to guess from whatever we can gather.
8		Barrier		NRER	I would say trust, if you want to have circular systems. A very simple example is industrial symbiosis. You cannot do any industrial symbiosis if you're not gonna trust your partners. And if you're not gonna exchange, you know, some information, some data.
9		Circularity		NRER	I really like the idea of a Bill of material. If the recycler would have like a little card, I think they would help them tremendously. That's what some of the recyclers that we interviewed that was one of the biggest problems that they have like different PV model that don't contain the same materials so they sometimes can't really apply this in processes.
10		Circularity		NRER	The problem is it's too expensive, so they could actually repair if they wanted to, but it just too expensive compared to the value that they they would sell it on secondary markets. They have the techniques, they have the knowledge for a lot of repairs. But it doesn't make sense economically.
11		Closed source	OS	NRER	Most of the output from this potential research would be made public. The only thing is that for phase two [of the research we might be doing], if there is a pilot scale recycling process that is developed, I'm sure that at first it's going to be kept private, and maybe there's a patent that's going to be signed. And I don't know exactly how much information will be made public.
12		Closed source		NRER	I have a senior researcher in the PV EIA and he works in collaboration with researchers in Australia, in Europe all about PV recycling. So there is like a big Research Center in France, and some of the folks there are studying recycling as well, so he's working with them. But a lot of the research regarding PV recycling in Europe is actually not made public. And when we try to find data [it's not possible].
13		Energy		NRER	They can't really do that anymore [repair solar panels] because the PV's are there was back in the time the quality of the panels were pretty good. They could do some basic repairs and it would still function. But now, panels are pretty cheap quality and so usually when it's broken, you can't really do anything with it anymore.
14		Energy		NRER	So, they have like 3 separate bins. One goes to landfill; one they recycle. But the recycling process is very, very basic: they take out the aluminium frame and then they just burn the whole thing in an incinerator to give some energy. And the third bin is whatever they can sell back on the on secondary market.
15		OS		NRER	Most of the codes that we're developing are publicly available. I don't know if they are open source, but anybody can use them most of the time. It's on the GitHub.
16		OS		NRER	We publish most of what we write. It's in a journal article and when we have the money we make it Open Access. If we don't, you know, it's still available for like libraries and stuff.
17		OS		NRER	I guess you have to look at the conditions, the context, how it happened and tried to recreate those condition. I mean not exactly the same but like trying to identify what would be the right condition for PV. So probably some of those conditions will be the same, but maybe some will be different.
18		OSH		NRER	It was a success in software engineering, right? If they succeeded, then my first reaction would be like, why wouldn't it work for hardware and like PV.
19		Background		OSSHR	We have this program that is called Open-Firm Academy and we work a lot with academics and I have to say like I was just very excited when you reached out. To me there's a lot of PHD's, a lot of master students that work on the topic of open source and open technologies in the US not that many in Europe that we know of. So I'm very happy that you reached out to us and yeah, I'm just curious who you are doing it with.
20		Background		OSSHR	I've been at work for like 4 years now. I'm not a technical person. And funnily enough, I'm not a political science person. I did my masters in new Media and communications. Uh, so we were basically researching the impact of social media and technologies on peoples lives, which is very nice, which I do at alpha as well, but very much from the from the openness angle. And as I said on open hardware like, I'm just very interested in it. Personally. We haven't had a chance to work on this much more than in the study for the European Commission.
21		Further research		OSSHR	When it comes to what should we do? There is a lot to be done and what I discovered was that there was basically no research, no papers that included open source hardware and policy in the same paper. So that was a very big challenge for us and we identified only a couple of people who were able to speak about it with us. It's basically only a couple of people. And then silicon is a very separate area where there is quite some experts on that, but they specialize on this. So, I would say there are these like 3 separate divisions.
22		Further research		OSSHR	What I think is the most crucial is just more research, and especially like if we want policymakers to realize. That this is actually important and yeah, there is startups like your startup. We we had some contacts with startups that are doing open hardware, but not that much. The European Commission loves Assamese and there is no open source hardware SMEs in the same alliance. There is no Horizon projects that are talking about open source hardware.
23		Further research		OSSHR	Because I see that just having a well stamped piece of research is very helpful, and having a number a couple of numbers that are speaking. Like: Going open source for this company allowed them to speed up their developments, allow them to exchange information with this Research Institute on the other side of the world.
24		Global N/S		OSSHR	(Question: The movement is very much coming from an approach of the global North.) Like digital colonisation.
25		Global N/S		OSSHR	Umm, there is some initiatives that are very much European and American companies led and I'm very critical of them like I've I think it could have some short term positive impact, but as such it's not fully ethical to me. But that's very much a personal opinion.
26		Global N/S		OSSHR	Now it's also the reason why we focus so much on Europe, to be honest, because we are happy to work with people from outside of Europe, but we just we know about Europe, we, you know like this is this is you know like we come from different European countries on Polish for example. So you know we still have different perspectives and we still share them and create something and we are very much open to the people from outside of Europe and in the last year it has been happening more and more but yeah. I don't want to go to African countries and tell them what to do, like that's not OK.
27		OS		OSSHR	I actually had the chat last week with a lady who's working on open EV chargers. It's open charger alliance. They're working on standardizing because they have this open standard for every chargers and they have problems with actually mandating it in Europe. But this is the most used standard in the US and South Korea, and in a couple of other countries, and they have problems with implementing in Europe because the European Commission wants an ISO standard. And they can't get it done so far.

28		OS		OSSHR	There is something called open silicon, which is basically an open infrastructure instruction set for creating these chips. So kind of an open design for a chip. And there is a lot of governance, a lot of projects that are around it. The most common one is risk 5. Umm, they have a foundation so they kind of work like open source software. They have a foundation for the project, kind of like. Umm, I could compare it to Linux for open silicon.
29		OS		OSSHR	Umm, so I would very much make a distinction between hardware and software. We are based in Brussels. We work a lot with the Commission a lot through the Parliament. There is much more awareness on the open source software. Uh, but there is also very much dedicated initiatives in the European Commission - so an open source program office. It's quite a small one, but they do have one.
30		OS		OSSHR	And recommendations for those [in open silicon] are very different because in software we are very much more advanced. It's much easier for us to propose recommendations such as I know tax breaks for open source software development.
31		OS		OSSHR	Such as favoring open source software in public procurement. Governments are huge buyers of software. It really worked in France. There is a lot of research on that. So no, these are like much more operational things, especially on the wave of the whole digital serenity motif that has been going on for, I would say the last three years.
32		OS		OSSHR	But I hope it's [OSH] going to join in there. This is something that I would that I would like to see. I haven't necessarily seen the the results of this more global cooperation on open source software because it's happening right now, especially for example in the in the space of digital payments of open wallets and stuff like that.
33		OS		OSSHR	Umm, but this is like very much a machine that is already running and I feel like it could be it could be a blueprint for open hardware.
34		OS		OSSHR	We are very much as an organization and as individuals more towards the vendor neutrality and more principle- based procurement and just you know choosing how to develop your digital infrastructure when it comes to open-source hardware.
35		OS		OSSHR	And this is something that Julieta wrote in this paper and I very much agree on this because we worked, you know, here and there and like generally open science. And it's rare that open hardware is a part of it, like explicitly.
36		OSH		OSSHR	In Europe, I don't know how long it's been going on, but because I did most of the research for this study like in 2020, 2020 was basically the year when we were doing this stuff. And I see that there is a rise in these things happening.
37		OSH		OSSHR	Do you do anything on standardization in your work? I mean we do a lot of work on standardization. Like throughout the years and we've been around for over 20 years and the little changed and also just like. It seems like a lot of standardization is moving to the open source space and then we just have to factory standards.
38		OSH		OSSHR	So yeah, I'm working on this [open silicon] now and the more hardware space, but this is, I would say it's in between open source software and hardware and very much a separate topic on of its own and on open source hardware. Yeah, I worked mostly for the on this study. What is interesting is even the fact that the European Commission requested to have open hardware included there because it was basically the first time that policymakers wanted to know more about open source hardware.
39		OSH		OSSHR	So the European Commission first thought that open hardware is mostly 3D printing. That's a pity. But over the course of the study, we worked with them quite closely. We invited many researchers, we had a working group on open source hardware and we quite established that this is not true. And of course, it's especially interesting for research.
40		OSH		OSSHR	Before our call I took a look at the kind of recent things that I received, so here I sent you a policy position, equitable research capacity towards the sustainable development goals. The case for open size hardware and this Julietta she's leading this. There are these monthly meetups on open science hardware. In this group there is also this really cool researcher, Joshua Pierce.He's doing a really, really good job.
41		OSH		OSSHR	When you talk about hardware, it's much more relevant for research for academia, but indeed there was this very much, I would say, archaic notion that open source hardware is 3D printing. Umm, I think 3D printing is great, but it's not going to change the world in the broader sense, in my opinion. Umm it can help many people, many companies. But it's not as vital, especially for digital infrastructure. Is that the that our governments, the largest companies, cloud providers are using.
42		OSH		OSSHR	So this is something that from my very much Brussels-based perspective I can say when it comes to science and research. There are people who can say more about it and you know from the more pragmatic perspective. Umm, but I believe it just like also about the explicit saying that open-source hardware is for example part of open science policies.
43		OSH		OSSHR	Yep, that's very interesting because when I was doing research on hardware, I saw that, uh, open source hardware was just like is very useful in many applications that in Europe we don't necessarily need. So like you just buy a product, right? And I remember there was this workshop at the European Commission got three years ago on open source software and hardware and there was this researcher who was talking about users of open hardware for researchers in Central Africa, I don't remember the details right now, but like it was, it was fascinating. Just, you know, like having these open designs allow them to conduct research, on a much tighter budget and with the same effectiveness. So like that, that was, that was really cool.
44		OSH		OSSHR	What is interesting, we are a very European very global North organization, but we have been working with the US for a long time like just different organizations from the US. Umm, of course on software, but in the last year or two there is a big, big uptake of initiatives on open source software and digital public goods and digital Commons globally. It's very much driven by many foundations, charities, so, you know, like think of a billionaire found, founded foundations and they are doing these global initiatives on connecting people in different countries, especially in the global South.
45		OSH		OSSHR	To use the same open source projects and designs and designs now projects, mostly software and this is something that I'm always asking them guys. Are you thinking of hardware as well? They're not at this step, just like any kind of like, more high level, more policy, more, you know, broad strokes initiative.
46		OSH		OSSHR	Yeah, there are different initiatives. I'm quite critical of the whole, you know, like we we've seen that a lot that especially European and American companies had these, you know, charitable initiatives that were theoretically open and nice. And actually it was just a way of hijacking the market. But in the initiatives that are happening right now, I see two types. One is this more that I'm a bit careful about.

47		OSH		OSSHR	Umm, but for example there is this initiative called code develop and they're working on connecting different governments from the global South on digital payments, but it's mostly run by the Government of India and by Indian companies with the solutions that are actually using that they're actually implementing. Umm, so it's led by them and supported with the with the American money. But the project is very much under the governance of India.
48		Barrier		OSSHR	And from my more policy perspective, we usually need numbers, and he has very good numbers.
49		Barrier		OSSHR	Umm there's, you know, there is the open source observatory. There's there's a lot of initiatives that are explicitly talking about open source software, which also is more relevant to an institution such as the European Commission, but also in the Member States. As such, if you talk about the government, open source software is much more relevant.
50		System Change		OSSHR	Umm, I got quite in touch with uh, with many open source hardware researchers and now I'm working on open silicon, which is a bit different. Basically, chip production. It's a very complicated ecosystem, especially during COVID resource supply chains shortages and like a lot of issues, a lot of money at stake. The European Commission put a lot of money now into implementing, just like having European chips and strengthening the European chips industry.
51		System change		OSSHR	We are very much fans of technological independence. I feel that this term is much more grounded in what we actually mean, and this can be used for diverse purposes by different political parties and political actors.
52		System change		OSSHR	What you're doing, and you know, like that's a that's a good thing and all the good luck in staying open. And from many, many conversations, I know it's not that easy always. And we are, as I said like we are not purists on open source but it's it's nice to feel open source literally for the innovation sake which I care about as a person working for not-for-profit.
53		Barrier		P2PA	Peer2peer always needs to have benefits: people want convenience. And big tech companies like apple and google bring convenience. That's why people keep using them. There needs to be an intrinsic benefit of using these kinds of technologies. And I think that dependence on centralised parties, people are more aware now that this is a dangerous assumption to make, with the privacy scandals that we see, and other developments.
54		Barrier		P2PA	We were thinking how can we apply blockchain and smart contracts specifically to this domain. And I realised after a lot of discussion that the problem we have is not really on the blockchain layer, or the peer2peer layer. It's more on the market layer. In the sense that we have different households that consume energy with different patterns; during the night they require more, or less, depending on their needs. So the biggest part of this paper we worked on is this market mechanism. Where we are using a decentralised algorithm, it proceeds in rounds; every 15 min households involved in this particular neighborhood all have a smart-meter, and then we compute the allocation of energy and resources, that would lead to the highest social welfare.
55		Barrier		P2PA	You have to start a movement with these kinds of things, and we're trying a little bit with peer2peer. And I would say that from an industry perspective it's not taken seriously at all.
56		Energy		P2PA	Smart-grids are, by definition, a grid, they're decentralised. They rely less on these centralised producers of energy.
57		Energy	Challenge	P2PA	The energy grid is not ready, we're still relying on traditional infrastructure.
58		Energy		P2PA	Things with energy trading are very much aligned with this idea too [common good].
59		OS		P2PA	We're in academia. The partners you're talking to are more aligned in industry.
60		OS		P2PA	Our lab has a profound focus on the common good. We have this idealistic vision of having things that can be used by anyone, that are free to use. And that's the root of our lab.
61		OS		P2PA	I believe that open software should go alongside open hardware. It brings convenience [open hardware]. It reduces the barriers to entry. If you have one party that says what you should do it's easier to avoid mistakes, and to be fair, I believe the whole open hardware ocosystem is a bit of a mess right now.
62		OS	Challenge	P2PA	I think interoperability, is a very challenging thing, and something that has a lot of focus from the research community. The more different types of open hardware there is, the more interoperability is going to be an issue.
63		OS	Challenge	P2PA	Do you want the people to decide on your protocols? I'm not sure if you would fully democratise this decision process, I'm not sure it would work either. It would probably need to be a sort of hybrid system.
64		OS	P2P	P2PA	Autonomy should always be with the end-user.
65		OSH		P2PA	If we don't use open hardware, what will happen is the hardware stack will be taken over by a Chinese or American vendor, as you see right now, and we will all be locked in into their ecosystem. And if we want to move away from that, it will be very very difficult.
66		OSH	Challenge	P2PA	The more choices does not always mean better. Best example is the power outlet – you need a different kind of adapter everyone.
67		OSS		P2PA	We've been developing our own software called tribler, and we've been developing it for 15-17 years now. And it's peer-to-peer and you can use it to download torrents. And it's always been open-source.
68		Other		P2PA	Working for the common good is basically what we are working on.
69		Other		P2PA	It's a bit of a double-edged sword – big tech companies being the first to capitalise on new innovations and being the ones building new standards.
70		P2P		P2PA	We applied blockchain technology to build a peer2peer energy trading market.

71		P2P		P2PA	End-colony optimisation – distributed algorithm for automisation, inspired by ants and how they collaborate in nature.
72		P2P	Energy	P2PA	Energy doesn't work that way [like cryptocurrency], you only contribute to the grid. You put energy on the grid, and no-one knows where it ends up. That's one thing that makes this domain much different from traditional blockchain. And I think this is also a pitfall to many people trying to apply blockchain to energy.
73		P2P		P2PA	Fully decentralised means there is no single centralised party involved.
74		P2P		P2PA	I've always worked on lightweight systems. It means that not much research usage is required to make sure the system is operational and works. I see that a lot actually with blockchain for example (Ethereum, bitcoin), they're very wasteful, very heavy. But that kind of heaviness is not required for a system to operate. With much more lightweight ledgers.
75		System change		P2PA	We're getting back to that era in the sense that we're seeing a large fragmentation of all these streaming services, and videos.
76		System change		P2PA	The master switch – explains how decentralisation and centralisation works. And what you usually see, is there is a new technology, and it starts out as an open infrastructure, that everyone can use [gave the example of the radio], and then people start capitalising and centralising the technology, and then it's monopolised, and then people start to complain, so it's broken open, and the cycle starts again.
77		System change	P2P	P2PA	And I think the internet is heading to a centralised, closed-walled garden idea, that apple and google. It is in the process of closing up. Peer-to-peer is the counter force. Is it successful? I don't know.
78					

Legend | Entrepreneurs | **Academics** | Renewable Energy

		Tag		Who	Quote
2		Background		SEE	We are a semi government organisation. So, we are a foundation but we are funded by this government. And our purpose is to accelerate innovation in the Netherlands. We do that by increasing the collaboration between companies or universities.
3		Background		SEE	My function is programme manager. And that means specifically that I'm responsible for the innovation programme that focuses on renewable electricity, which is consisting of solar energy and wind energy, and specifically inland.
4		Background		OSHI	[company] was started by a gentleman named Fab. OK. So Fab is a space engineer by background and has been working in energy access for more than 10 to 15 years, right. I think he started his journey sometime in 2009 or 2010 and he has been one of the culprits as well. Right? So when and when he started his journey and the energy access space, you know, he actually started his company and named Evergy in Tanzania, where they were, where they were giving access to clean energy, using the lightweight mini grids or DC based mini grids.
5		Background		OSHI	Right. And that was the genesis of creating our company. How can we help companies investing their resources in the places which will make more sense like which gives them the more return instead of in the R&D which it can be created by one company and being available to the others. We'll have a more returns that was the genesis of our company coming in.
6		Background		OSHE3	I studied renewable energies and started working in the field of wind turbines. At first a small wind turbines with a capacity of 15 kilowatts and then also that was my professional work to, in Germany it's like called income work or the translation that gives me money and on the site since 2016 I'm a member of the Ernie Wind Turbine Collective.
7		Background		OSHE3	And we are focusing on education, specifically on small wind turbines and off grid systems. And the site also renewable energies in general.
8		Background		OSHE3	We are with a two-person team now on it working one to two days per week. We are using our own GitLab on our server and have a git repository there.
9		Background		OSHE3	So, no one of us is working full time on that. We all have our jobs in different fields of renewable energy from wind turbine, solar to like energy efficient housing.
10		Background		OSHE3	And for this purpose we use small wind turbine manual, which is written by you, Pickett. And he started to design this small wind turbines in 1970s - 80s.
11		Background		NRER	I Did my PhD in Canada. And I joined NREL three years ago first as a postdoc. And I worked on, and still am working on a lot with modeling human behaviors, but little bit less.
12		Background		NRER	At first, doing some literature review about recycling processes. And then trying to figure out which would be the best recycling process to kind of push in the US. And then optimization models. That would look at where we should put those recycling facilities, accounting for transportation costs and things like that because. The US is huge in as soon as you start transporting things, it can drive up your costs a lot and then it might be a barrier for PV owners to opt for recycling PV at the end of life. And the third part would be to improve the spatial resolution of the PV model we have because we had some assumptions we used that were not really great. That would be the first phase, and in the second phase, it would be about implementing a pilot scale recycling process somewhere.
13		Barrier		SEE	That being said, the same technology production in US or Europe will be more expensive. Very recently, there was a report from McKinsey on the global PV or the other at the European reshoring, and I think they say if we do exactly the same, what they're doing in China, we will be 25% more expensive.
14		Barrier		OSHI	**The rest then reciprocate, or you will say the acceptance of open source. First of all open source is highly linked to only software. So people only understand open source as software. Most companies and stakeholders or actors in the energy access space really don't understand how open source.**
15		Barrier		OSHI	**How open innovation fits in the energy access space.. I think their biggest challenge is lack of awareness and lack of understanding what is open innovation. That's a bigger thing. And the second question that they often understand is they really don't have any understanding on the commercial side. Can you be still be commercially viable and be an open innovation?**
16		Barrier		OSHI	We are doing a lot of the work on in terms of awareness and the advocacy and how open information can fit in easily, fits in the current scheme of things, and how it is still possible for commerce companies to be commercially viable with the open innovation.
17		Barrier		OSHI	Open innovation, open source, is often associated only with the software. So that's the work that we are doing beyond just funding.
18		Barrier		OSHE3	But then yeah, we just stopped and just did it like on the site, and everybody just focused more on their jobs to have an income.
19		Barrier	Challenge	NRER	At least for us researcher, it would be great to have more data on end of life.
20		Barrier	Challenge	NRER	And if you want a circular economy to actually work, you have to rethink how companies are gonna work together. I guess my suggestion would be, you know start from scratch. You need more collaboration between companies, which is not necessarily what is happening.
21		Barrier		NRER	And even like right from the get go, if you want, if you want to use some byproduct from a company, you need to know how uch they're gonna, how much they're gonna produce, right. So you need to have access to that information. Uh, you need to trust that.
22		Barrier		NRER	And also for us researcher. Like when you try to model recycling like end of life in general it's very hard to find data. So we don't even know how much PVs we use right now. We don't really know how much spin recycle. We just try to guess from whatever we can gather.

23		Barrier		P2PA	Peer2peer always needs to have benefits: people want convenience. And big tech companies like apple and google bring convenience. That's why people keep using them. There needs to be an intrinsic benefit of using these kinds of technologies. And I think that dependence on centralised parties, people are more aware now that this is a dangerous assumption to make, with the privacy scandals that we see, and other developments.
24		Barrier		P2PA	We were thinking how can we apply blockchain and smart contracts specifically to this domain. And I realised after a lot of discussion that the problem we have is not really on the blockchain layer, or the peer2peer layer. It's more on the market layer. In the sense that we have different households that consume energy with different patterns; during the night they require more, or less, depending on their needs. So the biggest part of this paper we worked on is this market mechanism. Where we are using a decentralised algorithm, it proceeds in rounds; every 15 min households involved in this particular neighborhood all have a smart-meter, and then we compute the allocation of energy and resources, that would lead to the highest social welfare.
25		Barrier		P2PA	You have to start a movement with these kinds of things, and we're trying a little bit with peer2peer. And I would say that from an industry perspective it's not taken seriously at all.
26		Barrier		NRER	I would say trust, if you want to have circular systems. A very simple example is industrial symbiosis. You cannot do any industrial symbiosis if you're not gonna trust your partners. And if you're not gonna exchange, you know, some information, some data.
27		Barriers		SEE	These are some of the hurdles I see in this industry. And economies of scales they matter a lot and so getting big does make the production more efficient.
28		Business models		SEE	So that will be my main question: where is this open source model applied successfully on hardware products?
29		Business Models		OSHI	Often these are some core technologies which are required to bring together the overall product and may not be the core product.
30		Business models		OSHI	The thing is that again it depends on the product that they are open sourcing. If it is let's say one can open when we say an open source. You largely open source that design of it, right?
31		Business models		OSHI	But then companies can still come to you for manufacturing of that, depending on what. So I don't think it's possible for me to have a one fit answer for this kind of a thing. You know people can always open source a base design and then some additionality aspect of it can always be delivered as premium services.
32		Business models		OSHI	And this is the model that most companies you know [do]. This is what Spotify did. Spotify said their core mission was always to provide access.
33		Business models		OSHI	Freedom to access of for any music anywhere for what they in order to have a viable, sustainable business model. What they did is they allowed people to actually start creating their own personal list, or they have their access to the other people's list. Now these kind of additional services then they premiumize it.
34		Business models		OSHI	The open source design is a part of it, but it's not possible for every small company to do the production side of it. If you are a large enough company, you could take the manufacturing side of it. You could provide the consulting services for people who want to adopt this kind of a solution, right? So there are lots of potential possibilities for anyone to look at the commercial aspect, how to commercialize your open innovation.
35		Business models		OSHI	Additional services. There are many software companies that say we give you the base access, you can develop on anything of that because reality is any development that you create it needs a resources, so somebody has to feed on. Somebody has to cover for those resources to development. To cover that, you put a bill to it. I have seen, many companies actually provide access to the data so that the challenge is often not on the access to the data, but it can be. It is about what you inference from there. So if you are a company which had the really in-house resource, you could do with whatever, but often the realities and many of the smaller companies don't have.
36		Business models		OSHI	Many, many of the smaller companies don't have the access to everything, right? They don't have a in house resource and that's where they would actually, you know, they would actually go for the premium services, right. Whether the analytics side of it or rather the consulting side of it, right. So when I say a premiumize it where you can add the premium version for the analytics side of it, right.
37		Business Models		OSHE3	He created this manual and sold it on the Internet and you can buy it for a couple of EUR. I think 7 euro's or something.
38		Business Models		OSHE3	And they have this year for the first time a prototype fund for hardware as well and we applied there and got the funding for the documentation of our wind turbine that we developed so far, and that's what we are currently doing.
39		Business Models		OSHE3	The thing with the energy transition is like with our product with the small wind turbine. I don't really see a big impact I see it as a niche and because it is a niche, I think it's much more important that it is open source and that it is developed to become the very best wind turbine in the community and that failures and errors are shared and that currently like small one turbine manufacturers come and go. A person who buys one this year and who wants to have a spare part next year, but the company might not be there anymore.
40		Circularity		SEE	**And then a new trend that's coming up is... How do you say? See you could call it circularity. Or you could call it CO2 footprint or there are a number of ways to call it, but I think we will see a trend and lowering of the environmental impact of of the production and I think that development will we be strongest in Europe. I think because Europe has the most strongly developed framework for Environmental Protection and impact. So those are the trends that I've foreseen in the near future.**
41		Circularity		OSHI	Before open source hardware comes in I think these things [circularity] need to be looked at the design level because that's where you are able to actually really bring the circularity aspect right, because otherwise you are really looking at post- fix.
42		Circularity		OSHI	I think it has to be looked from a product-to-product point of view. And I wouldn't say a simple blanket approach will be possible at some times you know.
43		Circularity		OSHE3	Most open source projects also focus on how something is designed, and that it is designed in a repairable way.
44		Circularity		NRER	I really like the idea of a Bill of material. If the recycler would have like a little card, I think they would help them tremendously. That's what some of the recyclers that we interviewed that was one of the biggest problems that they have like different PV model that don't contain the same materials so they sometimes can't really apply this in processes.
45		Circularity		NRER	The problem is it's too expensive, so they could actually repair if they wanted to, but it just too expensive compared to the value that they they would sell it on secondary markets. They have the techniques, they have the knowledge for a lot of repairs. But it doesn't make sense economically.
46		Closed Source		OSHI	All of them are doing the same background technology stuff and at one point, you know, they realize that all of them are actually trying to reinvent the wheel of something which is not really a USP of them, right. It is required for their business, but it is not these background infrastructure technologies that they are not defining their core business right. But they're important they are. And result of which all of them were actually spending their limited resources, financial and as well as human capital resources in developing these technologies innovations. And had I had these innovations been available open source, they would have actually, you know, saved those. You know, those investments in these technologies and instead would have invested in in the spaces which are more relevant to them because one thing is for sure, which is, you know, in the energy access phase, the companies are always struggling with the financial resources, right. They're both financial and as well as human capital.
47		Closed Source		OSHI	Sometimes we'll lot of most of them were creating this not because they wanted to create it, but also nobody knew that somebody else is using the same thing, that there wasn't any knowledge sharing happening, result of which everybody was just creating all these solutions for themselves, which are replication and result of which you know the.

48		Closed Source		OSHI	So Fab decided as he got further down the line and he was engaging with the one of the donors and they were talking about the key challenges which are faced in this and this was that you know how often many of the actors end up reinventing the wheel purely sometimes not knowing.
49		Closed Source		OSHE3	Documentation on an open source licence online, quite often you can't access it; if you want to change it further, develop it. It's sometimes difficult because the files themselves used will need the property software.
50		Closed so	OS	NRER	Most of the output from this potential research would be made public. The only thing is that for phase two [of the research we might be doing], if there is a pilot scale recycling process that is developed, I'm sure that at first it's going to be kept private, and maybe there's a patent that's going to be signed. And I don't know exactly how much information will be made public.
51		Closed source		NRER	I have a senior researcher in the PV EIA and he works in collaboration with researchers in Australia, in Europe all about PV recycling. So there is like a big Research Center in France, and some of the folks there are studying recycling as well, so he's working with them. But a lot of the research regarding PV recycling in Europe is actually not made public. And when we try to find data [it's not possible].
52		Culture		OSHE3	Not being able to participate like seeing an error but not knowing how to how to post an issue or how to take part in further developing it so this is something that I really see as a big challenge and which would need to be overcome. And we as the open source community would need to have like regular Git courses once a month so that you don't need to wait for an opportunity to Start learning it.
53		Culture		OSHE3	Just to make it simpler and so people are not frustrated. Because Git is a quite big tool and we all have our projects and we are already tired with our projects and we can't afford to put like hours and hours of work extra work into just like side tools.
54		Culture		OSHE3	The meta anymore or I see a lot of projects or how you how you mentioned at the beginning that we all do it because of idealism and sometimes through this big motivation by pure idealism, we forget the aims or the needs in the real world. And for example, that's why when I first saw your product, I thought that is awesome. If this works and if they really manage to, it's a product that is needed worldwide.
55		Energy		SEE	I would break that down in three parts. I would break it down in technology development; In implementation; and in production, so if I shortly focus on the on the three, starting with technology development; I see there are a few robust trends from the past that I think will continue. The trends are lower cost and higher efficiency, so it's the basic trends that we have seen so far and there are still some room for efficiency improvement in the current generation modules. But we, the world is nearing the limits, so I expect shift to tender modules within the next couple of years. A lot of companies are trying to do this.
56		Energy		SEE	I think that the silicon perovskite tandem module will be the next breakthrough in the market. Though it's guesswork, because there are still challenges regarding lifetime reliability and stuff, so it's not a given that it what will happen, but there's so much money and like thought power, being spent on it. I think it will happen. And I think at the same time, cost reductions will take place. There's a lot of room for improvement there still.
57		Energy		SEE	Then second, on implementation. I think in every country in the world, we are going to see a big boom of solar. It's already happening in many countries and it will continue.
58		Energy		SEE	There will be places where solar will not be the biggest source of energy. For example, in Western Europe, wind energy is very favourable, but I think the prediction that solar energy will be the biggest source of energy in the world. I think it's going to be true. So we will see increasing solar implementation everywhere.
59		Energy		SEE	And then on production. Production is now centred in Asia, mainly China, and it is very recently that it is being regarded as a strategically risk. So, you see that the power blocks of this world. So the United States, the European Union, but also India for example. They are all setting up programmes to have a new or renewed PV industry.
60		Energy		SEE	I think that it's terrible that forced labour is in this production chain. However, I do not think that's the biggest contribution to reduction costs. Because the cost dropped by 90%, so a factor of 10 in the last 10 years. So the major breakthroughs in cost reduction is upscaling. It's reduced losses.
61		Energy		SEE	So that's a fact. So, there are a couple of ways Europe, or the US could have support mechanisms. For example, this inflation reduction act in the United States is doing exactly this. It's big support for producing in the United States. So, I think in the United States they now have the framework to overcome this cost difference already. Europe is still working on that.
62		Energy		SEE	But it could also be innovation. So if Europe is first in this new generation of products, then you could have this competitive edge. I don't think we should be too naive that we will outpace the Chinese, or once it's done in Europe, that it will not be copied to China.
63		Energy		SEE	I think yeah, the main solution for this reshoring will be support mechanisms.
64		Energy		SEE	So at this moment solar is, in for example Western Europe not yet so cheap that it's the cheapest source of energy. I mean there are still subsidy mechanisms in place, for Netherlands you have this large as the scheme. And so that means you are competing with all sources of energy. And there are parts of the world where solar is cheapest, so you could wonder why it should be lower cost, because we are the cheapest source of energy. In fact, it has become cheaper than it ever was. So, let's focus on other product characteristics like sustainability.
65		Energy		SEE	I think in the end you have this competition with other sources of energy. As long as it's there, I think cost reduction is favourable for the uptake of solar and on the long run. I mean it doesn't have to be. That becomes cheaper and cheaper so.
66		Energy		SEE	If you want to go further in sustainability, so if you want to phase out oil, for example, a feedstocks. Then you have your green electricity as a source, then you have all kinds of commercial losses. There will be harder to push this for the future of the market. But in the end we can.
67		Energy		SEE	You are talking about open source, but many technology developing companies for solar are trying or already doing a licence model so they've developed the technology and they licence this to other factories. This seems to work, so I think the licence model where in fact you have revenues flowing back to the technology owner. So then I wonder why Open source.
68		Energy		OSHI	At that time, you know, there were many companies in the sector, you know, in the solar space, not particularly the mini grid, but a lot of the other solar home systems company. They were all trying to do a lot of the background technology stuff.
69		Energy		OSHI	The Linux Foundation energy, is actually playing a key role in stakeholder mobilization.
70		Energy		OSHI	The reality is the energy transition is a massive and a mammoth task. If each company is going to try to do it themselves at their level, it's not gonna be possible. And that's where they are really pulling together the resources. By bringing people together, because in the energy transition space, a lot of the work which is going in making the grid smart. And that's where you know the software has a big role to play.
71		Energy		OSHE3	Open source could have a really big impact on the energy transition.
72		Energy		OSHE3	And it's not like wind turbine is difficult to deploy.

73		Energy		NRER	They can't really do that anymore [repair solar panels] because the PV's are there was back in the time the quality of the panels were pretty good. They could do some basic repairs and it would still function. But now, panels are pretty cheap quality and so usually when it's broken, you can't really do anything with it anymore.
74		Energy		NRER	So, they have like 3 separate bins. One goes to landfill; one they recycle. But the recycling process is very, very basic: they take out the aluminium frame and then they just burn the whole thing in an incinerator to give some energy. And the third bin is whatever they can sell back on the on secondary market.
75		Energy		P2PA	Smart-grids are, by definition, a grid, they're decentralised. They rely less on these centralised producers of energy.
76		Energy	Challenge	P2PA	The energy grid is not ready, we're still relying on traditional infrastructure.
77		Energy		P2PA	Things with energy trading are very much aligned with this idea too [common good].
78		Finance		SEE	With a hardware production, you need to start with, a lot of equipment, machinery, stuff. So, you need to invest a lot of money before you can start profiting, so there's a very different economic model. Like I think there are only a few sources of funding that can make this work. I think the funding needs to come from investors that share this ideal. So either you find one that's very rich, so like it's philanthropist, or you find many that support this or that. That will be crowdfunding.
79		Finance		OSHE3	We tried with the small wind turbine and got a little funding from university where they funded us for six months and they offered like we could use one office and they paid three people. This time we used to look for bigger funding like in Germany, it's called exist. It's like a funding from the government for two years for three people and you get like mainly the cost for the people and little money for hardware that is always a problem with like prototyping and hardware that you also need money to have a workshop to have to buy tools to buy hardware.
80		Finance		OSHE3	The guy who checked our proposal was a patent lawyer or a former patent lawyer, so he didn't really get the concept at all, and so we didn't get any further. Then we tried some proposals to other accelerators and stuff and got a little money here and there.
81		Finance		OSHE3	I'm hoping to just be paid to work in this field so that it's not just like meetings at night and all that stuff. That'd be really cool.
82		Finance		OSHE3	I think compared to software projects where you don't need extra things, like a workshop and tools to build something you have, you need. You need the laptop and a person and a house and an Internet connection. And the Internet connection is already there most of the time. The house is already there, the laptop's already there. The person just needs to put time in. So I think that's why it's there are much, much more open software projects.
83		Funding		OSHI	If we really want the sector to move forward, what are some of the specific things where we can make that done and the reality is you will always have this comment coming in: Ohh there aren't enough funding or financial excesses and all those are limited.
84		GS	Energy	OSHI	OK, the global S is largely focusing well, depending on whether you're in the low income country or middle income country or high income country; the high income countries are now focusing on energy transition, wherein low and middle income countries are focusing on energy access because large part of their population is still without energy. They don't have access to the basic energy services. So we have always worked in the energy access space because we focus on low and middle income countries. Instead of having that energy services being available through coal or through fossil fuel.
85		OS		SEE	If you can be successful or not because the production part and mainly the start of the production part, so it's the silicon mining. It's the furnaces, there you have huge economy of scale. I mean, even if you are open source these this has to be done by big. Well, I call them companies, but by big organisations.
86		OS		SEE	You get this working, so I think open source there. I think it will be very hard to have an open source model for that kind of development. Further down the value chain, if you are in the integration or installation parts. I think it's very applicable, so do it yourself solar installation is already being done. Many parts there is a [possibility].
87		OS	Circularit	SEE	And so there I think it can be applicable and I know where that you are looking to recycling or reuse, refurbishing, and I think it can be applicable there. The hard thing there is that if something is recyclable or refurbishable depends on how it was produced in the 1st place. So, if you don't have this open source model there, it's going to be hard to have it in the end of life stage also.
88		OS		SEE	I don't see any fundamental restraints to [open source becoming big]. However the startup-scaleup phase will be hard because you start small and you have to become big.
89		OS		SEE	And in general that happens with capital that happens with venture capital. I think venture capital and open source business models are poor combination. So I think there you need to look to do crowdfunding or philanthropy, and for scaling up I wonder if that can happen. That's why software start-ups are so interesting for investors: your CapEx, your capital expenditures are low. So you need a team of smart people to get something working and so you can keep everything for yourself and then you get rich or you share it. It's open source and the world profits.
90		OS		SEE	You have the challenge too. First you need to develop this technology so you have to spend money but the licence model can alleviate this high CapEx expenditure on these machinery. So maybe that could be an interesting comparison. If you look at successful companies that successful licence their technology in in solar industry and I think there have been examples. And then you could see how to and what is the difference between a licence model and an open source model. I think it's not even that big, in fact.
91		OS	Finance	SEE	The thing is still the idea of this: licencing companies. OK with the revenue from the licence firstly that is why investors in the modern company or fund the company are interested, because they think that with this licence, I can earn back my investment. But let's say you don't have an investor that wants his investment back in manifold. And then the revenues also enabled the original company to keep innovating. And that's also a risk. So if your funds dry up then maybe you have lunch at technology but you run the risk of like of that you have like it's a dying technology because you are not providing innovation anymore.
92		OS		SEE	So I think those are two reasons why differences between the licencing model and an open source I think. It's not impossible [open source innovation]. Because I know one disadvantage of the licencing model is that the daughter companies that are using the technology, they don't really have an incentive to innovate themselves because they basically get: this is how to produce. And in fact probably they are not allowed to add to the technology. So that's something, that's a force that you could use in an open source approach.
93		OS		OSHI	Now making it open source you are able to actually pull together the resources of different nature of different strength. Especially in the energy transition, it's the same which is being leveraged now in the immobility space. So instead of just creating that, can we have a smart TV infrastructure but instead of 1 company which is gonna be trying to create it, it's gonna take forever and will take a lot of resources. Instead different companies are pulling together and creating these open source infrastructures which can then be leveraged by different companies. And then can be continuously being updated by these companies.
94		OS		OSHI	One of the one of the strength of open sources that you have, you don't have a one brain, but you have one hundreds of brain working together in continuously improving that. Like every day somebody is challenging the other person for the betterment and for the improvement.
95		OS		OSHI	The transition is really depending a lot on the open source and I think the beauty of open source is collaboration and the community.

96		OS	Closed so	OSHI	Depending on who's bringing the value or the investing in, you might have to have a close source product. We are very clear about this: we don't say that there is, it's an either-or approach. No, there is a role for both kind of innovations, open source and closed source. So depending on you know what is a strength you as a company bring in that through that product that decides whether you are able to do open source or you know a close source.
97		OS	Finance	OSHI	And you can see that actually the European Union and European Commission is now investing heavily on open source, open data you know.
98		OS		OSHI	There are a couple of organizations which are in the forefront of making sure that even on the policy side, how it is an open. These policies, the public has an access to these policies and all that.
99		OS		OSHE3	And with our initiative we always of course try to focus on open source. We try to use 100% just open source tools for our software, for our back office, for our communication, for everything we do.
100		OS		OSHE3	After I finished university, I also realised that all the software that I was using before now cost a lot of money per year, so I also there switched from Matlab, first to Octave and from Octave now to Python, and from inventor to free CAD. And yeah, which is also like. It's difficult at the beginning, but I think it's definitely worth it you can share with everybody and just send a link for the software and the file and they can open with the software.
101		OS		OSHE3	Next week in Germany there's a kick off meeting for the open-source Alliance for everybody who's in open source hardware unites there. Then there's a new project started which is called open Tool Chain Foundation, which is reviewing what people need via a survey.
102		OS		OSHE3	It takes the idea of every open source hardware and what they need. Most of it needs open source software to produce the hardware so they are focusing on open source tool chains.
103		OS		OSHE3	There's a lot of movement in Dublin and open source ecology, and Germany.
104		OS		OSHE3	The thing that I think are beneficial of open source hardware is that it can be further developed by a community and customised for certain sites or if like a certain in this area, this material is more common or easier to get than this can be adjusted and documented. And the second part is of course repairing things.
105		OS		OSHE3	And there's the part about recyclability that you have if you have a good documentation online; because you know this is made out of this glass and this wood, and this metal, and so you know how to disassemble it.
106		OS		NRER	Most of the codes that we're developing are publicly available. I don't know if they are open source, but anybody can use them most of the time. It's on the GitHub.
107		OS		NRER	We publish most of what we write. It's in a journal article and when we have the money we make it Open Access. If we don't, you know, it's still available for like libraries and stuff.
108		**OS**		**NRER**	**I guess you have to look at the conditions, the context, how it happened and tried to recreate those condition. I mean not exactly the same but like trying to identify what would be the right condition for PV. So probably some of those conditions will be the same, but maybe some will be different.**
109		OS		P2PA	We're in academia. The partners you're talking to are more aligned in industry.
110		OS		P2PA	Our lab has a profound focus on the common good. We have this idealistic vision of having things that can be used by anyone, that are free to use. And that's the root of our lab.
111		OS		P2PA	I believe that open software should go alongside open hardware. It brings convenience [open hardware]. It reduces the barriers to entry. If you have one party that says what you should do it's easier to avoid mistakes, and to be fair, I believe the whole open hardware ocosystem is a bit of a mess right now.
112		OS	Challenge	P2PA	I think interoperability, is a very challenging thing, and something that has a lot of focus from the research community. The more different types of open hardware there is, the more interoperability is going to be an issue.
113		OS	Challenge	P2PA	Do you want the people to decide on your protocols? I'm not sure if you would fully democratise this decision process, I'm not sure it would work either. It would probably need to be a sort of hybrid system.
114		OS	P2P	P2PA	Autonomy should always be with the end-user.
115		**OS**	**Energy**	**OSHI**	**Decentralized or renewable energy has a huge role to play in providing basic energy access. And that's the reason we focus on energy access. So our work focuses largely on low and middle income countries in low and middle income countries, there are large population that do not have access to energy. That's why we focus on energy access and we do see how some core innovations being open innovations can really help in expediting that work.**
116		OSH		NRER	It was a success in software engineering, right? If they succeeded, then my first reaction would be like, why wouldn't it work for hardware and like PV.
117		OSH		P2PA	If we don't use open hardware, what will happen is the hardware stack will be taken over by a Chinese or American vendor, as you see right now, and we will all be locked in into their ecosystem. And if we want to move away from that, it will be very very difficult.
118		OSH	Challenge	P2PA	The more choices does not always mean better. Best example is the power outlet – you need a different kind of adapter everyone.
119		OSS		P2PA	We've been developing our own software called tribler, and we've been developing it for 15-17 years now. And it's peer-to-peer and you can use it to download torrents. And it's always been open-source.
120		Other		P2PA	Working for the common good is basically what we are working on.
121		Other		P2PA	It's a bit of a double-edged sword – big tech companies being the first to capitalise on new innovations and being the ones building new standards.
122		P2P		P2PA	We applied blockchain technology to build a peer2peer energy trading market.
123		P2P		P2PA	End-colony optimisation – distributed algorithm for automisation, inspired by ants and how they collaborate in nature.
124		P2P	Energy	P2PA	Energy doesn't work that way [like cryptocurrency], you only contribute to the grid. You put energy on the grid, and no-one knows where it ends up. That's one thing that makes this domain much different from traditional blockchain. And I think this is also a pitfall to many people trying to apply blockchain to energy.
125		P2P		P2PA	Fully decentralised means there is no single centralised party involved.
126		P2P		P2PA	I've always worked on lightweight systems. It means that not much research usage is required to make sure the system is operational and works. I see that a lot actually with blockchain for example (Ethereum, bitcoin), they're very wasteful, very heavy. But that kind of heaviness is not required for a system to operate. With much more lightweight ledgers.
127		System change		SEE	I mean, the Western world has been paying for years and years, around 50euros per MW hour of electricity. Solar can definitely beat that.
128		System change		SEE	Maybe we are now spending 3 or 4% of global GDP on energy and can we have a sustainable society where we spend 6% of GDP on energy? Probably we can. So, it's not a big deal. In fact, I think I've read a report of XX. It's this large consulting company where they said that when we have done the transition properly, probably our GDP part we spend on energy is probably lower than before the transition, so that is an interesting thought. So we are going to a cheaper system and yet we have to take this one hurdle.
129		System Change		OSHI	And often there is a limitation right, the low and middle income countries cannot have the energy services same way as the global N got it.
130		System change		OSHI	Even at the EU level, there is a lot of focus in bringing this transparency to the open source approach.
131		System change		OSHI	A background to the role of open source in the overall ways of working at a different aspects of the you know our day-to-day life, our business and the way we engage in the in the society.

132		System change	OSHE3	Now in Germany, there's an open knowledge foundation and they have an open prototype fund for software since several years, which is regularly funded by the government and is a success.
133		**System change**	**OSHE3**	**And that's the thing with Open Source, we can create more products that we really need in the world. That would be my dream, and specifically to energy transition.**
134		System change	OSHE3	On the big policylevel side of things, I think that when companies don't exist anymore, all this stuff needs to go open source and then society and humanity learns something of it. Otherwise we keep on doing the same mistakes again, because maybe next time another company comes around and thinks it's a good idea and and invests, thinking yes let's try. But it was done five years ago, but never published.
135		System change	P2PA	We're getting back to that era in the sense that we're seeing a large fragmentation of all these streaming services, and videos.
136		System change	P2PA	The master switch – explains how decentralisation and centralisation works. And what you usually see, is there is a new technology, and it starts out as an open infrastructure, that everyone can use [gave the example of the radio], and then people start capitalising and centralising the technology, and then it's monopolised, and then people start to complain, so it's broken open, and the cycle starts again.
137		System ch P2P	P2PA	And I think the internet is heading to a centralised, closed-walled garden idea, that apple and google. It is in the process of closing up. Peer-to-peer is the counter force. Is it successful? I don't know.

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Appendix 5 Survey

Survey on Intellectual Property in Start-ups/Scale-ups

Welcome to my survey on Intellectual Property (IP) in Start-ups/Scale-ups. I am carrying this out as part of my MSc thesis, and am very grateful for your contribution! The purpose of this survey is to get some insights into the start-up scene and IP currently being used. Please answer the following survey as truthfully as possible.

Time is precious, I know, so don't worry: it should only take you between 5-10 minutes to complete. So grab a cup of tea/coffee/water/juice/whatever you drink, and enjoy the survey!

* Required

Your rights

In accordance with the European General Data Protection Regulation (GDPR), I need **your consent to collect and process your data**.

This survey will not ask for your name; however, you will be asked some individual questions (e.g. gender, age, country of residency) which means in incredibly rare instances your data may be 'identifiable', therefore total anonymity cannot be guaranteed. Tracking of survey responses is neither possible nor intended and anonymous insofar as your name will never be collected nor associated with data you submit in this survey.

Why am I collecting your data? I am interested in not only what you have to say, but also the demographics of the respondents of this survey. I will use these results as part of my MSc thesis which you will have the option of receiving if you wish (last section of the survey will provide this option).

1. Do you consent to the storing and processing of the data you are about to provide? *

Mark only one oval.

- ◯ Yes, I agree (let's do the survey!)
- ◯ No, I do not agree

Skip to question 2

Part 1 - Demographics

A little bit about you

2. How old are you? (answer with only a number, e.g. 29) *

_____

3. What is your gender? *

Mark only one oval.

- ◯ Female
- ◯ Male
- ◯ Other
- ◯ Prefer not to say

4. Which country do you reside in? *

_____

5. Do you work in a start-up/scale-up? *

Mark only one oval.

- ◯ Yes
- ◯ No

Skip to question 6

Part 2 - Start-up / Scale-up questions

6. Are you in a leadership position in your start-up/scale-up? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Other: _____

7. How would you describe the position you are in for your start-up/scale-up work? *

_____

8. What best explains what your start-up/scale-up does? *

Mark only one oval.

- ◯ Hardware *Skip to section 4 (Open-Source (OS))*
- ◯ Software
- ◯ Both *Skip to section 4 (Open-Source (OS))*

9. What sort of IP (intellectual property) is used in your startup/scale-up?(e.g. patents, open-source, trademarks, trade secrets, etc.) *

_____

10. Do you know what Open-Source (OS) is? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ Maybe

Skip to section 4 (Open-Source (OS))

Open-Source (OS)

According to the Open Source Hardware Association (OSHWA), an Open-Source product and its design is one that allows anyone to "**study, modify, distribute, make, and sell the design or hardware based on that design**". More research has shown that to meet this criteria, it is important for the design of a product to be **transparent**, **accessible** and **replicable**.

So in other words, a company that utilises Open-Source as an IP, will share its designs to enable others to build (upon) it themselves.

Skip to question 11

Part 3 - Intellectual Property

11. What made you/your company decide to choose the IP you use? *

_____

12. Did you know about OS when you chose the type of IP to use? (if you were not involved in this decision, please state this) *

_____

13. Would you want to use OS in your start-up/scale-up as an IP strategy? *

Mark only one oval.

- ◯ Yes *Skip to question 16*
- ◯ No *Skip to question 17*
- ◯ Maybe *Skip to question 16*
- ◯ We already do *Skip to question 14*
- ◯ Other: _____

OS start-up/scale-up

14. What made you OS your start-up/scale-up? *

_____

15. What were the **most** important aspects which enabled you to OS your start-up/scale-up? *

Check all that apply.

- [ ] Having a good understanding of how OS works
- [ ] Having a clear idea of OSbusiness models and our opportunities
- [ ] Having the safety of revenue
- [ ] Support from my colleagues
- [ ] Support from my customers
- [ ] Support from my investors
- [ ] Support from my government (funding support)
- [ ] Support from my government (policy support)
- [ ] Support from my supply-chain partners
- [ ] Other: _____

Skip to question 17

Non-OS Start-up/Scale-up

16. Choose the **most** relevant categories of what you would need/want to OS your IP: *

Check all that apply.

- [ ] Better understanding of how OS works
- [ ] Clear business models
- [ ] Safety of revenue
- [ ] Support from my colleagues
- [ ] Support from my customers
- [ ] Support from my investors
- [ ] Support from my government (funding support)
- [ ] Support from my government (policy support)
- [ ] Support from my supply-chain partners
- [ ] I don't want to Open-Source my IP
- [ ] Other: _____

Skip to question 17

Thank you for filling in this survey!

Your participation is highly valued, so thank you for having taken the time. As mentioned, the results of this survey will contribute to my thesis. My thesis is researching the role of Open-Source Hardware in the Energy transition, and how we can enable a rapid and just one. If you are interested in the results of my thesis, feel free to contact me directly via the following email address:

P.L.Fleury@student.tudelft.nl

17. Is there anything else you would like me to know?

_____