Value Creation in Open-Source Hardware Communities: Case Study of Open Source Ecology

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Abstract--**Technical progress in production technology, the advancement and spread of information and communication technologies (ICT) as well as the spill-over of the highly efficient and innovative open source principles to the world of physical products represent a new set of tools and concepts to address the challenges of sustainable economic development. Correspondingly, we can observe (new) modes of value creation that put into question traditional economic strategies and assumptions by stressing collaboration instead of competition and knowledge sharing instead of black box engineering. Open Source Ecology (OSE) is a famous example of a nonprofit organization which fosters worldwide participation and collaboration to jointly develop open source hardware for operation in both developing and industrialized countries. Based on the concepts open source appropriate technology (OSAT), the community aims at the free access to the knowledge and know-how of low-cost and easy-to-build products to empower people to build and run a civilization. This case study describes and analyzes the value creation processes of OSE and derives new opportunities for business models based on openness.**

I. INTRODUCTION

The story of the open source movement has come a long way and its success can be characterized both, unique and revolutionary. Much of what we take for granted while browsing the Internet and using modern information and communication technologies (ICT) would not work without open source software (OSS) (e.g. Linux, Apache, Mozilla, Google, Android, and iOS) [1]. Even more strikingly, the Internet as we know it heavily relies on the accomplishments of the open-source community. It is hard to imagine what the world would look like without it.

The OSS spirit increasingly influences the corporate environment, too. IBM, HP, Dell, Oracle, SAP are just some amongst global IT players that make use of OSS [1]. The results of the "2015 Future of Open Source Survey" (1300 responses from 43 organizations from start-ups to open-source users, vendors and global actors) speak for themselves [2]: 78 % of the respondents reported that their organizations would run all or parts of its operations on OSS. This share almost doubled within 5 years. 66 % stated to offer software products that are built on OSS. Even more interestingly, 64 % responded that their organizations would participate in open-source projects themselves. This corresponds well with projections of the worldwide revenue of OSS which is forecasted to be about $ 55 billion in 2018 (a tenfold increase since 2008) [3].

Within the last 10 years, the spirit of the open-source movement (e.g. collaboration, knowledge sharing, and openness) spilled over to the world of physical objects too, namely open-source hardware (OSH). The success story of OSH is just as impressive. About one thousand OSH projects in a broad range of technology fields can be found such as:

- automotive (e.g. Local Motors, OScar)
- computer systems and electronics (e.g. Arduino, Adafruit, Bug Labs, Beagle Board)
- environmental (e.g. WikiHouse, SunZilla, Global Village Construction Set)
- robotics and drones (e.g. ArduCopter, OpenROV),
- machine tools (e.g. RepRap, Fab@Home)
- medical tools and equipment (e.g. handiii, OPP)

Based on some of those projects, businesses have been evolving that design and sell open-source hardware. In 2010, 13 of the biggest OSH companies (e.g. Sparkfun, Adafruit, Arduino, Bug Labs) represented cumulative revenues of about $ 50 million and they are further growing (e.g. Adafruit: $ 22 million, Sparkfun: $ 39 million in 2013) [4]. The 3D printer project RepRap is another prominent example where an OSH project turned into a million dollar business and boosted a technology. It started as a small community project where people wanted to jointly develop open-source 3D printers whose documentation was freely accessible [5]. MakerBot started selling building kits and ready-to-use printers that were based on the RepRap documents. Within 3 years MakerBot sold 22,000 3D printers. Finally, in 2013 MakerBot was sold to Strasys for more than $ 400 million as the market for 3D printers exploded [6].

The rise of the open-source movement goes along with a paradigm shift in (industrial) value creation. We observe new patterns that cannot be described with traditional economic notions. A modern approach sums up phenomena like open-source under the term bottom-up economics. It is characterized by networking, knowledge sharing, collaboration, co-creation and decentralization enabled by modern ICT. The range of distributed value creation systems (for tangible, intangible and informational goods) varies from production networks that integrate external actors through Open Innovation, Crowd Sourcing etc., via communities of knowledge creation (e.g. Wikipedia), open-source communities up to peer2peer-production approaches and open, networked manufacturing workshops (e.g. FabLabs, TechShops, maker communities).

From a social point of view, these collaborative communities bear great potentials, too. They empower people to participate in value creation, to study and learn, to share ideas and built on each other's ideas. New means of production enable people to be a producer on their own using

local resources in an efficient and sustainable way. In this paper we focus on OSH communities and the way they create and capture value. We give an overview of advantages and disadvantages as well as suitable licensing and business models.

Furthermore, we present a case study on Open Source Ecology (OSE) in order to find out more about the process of value creation in OSH communities. First, the organization will be introduced followed by its value creation systems and processes. Afterwards, we analyze the business model along the Business Model Canvas and give a strategic outlook. Finally, we draw implications for management and science.

II. BASICS OF OPEN-SOURCE HARDWARE

A. What is open-source hardware?

Consequent upon OSS, open-source hardware entails physical objects whose relevant documentation and designs (schematics, assembly instruction, bill of materials, design files, user manuals, source code etc.) are freely accessible [7]. These open designs can be converted in tangible objects with the help of modern digital manufacturing means. According to the Open Source Hardware Association, anyone shall be given the freedom to "study, modify, distribute, make, and sell the design or hardware based on that design". This transparency enables users to have full control of the technology (e.g. repair, individualize). By using standardized components and processes, the knowledge exchange and spread of OSH designs shall be facilitated.

The process of OSH development and design is highly efficient and innovative for several reasons: First, the OSH community comprises a huge number of like-minded, but heterogeneous people from all over the world who mostly voluntarily collaborate on different projects. Second, information can freely circulate. People share ideas, learn from each other and build upon each other's ideas which shall then be contributed to the community again [8]. Last, OSH fosters sustainability when it comes to resource efficiency (e.g. standardization, peer review, crowd sourcing), technological literacy (e.g. learning, sharing, participation), and user empowerment (e.g. repair, service, individualization).

Organizations in rather traditional (and strongly competitive) markets/industries might consider aspects of openness in their business models as well (Open Innovation, Crowd Sourcing etc.). The question is if an organization is able to attract users to collaborate and if it is willing to open up and share its knowledge.

B. Who participates in open-source (hardware) projects and why?

The open-source community is a highly heterogeneous group of people who participate in projects for various reasons. Most empirical results stem from analyses from open-source communities, however the motivations to participate in OSH projects might be quite similar. The motivations entail [9,10,11]:

- Problem solving (for personal/business use)
- Reputation and signaling
- Identification with the community
- Learning/studying
- Altruism
- Fun

With respect to the OSH community, we may look at the findings of a survey of the OSHWA in 2013 (1007 respondents, multiple answers possible) to find out more about the contributors [12]: About 70 % are hobbyists followed by programmers (71 %) and engineers (53 %). Furthermore, there are designers (35 %), inventors (33 %), entrepreneurs (29 %), students (31 %), educators (22 %) and researchers (28 %). More than 80 % of the users participate in OSH projects for fun and/or learning. More than 50 % are interested in creating products that did not yet exist or to create better/cheaper products. Nearly 50 % responded to join projects for work or business interests. When it comes to the use of OSH, nearly 90 % responded to use the products as building blocks for personal use. 66 % want to learn about hardware and 50 % use OSH product as building blocks for professional/work projects.

C. Licensing

One of the major issues with OSH is licensing. It is crucial for all authors and users of open-source works to know about the terms and conditions. The aim of OSH licenses in particular is to balance the initial rights of authors derived from copyright law with the principles of the open-source movement (free access, sharing etc.). OSH licenses make sure that ideas may freely circulate and attribution to contributors is given [8]. No one shall be allowed to restrict the access to OSH. Thus, the rights of users (copy, distribute, sell etc.) are very strong compared to authors who may determine a certain license in the first place. Afterwards, however, their influence is limited to enforcement in case of infringement.

Most OSH licenses were derived from prevailing OSS licenses, but there is a major difference between OSS and OSH: The outcome of OSS projects usually are programs (lines of code as expression of ideas) which are subject to copyright and thus give the author the "right to copy, the right to distribute, and the right to create derivative works" [13]. Copyright, however, does only cover the expression of ideas and not the ideas itself. In OSH projects, this is a problem as the aim of an OSH project is the implementation of an idea in a useful physical product. Still, the schematics and designs are subject to copyright law, the tangible product, on the other hand, is not.

One way to protect ideas/inventions and control the manufacturing and distribution of physical products derived from it, is to apply for a patent. Patent law, however, is not a

feasible way for the OS community as it contradicts the principles of open-source (sharing, openness, collaboration, freedom). Furthermore, to get a patent granted takes a long time and requires enormous financial investments. However, organizations or companies might apply for patents anyway. One solution to be part of the OSH despite having patents would be to grant an open license to the patented technology.

Another way to control the distribution of OSH in the marketplace to some extent is to obtain a trademark. A logo or name could help to identify OSH and link it to a company/organization in terms of quality, reputation, and recognizability (e.g. Firefox, Arduino).

On the basis of the Open Source Definition for OSS, the Open Source Hardware Definition 1.0 was developed accordingly [7]. It determines the conditions for the creation and use of OSH and sets guidelines for appropriate licenses. A broad range of licenses for OSH have been evolving that are either permissive or non-permissive (copyleft). Also, some licenses are not truly open-source as they allow restrictions on the use of OSH (e.g. "non-commercial", "no derivatives"). Even though aspects about the distribution of physical items are considered in some licenses it is questionable if they were enforceable in case of infringement (unlike a patent). The most prominent licenses are Creative Commons, GPL and TAPR Open Hardware License.

D. Potentials (and challenges) of OSH

It was already mentioned that value creation in open-source projects is different from traditional approaches. Open-source projects are characterized through a highly innovative and efficient process of decentralized value co-creation. A crowd of independent, interested and mostly intrinsically motivated users is willing to jointly develop a product, to share knowledge and build upon each other's ideas without a formally monetary compensation. However, this kind of value processes poses challenges too when it comes to governance, coordination and project management [1]. Organizations that want to go open-source should consider the pros and cons, e.g. [13,14,15,16,17,18] (Fig 1).

To sum up, following the open-source movement offers great opportunities for rapid and efficient generation and development of new ideas as well as problem solving. It is important to mention though that these ideas are not coming without giving something in return (e.g. attribution, knowledge sharing, and compensation). Setting up and moderating an OSH project requires an open mindset and the capability to act within a highly decentral and adhocratic network. Organizations will not be able to fully utilize the potential of OSH unless they are willing to play on eye level with the community users.

E. Open-source (hardware) business models

At first view, it seems hard to imagine how one could earn money by applying a business model that is based on openness, sharing and collaboration compared to traditional approaches based on closed systems and secrecy. The introductory examples, however, proof that it is possible. In particular, as the outcome of OSH project usually is a tangible product that requires the use of resources and production capabilities. The OSS industry is a billion dollar market and OSH is following that path. Companies earn money because (and not despite) of openness. Furthermore, there are non-profit organizations that use other sources of income to run the organization and provide the natural resources and means of production to develop and build OSH.

As the OSH industry still is quite immature, a favorable business model has not yet been evolving. Rather, organizations tend to apply a mix of different models. It should be stated too that some of those models are not truly open-source as they restrict the use of their products (see licensing) or mix its products with "closed" elements.

Potentials	• Lower R&D costs (efficient and innovative through Open Innovation) • Better products (peer review, "bug-fixing", testing, customization) • Product as a platform (standardization, modularization, adaptability) • Lower/no legal fees and quicker time-to-market (no patenting) • Collaboration and synergies (partnerships, open standards) • Ethical bonus for the brand (transparent, educational, sustainable) • Lower costs for support and marketing (high visibility, community, viral effects) • Better employees (attractive to highly motivated/qualified/reputable people)
Challenges/ Risks	• Legal risks (copyright vs. patent law) • No governance, adhocracy • Liability/warranty/safety issues (for users) • Project outcome unclear • Community is hard to incentivize • Success is dependent on constant attractiveness of the project • "Uncool" projects might not be supported • Interoperability between closed and open components

Fig. 1 – Potentials and challenges of open-source hardware

Secondary value creation	**Business model**	Education & training	Your Channels	(Crowd) funding	Donations, sponsoring, public research	Foundation/consortium model
	Value creation/ funding sources	Workshops Lectures Consulting Hackathons	Advertisement Product partnerships Certificates	Campaigns Venture capital	Supporters Public funding	Membership fees by individuals/ organizations/ companies
	Examples	Open Source Ecology SparkFun Local Motors Michigan Tech	Sparkfun Arduino Local Motors MakingSociety	Open Edge Open Source Ecology	Open Source Ecology WikiHouse Open Ephys	Local Motors Open Source Ecology
Primary value creation	**Business model**	Producing and selling OSH products	Selling services	Offering support services	Hardware-on-demand	Closed parts/dual licensing
	Value creation	Professional manufacturing (Quality/Warrenty/ Shipping)	Provide professional services using OSH (printing, data etc.) Consulting	Installation maintenance Repair/servicing	Customization Adapations Individual solutions	Freemium models Open core with closed Add-ons Non-commercial CC
	Examples	SparkFun Arduino MakerBot WikiHouse	Arduino WeDesign Local Motors Thingiverse	Local Motors RepRap	Thingiverse Pinshape	Local Motors MakerBot LittleBits

Fig. 2 - Overview of OSH business models

These days, a wide range of business models can be found. They differ with respect to the value creation activities. By primary value creation, we understand the direct value creation through or with the use of OSH. Secondary value creation, on the other hand, covers activities that either support OSH processes (funding, PR) and or spreads knowledge about OSH (workshops, lectures etc.).

Major business models of OSH organizations along the OSHW Business Model Matrix [8] (Fig 2).

III. CASE STUDY: OPEN SOURCE ECOLOGY

A. Profile

Open Source Ecology (OSE) is a nonprofit and OSH organization located in Maysville, Missouri (US) which was founded in 2003 by Marcin Jakubowski. It is also referred to as "a network of farmers, engineers and supporters building the Global Village Construction Set" (GVCS) or a community/global collaborative movement which jointly "develop[s] open source technology for sustainable living" and "to enable post scarcity economics" [19].

Its mission is to "create an open source economy - an economy that optimizes both production and distribution, while providing environmental regeneration and social justice" [20]. Towards an open source economy, the aim is to "develop a modular, scalable platform for documenting and developing open source, libre hardware - including blueprints for both physical artifacts and for related open enterprises" [21].

OSE refers to itself as a "hybrid organization" with respect to the nonprofit notion: "Generate revenue from related product sales" and "capture donations and foundation funding" to follow the corporate strategy ("develop education and research for the common good") [22].

OSE comprises voluntary enthusiasts from all over the world. "Collaborators" regularly join in to help bringing the GVCS to life. "True Fan" support the community with regular donations. Further financial backing is assured by foundations (Shuttleworth Foundation, Ewing Marion Kauffman Foundation) and other individuals. The heart of OSE, however, is OSE International as the umbrella organization. It is led by Marcin Jakubowski as CEO. Together with a handful of paid staff and volunteers (the development team) he coordinates the major activities. Members of the Board of Directors are Marcin Jakubowski (chair), Cameron Colby Thompson, Sunny Bates, Alicia Gibb, and Joshua Pearce. In the future, local chapters are to be organized in regional groups all over the world that shall discuss and spread the idea of OSE and collaborate on relevant projects. Within so called "OSE villages" enthusiasts shall gather to apply and test the principles and technologies of OSE in a community-like environment. Commercial affiliates supply OSE with technologies, material, service etc.

The so called Factor e Farm (FeF), set up in 2007 and located in Maysville too, is an experimental environment where the ideas of OSE come to life. A few people live, work and learn together using local and regenerative resources. It is referred to as a "socio-technical experiment" and a "test bed for systems-level innovation" [23]. It is where the major part of value creation, the physical implementation and testing of the OSH in particular, takes place.

In 2011 after a talk of Jakubowski at the TED conference, OSE received worldwide media coverage and attracted many supporters and fans.

The GVCS is "a modular, DIY, low-cost, high-performance platform that enables fabrication of the 50 different Industrial Machines that it takes to build a small, sustainable civilization with modern comforts" [24]. The machines comply with the concept of open source appropriate technology (OSAT). It refers to "technologies that are easily and economically utilized from readily available resources by local communities to meet their needs and must meet the boundary conditions set by environmental, cultural, economic, and educational resource constraints of the local community" [25].

Staff and volunteers are jointly and collaboratively developing the products of the GVCS continuously at the FeF and online via on-topic projects, design sprints, workshops and other forms of collaborations. All documents and data are licensed as Creative Commons Attributions-ShareAlike (CC BY-SA). The 50 products are subdivided in 6 categories that cover all relevant areas of living and cultivation:

- Habitat (e.g. brick press, bulldozer, cement mixer, sawmill)
- Agriculture (e.g. tractor, soil pulverizer, bakery oven, seeder)
- Industry (e.g. 3D printer, CNC torch table, universal rotor, laser cutter)
- Energy (e.g. power cube, wind turbine, heat exchanger, steam engine)
- Materials (aluminum extractor, bioplastic extruder)
- Transportation (car, truck)

The "Civilization Starter Kit" is a freely available working document/compendium that entails all relevant information (documentation, files, codes, videos, tutorials, manuals etc.) of the GVCS that is necessary to start building products of it from scratch. The goal is to provide a single package to be used by anyone interested once the development of the GVCS project is accomplished.

By end of 2015, 14 of 50 the GVCS machines are being field tested mostly as prototypes. The CEB press (brick press) is almost finished (95 % completion). Other machines as the 3D printer, the power cube and the laser cutter are following with completion status of more than 80 %.

B. Value creation at OSE

To better understand the value creation at OSE, we used a value creation taxonomy that comprises artefact, processes and system structures [26,27]. Then, the OSE design framework and the OSE and GVCS specifications were analyzed and clustered respectively [28].

1) Value creation artefact

Focal point of the value creation of OSE is the development of the products of the GVCS. Like a LEGO set, the machines are broken down into modules that can be developed independently. The scalable modules will be used in any other machine that requires its function. The requirements of the modules and machines are different from industrial products. Still, the industry standard is used as a benchmark: The OSE products shall perform better and be cheaper. The entire documentation of the products is openly shared and accessible on the OSE wiki.

Value Creation Artefact	Structure	• Open-source (development, documentation etc.) • Low-cost (on average 8x cheaper than industry standard) • Modular / scalable (component, module and machine level) • Robust / simple design • Flexible fabrication (minimal fabrication requirements)
	Function	• High performance (industry standard) • Industrial efficiency (productivity standards) • Lifetime design • Flexible (Multi purpose) • User-serviceable • DIY (control, knowhow)

Fig. 3 – Characteristics of the OSE value creation artefact

2) Value creation process

The product development is carried out in the spirit of the open-source movement. Anyone who is interested may participate in any project or process at any time. Special issues are elaborated event-driven via design sprints and open projects both on-site and online. The process can be summed up as: Efficient and innovative global collaboration paired with local prototyping and manufacturing. This approach requires very specific process procedures for design, development, fabrication as well as documentation. Thus, a very detailed description as well as continuous revision is crucial. Replicable best practice processes and business models too will be freely accessible to foster a distributive economy by franchising open business models.

Value Creation Process	Activities	• Open collaboration / collaborative production • Parallel development / division of labor • Best practise • Construction set approach • Scalable processes and projects
	Strategies	• Sustainbility • Open franchising / open business models • Closed Loop Manufacturing • Agility • Efficiency (on global performance) • Local approaches (sourcing, manufacturing) • Sufficiency • Distributive economics

Fig. 4 - Characteristics of the OSE value creation process

3) Value creation system structure

In open-source organizations it is hard to draw clear boundaries of a system structure. It is questionable if there are any after all in OS systems. In the case of OSE, there is a physical and a virtual sphere of value creation with a high degree of exchange and interaction. Both systems are important for the advancement and viability of OSE. Thus, project and process coordination as well as communication in the adhocratic and open organization are critical.

Value Creation System Structure	Organization	• Resilience (adaptable systems for different environments) • Replicable enterprises • Viability • Flexible fabrication
	Coordination/ Communication	• Transparency • Participatory • Adhocratic • Network of like-minded communities

Fig. 5 - Characteristics of the OSE value creation system structure

C. Business model analysis

We used the Business Model Canvas (BMC) [29] to briefly describe the key characteristics of the OSE business model. It is important to mention though that the categories of the BMC (and other business model concepts) are insufficient in considering all aspects of new phenomena like OSH. For example, a clear demarcation between customer/consumer, user und producer/partner cannot be drawn anymore [30]. A user can be a contributor and consumer at the same time without being a customer (from a traditional viewpoint). It was pointed out further up too that the value creation processes can differ from income generating processes as it is in the case of OSE. The primary goal of value creation doesn't necessarily have to be tied to profit making and might have other non-monetary purposes instead. Consequently, the value proposition has many facets. In the end, however, an organization must find a suitable way for sustainable operation.

1) Key Partners

OSE has different partners that are of major relevance for the success of the projects. First, funding has to be assured as it is a major source of income. That includes engaged foundations, but also the crowd of TrueFans (about 300 at the moment). Second, PR is highly important for a nonprofit organization like OSE and so are the relevant partners (TED, OSHWA, and universities) as well as all supporting community users. The most important partners, however, are all collaborators that are engaging in developing the products or supporting the process, e.g. community users, volunteers, commercial affiliates, Wikispeed etc. OSE has to keep a strong focus on the communication and cooperation with its stakeholders.

2) Key Activities

There are many important activities, but the key activity (and major value creation process) is the development of the GVCS. The documentation process and corresponding communication/PR activities towards and with the user community are crucial for an OSH organization to keep the interest level high. Offering workshops (for co-creation experiences) is not a core activity itself, though it is a promising approach for OSE to enable people to build and use their own OSH and to generate income via secondary value creation.

3) Key Resources

Physical resources that are of interest are the Factor e Farm and all the equipment and production means it entails. The non-tangible assets, however, are far more important for OSE, e.g. webpage, blog, wiki, designs, and trademark. Another key asset are the human resources, both online through supporters and collaborators from all over the world and offline with the partners and developers as well as the staff and volunteers on the FeF.

4) Value Propositions

The value that OSE delivers varies widely as the "customer" has a many faces. Primarily OSE develops designs and documentation for open-source hardware that is modular, robust, low-cost, easy-to-build/use/service, and freely accessible. Furthermore, it offers unique co-creation/DIY experiences via of workshops. OSE reduces dependencies, empowers and teaches users and fosters a more sustainable and efficient economy as well as technological and collaborative literacy. It has a strong ethical position and enjoys an excellent reputation in the media.

5) Customer Relationships

The value of customer or better user relationships for OSE was outlined in the Key Partner section. The OS communities and other social media with fans and followers are essential for OSE. They seek for regular updates and multichannel information. The TrueFans need special attention, too. Maintaining these various relationships is a key to the success of OSE.

6) Customer Segments

OSE mainly addresses three groups of (potential) users of the GVCS and participants of corresponding workshops. First, anyone who is interested in OSH and the OSE vision (e.g. FabLabs, hobbyists, DIY makers, OS enthusiasts, students) for the purpose of studying, developing and using OSH. Second, professionals and volunteers in the context of development aid who could deploy the GVCS to empower local communities (e.g. aid organizations, governments, official institutions). Last, basically any local community that seeks access to technology and resources and wants to live in an autonomous and sustainable manner.

7) Channels

The interaction and communication channels are web based, naturally. The OSE homepage is the entry point where basic information about the organization, the (bookable) workshops and the projects as well as a blog can be found. The OSE wiki is an important multilingual database were all relevant information, product and process documentation, a forum and project schedules are located. OSE is communicating with its supporters and the OSH community on all relevant social media via posts, status updates, newsletters, videos etc. Increasingly important is the physical contact to enthusiasts via workshops, university lectures, and speaking engagements.

8) Cost Structure

In 2014, the OSE operations expenditure added up to $ 256 k. Prototyping of the GVCS machines is the most expensive matter of expense (77 %) followed by personnel costs (15 %). Overhead, travelling, fuel, and other expenses play a minor role (8 %). The costs structure highlights the importance of voluntary collaborators for the advance of OSE. The low overhead is a sign for very efficient operations.

9) Revenue Streams

OSE was able to generate overall income of $ 278 k in 2014 (surplus of 8 % compared to 2013). The term revenue is misleading in the context of OSE as the major source of income still stems from foundations (52 %) and donations (19 %). However, revenues from workshops (13 %) and lectures/speaking engagements (11 %) are of increasing importance and essential for the long term viability of OSE. It is a sign too that offering co-creation experiences for sale is a promising approach for OSH and the distributive enterprise. OSE is planning to expand the workshop program, set up an "Entrepreneur-in-residence" model and seeks partnerships with local producers.

D. Strategic outlook

Since the early days, the business model of OSE has been changing a lot. From selling GVCS products to a nonprofit organization which offers co-creation experiences. The GVCS roadmap had to be adjusted many times too. One thing, however, did never change: To succeed with the GVCS and to demonstrate the viability of an open-source economy.

These days, the business model is working well on a small scale. Still, without the backing of foundations and donors OSE would not be able to proceed. Thus, revenue generating activities need to be extended for sustainable operations and advancement of the GVCS. OSE is going to enlarge the workshop program and learning experiences and wants to openly franchise that model along the idea of a distributive enterprise with open business models to be replicated all over the world (OSE campuses, OSE fellows, R&D centers, OSE chapters, entrepreneurs-in-residence etc.).

OSE has demonstrated that it is possible to collaboratively and efficiently develop products in an open and sustainable manner. Even if the impact of OSE is small these days, it might be increasing rapidly once the GVCS is finished and people can produce products by themselves, buy DIY packages and/or co-create the products in FabLabs.

IV. IMPLICATIONS

Technical progress and the advancement of ICTs as well as increasing social and economic imbalance and ever-scarce resources ask for new means of value creation especially with focus on sustainable economic concepts. The open-source hardware movement and OSE in particular represent a promising approach towards an open-source economy that is characterized by knowledge sharing, participation, openness, collaboration, by open access to knowledge and technology as well as sustainable value creation in a post-scarcity society.

The open-source software industry is proof of concept for viable and competitive business models based on open-source. In the realm of hardware, the emergence of companies utilizing OSH can be observed, too. However, the tipping point is not yet reached except for some niche actors. We don't know yet if the story of OSH will be a game changer as it was in the case of open source software.

How will traditional industry face these new challenges? Will they be agile enough to adapt their business model and, thus, stay innovative? Companies like Tesla Motors and Toyota went a step towards openness when they recently announced to grant a free license for patented technology.

Many questions are unanswered with regard to open source hardware. New business models and value creation concepts are necessary to fully understand, describe and, in the end, to harness these new phenomena. New machine concepts and production technologies that are different from the high-tech industry standards have to be developed, too. Finally, an OSH theory finding process needs to be initiated in order to fully describe and understand this new phenomenon.

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