Open Hardware for National Security

Subjects: Others

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Free and open-source hardware (FOSH) development has been shown to increase innovation and reduce economic costs. The opportunity to use FOSH as a sanction to undercut imports and exports from a target criminal country. A formal methodology is presented for selecting strategic national investments in FOSH development to improve both national security and global safety. First the target country that is threatening national security or safety is identified. Next, the top imports from the target country as well as potentially other importing countries (allies) are quantified. Hardware is identified that could undercut imports/exports from the target country. Finally, methods to support the FOSH development are enumerated to support production in a commons-based peer production strategy. To demonstrate how this theoretical method works in practice, it is applied as a case study to a current criminal military aggressor nation, who is also a fossil-fuel exporter. There are numerous existing FOSH and opportunities to develop new FOSH for energy conservation and renewable energy to reduce fossil-fuel-energy demand. Widespread deployment would reduce the concomitant pollution, human health impacts, and environmental desecration as well as cut financing of military operations.

energy policy | energy conservation | climate change | global safety | open hardware

1. Introduction

Free and open-source software (FOSS) is released under a license that allows anyone to use, copy, study, and change it, and the source code is openly shared so that people are encouraged to voluntarily improve the design in exchange for requiring adaptations to be re-shared with the same license [1]. This gift economy [2] results in rapid innovation [3][4] and using FOSS licenses has been widely [5] and repeatedly [6] successful [7]. FOSS has become a dominant form of technical development in the software industry and now 90% of cloud servers [8] run open-source operating systems (this includes most internet companies such as Facebook, Twitter, Yahoo, Google and Amazon) as do 90% of the Fortune Global 500 (e.g., including less-tech-focused companies such as Wal-Mart and McDonalds) [9]. Similarly, 100% of supercomputers [10], over 84% of the global smartphone market [11] and more than 80% of the internet of things (IOT) market [12] also use FOSS.

The same open-source development paradigm [13][14] has started to democratize [15] manufacturing of physical products [16]. This is known as free and open-source hardware (FOSH). The Open Source Hardware Association defines open-source hardware [17] as:

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. The hardware's source, the design from which it is made, is available in the preferred format for making modifications to it. Ideally, open source hardware uses readily-available

components and materials, standard processes, open infrastructure, unrestricted content, and open-source design tools to maximize the ability of individuals to make and use hardware. Open source hardware gives people the freedom to control their technology while sharing knowledge and encouraging commerce through the open exchange of designs.

Open hardware uses viral licenses (e.g., CERN [18]) that demand if users make modifications, they must share their improvements with the global community [19]. FOSH is demonstrating rapid innovation [20][21][22] and is approximately 15 years behind FOSS in terms of technical development [23]. Both technologies have followed an exponential rate of growth in the peer-reviewed literature [23].

One of the core strengths of FOSH is the ability to replicate the hardware from digital designs [24][25] that themselves can be customized [26] with FOSS [27]. Digital fabrication of open-source designs enables wealth growth [28][29][30] and helps even the poor access high-value products such as state-of-the-art equipment [31]. It is well known that open hardware can create opportunities for distributed manufacturing that radically undercut commercial products [32][33][34][35][36]. For scientific hardware, for example, researchers can expect to save approximately 87% compared to proprietary products [37]. The savings are strongest when a form of distributed manufacturing is used (e.g., the open-source self-replicating rapid prototyper (or RepRap) [38][39][40][41] dramatically reduces additive manufacturing costs [42] and increases the number of 3D printing designs exponentially [43] that now number in the millions). The literature shows that low-cost open-source 3D printers can even reduce costs for mass-manufactured consumer goods, on average by 90–99% [43][44].

These savings can be scaled to the national level by investing in the development of new open-source software [45] and hardware of strategic interest to a specific country [46]. In the analysis completed in Finland, one of the secondary advantages is that imported products could be offset by manufacturing products internally from open-source designs [46]. This advantage can be leveraged to act in the same way as a sanction if applied to undercut imports from a specific country and technology sector to increase national security and global safety. Although FOSH is becoming well known, the strategic development of it to meet national goals outside of scientific research has not been explored.

2. Countries Positioned to Use the FOSH Model

Russia primarily exports to the EU (USD $188), China (USD $58.1B), the Netherlands (USD $41.7B), Belarus (USD $20.5B), Germany (USD $18.9B), and Italy (USD $16.7B) [47]. Thus, these countries are in the best position to spearhead the FOSH development. Europe is particularly well endowed with fablabs and makerspaces as shown in **Figure 1** [48]. Thus, they are well prepared to follow a distributed manufacturing (e.g., DIT) model to fabricate EVs, energy conservation equipment and renewable energy such as PV FOSH. In addition, China is already a major open-source technology proponent [49]. China, for example, developed the open-source Kylin operating system, and by 2019, a NeoKylin variant was compatible with more than 4000 software and hardware products and ships pre-installed on most computers sold in China [50]. Combined, Kylin and Neokylin dominate the domestic Chinese market with over 90% of the operating system market share in the government sector [51]. In

addition, China is already the leading manufacturer of solar photovoltaics modules, and thus appears well positioned to benefit from FOSH development of peripheral technologies (e.g., racking and electronics) that would increase the size of their market throughout the world faster than it is already increasing.

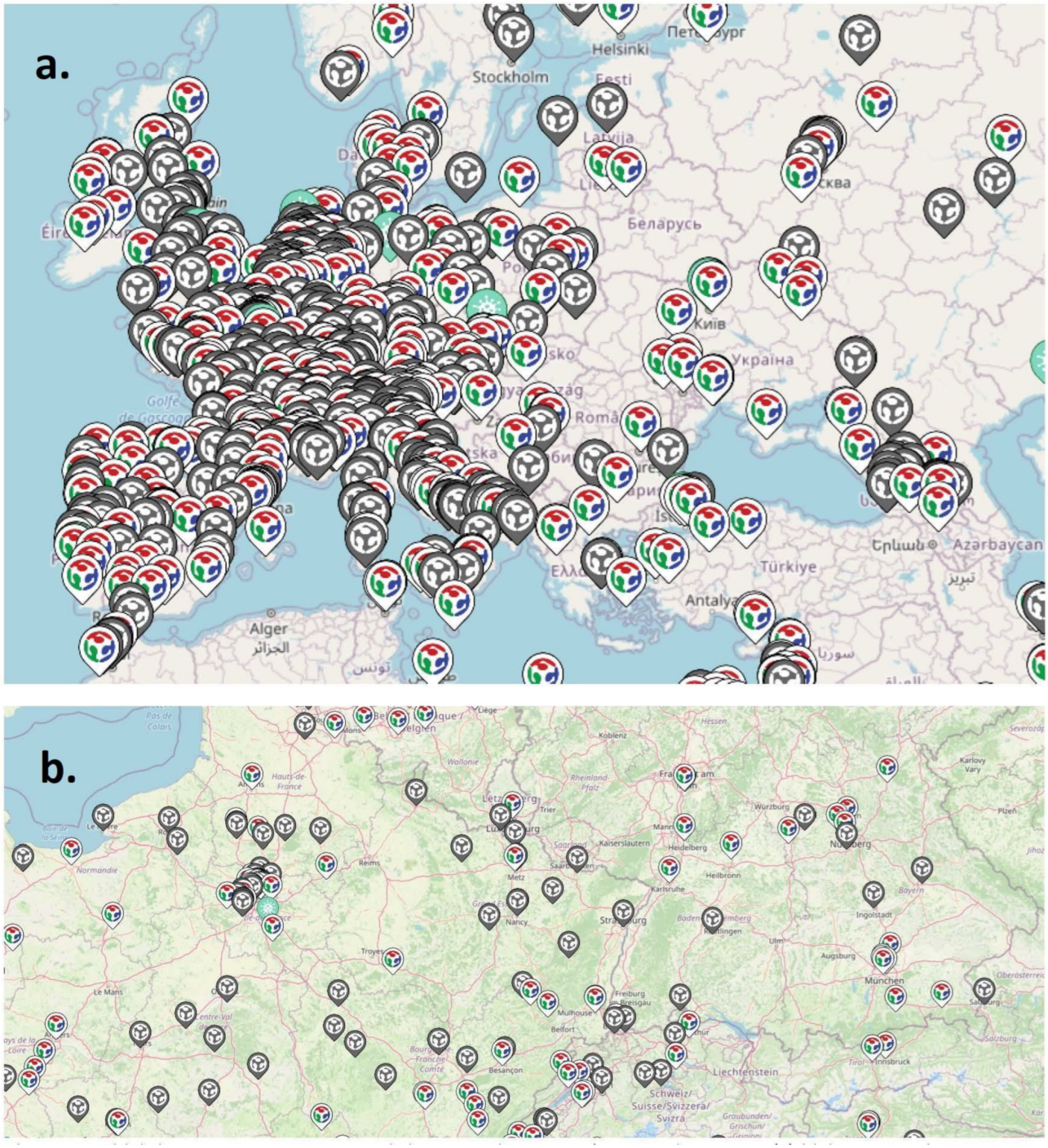

Figure 1. Fablab locations (**a**) throughout Europe and (**b**) zoomed-in view showing clustering of fablabs in population centers [47].

3. Target Response

If a wave of FOSH was developed that made energy conservation, heat pumps, EVs and PV extremely inexpensive to manufacture locally, and countries that import Russia's goods adopted the 'design global—manufacture local' system, Russia's current fossil-fuel-export model would be made obsolete. If Russia attempted to maintain business as usual, it would be economically devastating. As this would be a distributed method of resistance and any retaliation would be against customers, such retaliation would be futile. Instead of maintaining the status quo as an aggressor nation and fossil-fuel exporter, Russia has the opportunity to lift its own citizens out of poverty [52] by leveraging the FOSH funded by external countries to manufacture fossil-fuel-conserving products to meet their own domestic demand and help transition them to a sustainable more diversified economy. This would not only help improve climate stability, but it would also directly improve domestic economic security and thus the perceived need for militarization and aggression.

4. Funding National Strategic FOSH Development

There are several ways the open hardware development could be funded. First, federal governments can use standard calls for proposals (CFPs) specifically requiring open-source licensing of the FOSH technologies listed. Already, for example, the U.S. National Science Foundation (NSF) is investing USD $20 million in the Pathways to Enable Open-Source Ecosystems (POSE) program [53]. The NSF aims to "harness the power of open-source development for the creation of new technology solutions to problems of national and societal importance" [53]. Prior work has shown that open-source investment should result in an extremely high return on investment (ROI) in FOSH [29]. The funding would work as normal university or industry grants/contracts, with the exception that rather than fund researchers and allow them to gain a monopoly on the intellectual property, instead there would be an open-source license agreement mandate. In this way, the researchers are still funded, but the benefits of the research accrue to society more directly. Surveys indicate that the vast majority of faculty would be amenable to open-source development as they would accept an open-source-endowed chair requiring them to open source all of their work [54]. Additionally, national and international funding agencies may wish to sponsor challenges or contests such as the XPRIZE to promote development of FOSH toward specific technical goals by offering "bounties", scholarships, tax breaks, national park passes, lottery entries, awards or even citizenship. The latter rewarding of innovators of citizenship could be a particularly strong incentive to innovate given the current demand in some countries.

In addition to funding and incentivizing FOSH development, governments can also use their purchasing power to accelerate the adoption of FOSH developed in the national interest. This can be achieved by having purchasing policy preferences for open-source technologies. This would include prioritizing funding for open-source technologies over purchasing proprietary commercial products. The government could also make bulk purchases of materials or provide tax breaks for those manufacturing or purchasing FOSH that supports the national interests. Lastly, national governments have the opportunity of creating a free online database of tested, vetted, and validated FOSH to further national interests. It could act as an equivalent to a digital twin model being used in industry [55]. The database would include the bill of materials (BOMs), digital designs files (e.g., CAD), instructions for assembly and operation, and raw source code for all software and firmware. In order to vet designs,

governments could provide funding to universities, companies, and/or utilize technical staff at government labs. Already, the U.S. National Institute of Health maintains an open design database called the 3D Print Exchange [56] and the United Nations is evaluating starting an open hardware database for appropriate technology to meet its sustainable development goals [57].

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