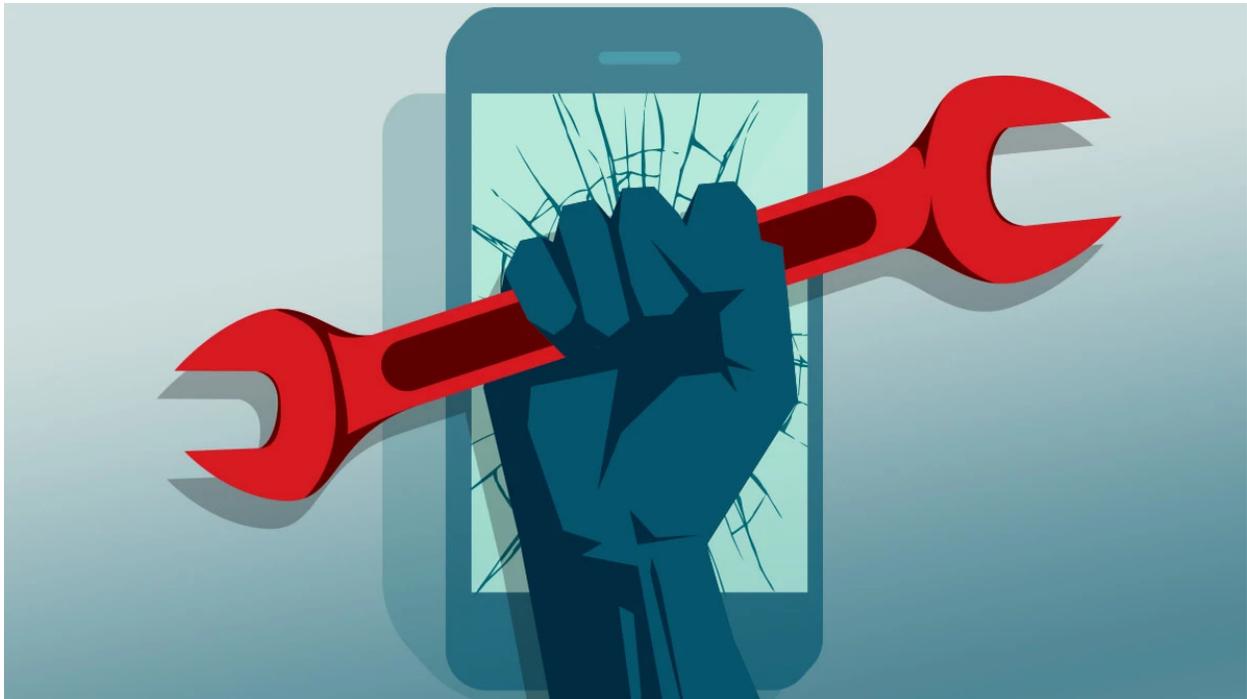


Reviving a Shared Culture of Repair

“Right to repair is the idea that consumers should have the freedom to choose between different options to repair their devices without interference by corporations.”



Source: Consumer Reports

Kevin Guan

guankw@uci.edu

Institute of Electrical and Electronics Engineers

Summer 2022



WASHINGTON
INTERNSHIPS
for STUDENTS
of ENGINEERING



About the Author



Kevin Guan is a rising senior at the University of California, Irvine. He is an electrical engineering major with a specialization in Semiconductors and Optoelectronics as well as a concentration in Digital Signal Processing. He was also an undergraduate researcher working on IGZO Thin Film Transistors. He will serve as the president of UCI's chapter of IEEE-HKN that he has been a member of since his freshman year. He plans on pursuing a doctorate and will continue working at the intersection of technology and policy.

About the WISE Program

The Washington Internships for Students of Engineering (WISE) program was founded in 1980 through the collaborative efforts of several professional engineering societies and has become one of the premier Washington internship programs. Each summer, the WISE societies select outstanding 3rd or 4th year engineering and computer science students, or students in engineering and computer science graduate programs, from a nation-wide pool of applicants. The students gain exposure to legislative and regulatory policymaking through leaders in the Administration, federal agencies, and advocacy groups. In addition, each student is responsible for independently researching, writing, and presenting a paper on a topical engineering-related public policy issue that is important to the sponsoring society. For more information about the WISE program, visit www.wise-intern.org.

About IEEE

The Institute of Electrical and Electronics Engineers is the world's largest technical and professional organization dedicated to advancing technology for the benefit of humanity. IEEE and its members inspire a global community through its highly cited publications, conferences, technology standards, and professional and educational activities. There are more than 422,000 members in more than 160 countries, with more than 50% outside the United States. It includes 543 affinity groups, 39 technical societies, 4.5 million publications, over 1,250 active standards, and more than 1,900 conferences in 103 countries a year.

Acknowledgements

I would like to thank IEEE-USA for hosting this summer's cohort as well as Erica Wissolik and Russell Harrison for their invaluable advice. Many of the meetings and connections I made this summer would not have been possible without the help of our faculty member in residence, Gilbert Brown. I would also like to thank Kyle Wiens, Ron Katznelson, Mark Wingate, Elizabeth Chamberlain, Tomoko Steen, and Elaine Gin for helping me look in the right places. And thank you to the rest of the WISE interns for making this experience one to remember.

Table of Contents

| | | |
|------|------------------------------------|----|
| 1. | Executive Summary | 1 |
| 2. | Background | -- |
| 2.1. | Why Does “Right to Repair” Matter? | 3 |
| 2.2. | Socioeconomics and Environment | 4 |
| 2.3. | Intellectual Property | 8 |
| 2.4. | Antitrust and Consumer Protections | 10 |
| 2.5. | Safety, Security, and Privacy | 13 |
| 3. | Public Policy Recommendations | -- |
| 3.1. | Recommendations for Government | 15 |
| 3.2. | Impact on Secondary Markets | 17 |
| 3.3. | Alternative: Subscription Models | 20 |
| 4. | Final Notes | 22 |
| 5. | References | 25 |

1. Executive Summary

The "Right to Repair" movement is a multilateral approach to reincorporate a culture of repair back into a predominant culture of replacement and obsolescence. This movement has both state and federal initiatives as well as community outreach and partnerships with industry [1]. The idea is that a firm should not be able to exert their influence over people's lives through the products that they offer. These firms should also not externalize the costs associated with manufacturing their devices that allows them to lower their prices by negatively affecting society and the environment. The lack of repair options now when compared to options in the past is due to how the industry has shifted to a business model that is more efficient when replacing than repairing [2]. These are some of the main motivators of the right to repair movement that strives to create a sustainable future where consumer decisions are not affected by tactics utilized by manufacturers [3]. A sustainable future is achieved when less electronic waste is produced, negative externalities from resource extraction and manufacturing is reduced, and more electronics are reused than recycled or discarded. Expecting consumers to shield themselves by making careful purchase decisions cannot serve as a substitute for institutional changes that serve as protections for all consumers, particularly for those without the luxury to pick and choose. These structural changes prevent corporations from infringing on this right through the law, markets, and product design. It is the government's responsibility to secure this right for consumers, which can help extend product lifespans, improve second hand markets, and save repair costs [4].

But different tactics can be used to prevent this from happening [5]. Intellectual property laws restrict the repair process through limitations on parts and tools and can prevent repair practices from being resolved entirely within the courts. The burden of providing evidence of monopolistic behavior by corporations also prevents antitrust laws from being utilized effectively. If firms truly do have a monopoly over repair, these laws should be used to prevent their refusal to deal or right to deal exclusively. Tying or predatory product design must also be handled within the courts by making well-founded cases that a firm is violating antitrust laws. Consumer protection laws can also be used if unfair or deceptive practices hurt consumers, perhaps over things like warranties. There is also the issue of safety, security, and privacy. These are usually catchall terms that corporations could say will be compromised if repair is allowed for all electronics. The extent that businesses should be concerned with these issues is the potential overlap with their liabilities. A firm is only in the business of producing goods

and services while following reasonable standards of safety and security, where securing user's data should be a standard security practice to ensure privacy. Firms can potentially overreach in the pursuit of these ideals, but these are issues that fall within the government's responsibilities, and it should be left to the government to decide what decisions or standards are made that affect the safety, security, and privacy of their citizens. Any misuse by their customers should be handled and regulated by the government depending on the type of technology. These same firms also do not handle these issues once they mark a product as obsolete, further demonstrating the extent of their liabilities. So withholding information is generally not a sufficient security model since good actors like security firms can help provide security fixes that would otherwise be exploited without disclosure.

Thus, changing federal laws in the following ways will help restructure the markets, make designs more sustainable, and improve consumer norms that places greater value on local businesses and community support:

1. Mandating a Federal Degree of Reparability
2. Making revisions to Intellectual Property Laws

Such an agenda has the following outcomes:

1. Secondary Markets will help keep the economy efficient and improve innovation in areas with greater interest.
2. Businesses are incentivized to make their product designs more sustainable.
3. Consumers have more power and discretion to make better purchase decisions.

2. Background

2.1 Why Does “Right to Repair” Matter?

Repair is typically not on the top of people’s minds when they use their devices. It only surfaces when something goes wrong [6]. In these situations, firms have implemented strategic measures that impact the possible options that are available to consumers. A key narrative is to promote replacement over repair due to the efficiency that comes with economies of scale. However, as this paper will discuss, there are social and environmental factors that are not adequately considered in such business models. Replacement also becomes a problem when it becomes forced onto people without the resources to become early adopters of new technologies [7]. Thus, the government needs to implement changes that protect all consumers. And the government is perfectly poised to implement these changes, but it faces numerous obstacles and distractions that prevent it from fulfilling this responsibility. The most obvious one is that the largest corporations also have the largest pool of resources to keep the market conditions favorable to their businesses through efforts like lobbying [8].

Resistance to implementing right to repair legislation can be boiled down to instituting changes that would increase research and development costs for new goods and outcries from industry for being compelled to make sizable changes to their business models. What is not directly communicated is that the current costs of most consumer goods do not reflect the true sticker prices they would have if businesses did not externalize costs. This negative externalization is not clearly communicated to the consumer, especially within a globalized economy where marginalized communities are impacted the most. And the amount of resources available to industry is not growing but is rather being used up slowly, albeit more efficiently but perpetuating the dichotomy of an era of abundance from a preceding era of scarcity. Thus, securing one’s right to repair ensures that the benefits of future technologies are accessible to all.

These four goals, described by the right to repair movement, should be met [9]:

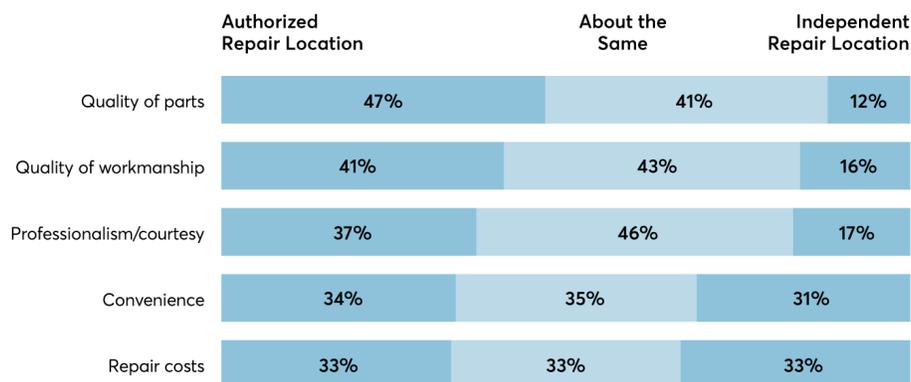
1. The device should be constructed and designed in a manner that allows repairs to be made easily.
2. End users and independent repair providers should be able to access original spare parts and tools (software as well as physical tools) needed to repair the device at fair market conditions.
3. Repairs should by design be possible and not hindered by software programming.
4. The repairability of a device should be clearly communicated by the manufacturer.

2.2 Socioeconomics and Environment

One of the goals of restoring repair is to have access to replacement parts and other tools so that independent repair shops and even consumers are able to start the repair process themselves. If manufacturers do not give independent repair shops their Original Equipment Manufacturer (OEM) parts, these independent repair shops will have to source these parts from existing products and third-party vendors, both of which can be hard to come by and will likely increase delays in service if existing inventory dries up. Certainly certifications would help improve the quality of these non-OEM parts, but the quality of these salvaged and third-party parts are not of immediate interest because of the uncertainty of their availability. What is of interest is that the products destined for the secondary market can utilize the incoming stream of products that will not work. This situation can arise when there are two broken products that, when combined, have the required parts to make one of them work such as with hospital ventilators [10].

The problem is not about whether or not consumers should use third-party parts but is about the quality of service. And surveys show that consumers are equally receptive to using foreign parts and satisfied with the quality of services from an independent repair shop [10]. For the consumer, the path that leads to the lowest downtime has the greatest impact on their perceived convenience and satisfaction, which are some of the main criteria for the success of any business. The two also have entirely different agendas: manufacturer's wish to sell more units through replacement whereas repair shops want to help fix people's existing devices. For example, Apple's repair programs often give customers refurbished products, and their trade-in programs consolidate inventory for used Apple devices, which can have a sizable impact on the secondary markets.

Which Was a Better Experience for Smartphone Repair?

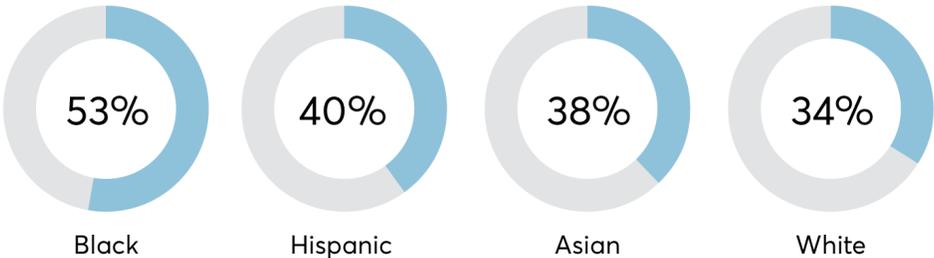


Source: CR nationally representative survey of 2,075 U.S. adults conducted Nov. 11 to Dec. 6, 2021. Respondents had smartphones repaired at both authorized and independent repair locations.

Source adapted from [11].

The importance of the secondhand market is made apparent when considering the different levels of access to the internet and other devices that improve standards of living and life prospects. Those who lack the resources to be early adopters of new technologies are most affected by the loss of repair within the secondhand markets. Perhaps it is the stigma of buying used that makes customers gravitate less towards them, but the factors that are weighted within this value calculus should be considerably different. Thus, a cultural shift would also take place to help people understand the value of buying used, primarily from a functional perspective. Again, those most affected by the loss of repair are low income households and communities of color that lack access to new technologies. For example, internet access for many households is limited to their smartphones, a platform that cannot adequately host all the activities that one might want to do online such as learning to code or doing online homework assignments [11].

Americans Who Say Repairability Is Very Important When Buying a Mobile Device



Source: CR nationally representative survey of 2,075 U.S. adults conducted Nov. 11 to Dec. 6, 2021. Responses are from people planning to get a new smartphone. Black, Asian and white are non-Hispanic. Asian includes English-speaking respondents only.

Source adapted from [11].

In a culture where replacement is expected, various parts of the economy can also be affected. A business model that pushes minor iterative changes each year and withholds substantial hardware changes for a longer period can quickly become unsustainable if more people are encouraged to replace their existing goods for the newest ones. To achieve a circular economy, there are greater benefits when existing products are repaired and sent into the secondary market than simply recycling them for materials [12]. For example, trade-in programs and other recycling programs can take existing products to help offset the costs for new products. What this actually does is undercut subsequent markets that would benefit from old inventory as these markets can promote the exchange of a product that is still functional. In addition, the way firms set up their supply chains can inherently build risk and instability if demand and supply does not follow expected forecasts. Having a healthy secondhand market that fosters repair can help insulate the shock from these economic downturns. This can

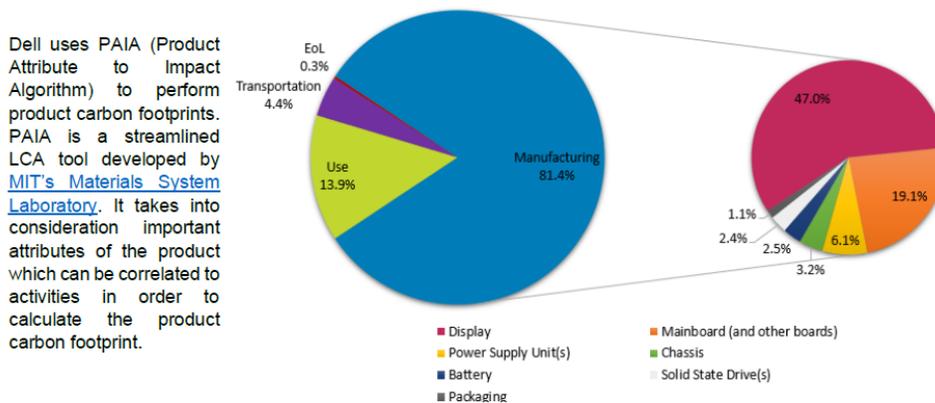
help tide over older investments and keeps more goods cycling within the secondhand market if repairable.

And as business operations scale up exponentially, the world's supply of valuable resources begins to dwindle, clearing the way for more destructive extraction methods to fuel the growing demand for low cost goods. The problem is that the process of manufacturing electronic devices is resource intensive and utilizes chemicals that are thousands of times worse than carbon dioxide [10]. These are treated as a near constant percentage of overall emissions because of the ubiquity and demand for the newest and fastest products. Extraction of these rare earth metals, which are found in low concentrations by nature of batch microfabrication, are currently very limited, and most end up in the landfill, where it can poison the surrounding environment or leach into waterways. The different methods of extraction will not be considered in depth as new fabrication methods call for different materials [13]. Some are more harmful than others, especially those that are radioactive or are sourced from regions around highly destabilized societies like cobalt from the Congo [14].

This product's estimated carbon footprint:

322 kgCO₂e +/- 70 kgCO₂e

Estimated impact by lifecycle stage with breakout for manufacturing by component:



Source adapted from [15].

Generally, the export of electronic waste is not a heavily regulated space. This is banned by the Basel Convention, but the practice still occurs through the use of misleading labels about what exported containers carry, and even recycling centers may outsource some processing to developing countries [10]. These communities have little leverage to ask for better working conditions, often using crude methods of extraction, exposing themselves to harmful chemicals in the process. Thus, more work can be done to handle electronic waste domestically and abroad. Export controls and

sanctions could help prevent the trade of products that are noncompliant. In addition, certifications and disclosure of sourced materials can only do so much in conveying a product's environmental impact. This argument has a similar position towards other labels such as ESG investing or Dolphin Safe certification of tuna, where greenwashing can mislead consumers about these guarantees [16]. Other efforts such as utilizing carbon offsets should be used as a last resort [17]. Thus, regulating programs and certifications like the energy star certification, eStewards program, R2 program, ETBC's Electronics Recycling Scorecard, or the EPEAT registry, perhaps through the Environmental Protection Agency, could be a potential solution [18]. For devices that are no longer suitable for even the secondary market, better technologies that allow for the extraction of rare earth metals that went into making them will be needed. New startups that tackle these challenges should be encouraged to de-risk these problems that even the largest firms have neglected and to foster a reliable and viable domestic option to recycle dysfunctional devices [19].

Additionally, inspiration can be taken from policy initiatives abroad [20]. For example, France's repairability score is laudable, but the efficacy is yet to be proven. These scores are all relative to products within a target market and compresses different categories of information into a single entity in the same way sticker prices compresses the knowledge and effort that went into making a product. The validity of the information provided would also have to be vetted as manufacturer's have high discretion in providing the required documentation, which waters down the accuracy of these scores.

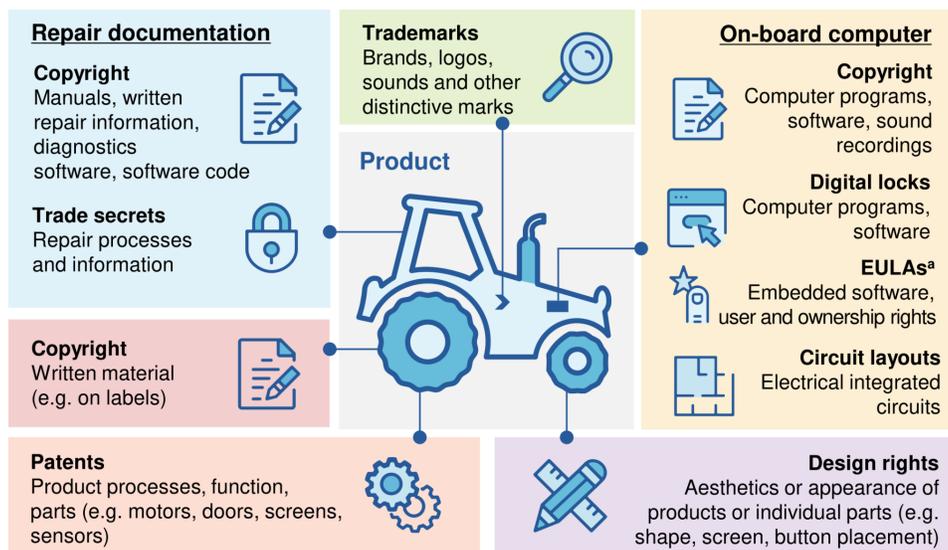
France's score system is based on the following criteria [10]:

1. documentation
2. the disassembly process
3. access to spare parts, delivery times, and availability to independents
4. price of spare parts
5. specific product type considerations

In the end, manufacturer's are not going to slow down the demand for the raw materials they need to build their devices because there is growing demand in the market for firms to compete in. There are two ways to stop the environmental impact of industrial output: slow down demand or increase research and development on new technologies. Much more focus has been on the latter because of how innovation follows where the most capital is allocated and extends towards new technologies that early adopters claim will disrupt the markets like blockchain [21]–[23]. However, this understanding of the nature of innovation fails to account for the types of innovations that would prove valuable for society. By influencing market signals, demand can be driven high artificially for useless features. By extending time horizons, value can be calculated in a way that places more weight onto sustainability measures.

2.3 Intellectual Property

With the complexity of electronics increasing with each new generation that brings tighter integration between hardware and software while improving capabilities of vertically integrating technology, the intellectual property (IP) that guards these inventions becomes increasingly intertwined. These products include utility and design patents, trademarks, copyrights, and underlying trade secrets. The way each of these components of a company's IP is manifested within a product gives a company fine control over how these products are received within the market and what rights users have in using their products as they wish. Depending on whether the components are hardware parts used to restore functionality or software and tools used to run diagnostics, the repair process can be made more difficult if not impossible. Historically, there has been precedent that indoctrinated some degree of a right to repair dating back to *Doan v. American Book Co.*, which established that the "right of ownership in the book carries with it and includes the right to maintain the book as nearly as possible in its original condition" [10]. This can be linked to the principle of exhaustion that prohibits manufacturers from enforcing their IP rights after the first sale of their products.



Source adapted from [20].

In terms of hardware, utility patents cover functional aspects of an invention or process and must meet the criteria of being new but not obvious, giving patent holders a time-limited monopoly over the invention's distribution in exchange for its public disclosure. On the other hand, design patents cover non-functional aspects of an invention and, in the past, were only applicable to human creations and not machined products or parts of a product. The latter criteria has been eroded away to the point that even parts of parts such as the shaft of a drill bit can be given a design patent [10]. The ubiquity of design patents have given firms greater power in reducing access to

repair through enforcement of IP. Another type of IP includes trademarks which are distinct indicators that convey to the consumer the source of a particular good. It aids in the identification of goods that associate a particular firm and the quality that a consumer expects from products carrying their trademark, which must also clear the functionality doctrine similar to that of design patents. Trademarks can be subject to "fair use" to provide the minimum and efficient means of communicating details about a product with a trademark. Trademarks can restrict repair through provisions that govern grey-market goods that bear regional discrepancies for products such as different warranties. This becomes an issue when independent repair shops attempt to place an order with the contractors that manufacturers outsource the production of their devices to or with other refurbished parts vendors. If certain parts with a firm's trademark are claimed as illegitimate, these parts can be labeled as counterfeits, allowing firms to elect nonjudicial procedures to prevent the import of these goods at the border [10].

In terms of software and information, copyright is related to the right of expression of a creative work and not the ideas it represents, excluding functional elements like systems, methods, and processes. And copyrights cannot be enforced when one can successfully argue that how they are using a work is fair use [24]. The merger doctrine also establishes that works that can only be expressed in a limited number of ways cannot be granted copyrights such as directions or otherwise functional procedures due to the nature of how accurate a work must be [10]. Most scientific and engineering works are separated from creative works except for computer software. Copies of software for the purpose of repair in a computer's memory is allowed under section 117 of the Copyright Act [10]. However, this copy must initially reside on the owner's machine for this to apply. But firms can tie this software to a license in order to lock it down and are enforceable if related to copyright. Section 1201 of the DMCA does not exempt the trafficking of software that circumvents technological protective measures (TPMs), rendering the cross-communication of information related to repair for secondary markets unfeasible and can prohibit cracking things like Digital Right Management (DRM) for the purpose of repair [25], [26]. In addition, there are both state and federal protections for trade secrets, the Uniform Trade Secrets Act and the Defend Trade Secrets Act, respectively. These acts grant certain protections as long as the proprietor made some reasonable effort to secure their secret. However, these protections do not prohibit reverse engineering. Misappropriation can also occur when information is leaked from somewhere within the firm. But once the secret has been shared with others, subsequent parties cannot be held liable for misappropriating it, only the first party. That is why non-disclosure agreements, non-compete clauses, and work-for-hire (employee poaching) are typically enforced by the largest corporations, which inevitably decreases competition. This also provides limited whistleblower protections under constitutional rights for the purpose of public "fair use" and not for personal advantages, which can have applications for increasing access to repair [10]. Indeed, most manufacturers' claims can only be substantiated with IP law and serves as the main tool in preventing undesirable market

behavior. Contract law and licensing can also assist businesses as these supersede some federal protections.

2.4 Antitrust and Consumer Protections

Balancing intellectual property and antitrust laws has always been a difficult thing to do because of the differing positions each takes on how best to ensure innovation and competition. The former grants time-limited monopolies to provide monetary incentive for the public disclosure of inventions, and the latter breaks up monopolies if such firms increase barriers to participating in the market or exhibit anti-consumerist behaviors. But more recently, antitrust law has been diminished by vocal groups such as those that believe the government should minimize their involvement within the markets for the purpose of "maximizing consumer welfare and allocative efficiency" [10]. However, an unintended consequence of absolving the government of this responsibility is that the path towards maximizing market efficiency leads to greater consolidation of market power through monopolies. Much of this influence is attributed to permitting firms with greater resources to rely on strong intellectual property laws in safeguarding access to innovative technologies. Another piece of this issue includes the ramifications of the seller's advantage where information is unevenly distributed and can reduce the market efficiency if consumer decisions can be effectively influenced. An example of where this information can be used is in the pricing of external warranties. Manufacturer's potentially know how long their products should last under normal usage from their internal testing and other data collected from their volume sales and marketplace activity, especially with forecasting bolstered with data mining. Thus, a smart business decision would be to set the duration of these warranties before the product fails. Businesses would typically not offer services where they will lose money if not for the purpose of improving client relationships or gaining other immaterial advantages. And these warranties typically offer replacement over repairs, where the former is often more convenient and has the added benefit of increasing production volume at the expense of externalizing costs in the process of manufacturing more products.

In addition, the Magnuson-Moss Warranty Act of 1975 states that any warranty over \$5 must disclose all terms and cannot be conditioned on warranties on particular brands of parts or services if it is not offered for free [10]. Any contractual terms are also not protected but are, instead, governed by state insurance laws. However, many products still come with warnings that a manufacturer's warranty will be voided if the user attempts to disassemble and repair their purchased device, often found on stickers placed on the product. In light of a growing number of offenders, the FTC is working on improving the industry's compliance with this law [27]. Given the wide discretion that industry is able to use in marketing their products and services, customer behavior can clearly be influenced towards purchase decisions that benefit corporations for the purpose of increasing their market share. To insist that the customer is able to gather

relevant information related to lifecycle pricing should be considered an idealistic interpretation of what a consumer is willing to do within a capitalistic market.



Source adapted from [28].

Moreover, firms can only be expected to provide parts and support for their devices for up to seven years based on the California's Song-Beverly Consumer Warranty Act [10]. This is an example of how a state-led initiative has a substantial impact on the industry's business model because the market in California is big enough to refactor their supply chains. In the future, this inventory requirement can be met by 3D printing replacement parts by simply distributing the final CAD file with licenses, a win for both sides of the right to repair movement. In the meantime, the average product life cycle can only be influenced through law and consumer expectations. And other state-led initiatives run the risk of businesses simply not selling their products in these regions, hurting the customers there the greatest. Still, other state bills have been introduced like the Washington bill for right to repair which is the most comprehensive of all the states [25]. Some federal initiatives include the American Innovation and Choice Act and the Open App Markets Act which are two antitrust bills that were recently introduced in 2022 [29]–[32].

In the past, antitrust law has successfully been used to break up monopolies like Standard Oil. A more recent example was the antitrust suit against Microsoft. This firm was able to avoid being broken up into two entities, with one providing the operating system and the other providing software applications, by agreeing to a settlement which had included provisions such as giving third party applications more support. The fallout of this case will not be discussed further as what is of importance is the notion that firms that wield extraordinary influence over the way consumers can use new technologies should be held accountable if they negatively impact competition and innovation in the markets. Thus, the argument that right to repair will force compulsory licensing is a valid concern, but it will only be an issue if the manner in which firms construct these arrangements exhibits a monopolistic behavior, serving the firm's interests over the interests of their customers. The purpose of intellectual

property must place the advancement of technology for the public good before the monetary incentives of those first to file.

The largest technology firms are also responsible for responding to demand within the online marketplace. Search algorithms show the most popular sites for buying a certain product, of which customers would customarily click on those on the first page of results such as Amazon. Most people can find good bargains online, comparable with those at retail stores and rarely think about buying used unless they are goods like books as opposed to electronic devices that constantly have new models introduced into the marketplace, boasting more features than the last generation. But other online marketplaces like eBay can only offer a fraction of the sales volume that vendors can get at Amazon. Much of this is associated with how the experience and know-how of shopping online is solidified early on, making convenience and ease of use an important factor in the online marketplace. In addition, the secondary market for used goods may seemingly coexist with the primary markets for new goods on these sites, but there are surely much more inconveniences associated with buying used goods that makes the discount not worth it for buyers when compared to new products that would have better customer protections and have a higher change of meeting customer expectations. Competition within these online marketplaces can also be affected by decisions meant to increase the profitability of selling products online. One example of an agreement between two firms that undermines competition is the deal between Apple and Amazon to sell the former's products directly on the latter's site. The terms of the agreement require Amazon to remove any refurbished or used product listings with Prime shipping, effectively shutting out third-party sellers from Amazon's massive online marketplace because of the dominant market position Amazon has in e-commerce [10]. This agreement is being actively investigated by the German Federal Cartel Authority [10]. In addition, relying on manufacturers to support the market for repairable goods may not lead to desirable outcomes due to these firm's contradictory agenda of increasing revenue streams. For example, the contract that allows independent repair shops to access parts and tools from Apple requires the latter to have an outsize control over the former's operations such as agreeing to impromptu audits and sending their customers' identifying information [33]. Predatory agreements and practices may be grounds for a potential suit, the burden of which must establish whether or not a firm violates antitrust laws like the Sherman Act or the Clayton Act using the rule of reason [10]. Some indicators of potential illegal monopolies include exclusive dealing that prevents the emergence of new products for the purpose of reducing competition.

There are also consumer protection laws that can help prevent corporations from exerting outsized influence over their customers. One aspect of an imbalanced relationship can be quantified by harm where any added expenses, delays, or inconvenience can negatively impact consumers. Consumers cannot be expected to factor in life cycle pricing if not immediately accessible at the point of purchase, where other factors such as negligent advertising and being locked-in to a firm's ecosystem of products and services can more easily sway consumer decisions. These market

pressures expound the difficulties of the average consumer from having enough information at the time of purchase. Here, false advertising law can be pulled in to combat warnings that a device is insecure due to unauthorized repairs due to electing third-party services. Bringing charges against firms through state-led initiatives may be easier to pursue but these also have their limitations [34]. These types of cases, especially class-action suits, do not give nearly enough reparations to each plaintiff. The value of these cases comes from establishing precedent. In addition, the right of intellectual property owners to exclude has had different interpretations within different courts, making it unclear when to properly exercise these rights, which must be resolved in future cases that must make it clear that IP holders should not have total immunity from antitrust laws. But each case would have to provide the burden of proof that established the reasoning for such an outcome.

Unfair practice suits can be brought based on the following [10]:

1. substantial injury to consumers
2. not outweighed by countervailing benefits
3. not reasonably avoidable

Deceptive practice suits can be brought based on the following [10]:

1. a representation, omission, or practice that is likely to mislead the consumer
2. as evaluated from the perspective of a reasonable consumer
3. the representation, omission, or practice must be material

2.5 Safety, Security, and Privacy

Consumer safety should not be overlooked, but it is for the government, not businesses, to decide the best way consumers should be protected such as when conducting self-repair. As long as companies are not held liable, the government can determine safety standards that must be met. The goal of a business is to introduce goods or services into a market where there is demand. There are reasonable safety standards they must meet in the design of their products, but these rules fall within the responsibilities of the government. Internalizing these safety concerns only increases costs and the influence of firms over how customers may use their products, as seen by firms citing safety concerns over their refusal to allow third-party repairs [35]. Furthermore, concerns over unauthorized modifications such as emissions and safety shut-offs are also not within a company's jurisdiction. This also applies to stolen electronics since the transfer of ownership should be held as a higher priority over allowing firms to lock down systems tied to a single user, which would prevent reuse on the secondary market. Manufacturer's could argue that limiting repair increases reliability, safety, and security, but these actions make customers more reliant on their services. In addition, manufacturers only are required to support their products for 7 years, which most firms elected to respect across all regions it conducts businesses in. Manufacturers generally will not be held accountable for self-repair if the information

they provide is holistic and includes all safety warnings without losing clarity and feasibility, much like the warnings involved with operating heavy machinery [36].



Some smartphone repairs require a downpayment for consumers to rent the official equipment for doing repairs among other hurdles.

Source adapted from [37].

Additionally, concerns over the integrity of the security stack of a product are also brought up as grounds for refusing to give third-parties access to their diagnostics or other software tools and information [38]. However, most modern security models separate the functions of every core function of the product and should be examined as a case study of how security of popular platforms should behave. Video game consoles are an extreme case where the security model assumes that even the owner of the console could not be trusted to prevent piracy and cheating. In these systems, most communication and secrets in the console are encrypted, with the CPU nearly the only component that can be trusted [39]. Different methods of securing a console can have ramifications on repair. For example, having serialized components that tie components such as optical drives to the motherboard is a design that inherently builds greater risk of failure into the device. Implementing a hardware-based firewall to monitor the communication protocols between the optical drive and the motherboard is a more robust solution [40]. However, it would certainly incur higher costs for its research and development whereas it costs less investment to tie these components together with serial numbers, a process that can lead to higher defect rates. These consoles are also sold at a loss because their business model makes back profits by selling games. Thus, repairability of consoles would not be of primary concern if the firm would rather sell a replacement because of how low they priced their consoles.

These low costs may not also reflect the externalities that accumulate in the process of manufacturing these devices if they are sold at a loss [41].

For these firms' claims to be substantiated, disclosure of a high level abstraction of their security model for a product and evidence of vulnerabilities should be the bare minimum in establishing a proper case for preventing access for the purpose of repair. In addition, many of these vulnerabilities can be potentially mitigated by adopting an industry standard such as properly encrypting and anonymizing all communications. Revisions of a standard offer a snapshot of the field's knowledge about the best security practices. Thus, withholding information is not a security model that companies should rely on. As long as a degree of discretion is used to prevent liability, security issues and misconduct from abusing software to get around regulations is outside of the scope of companies. Thus, firms need to support their blanket statements of compromised security caused by distributing software tools if they are to restrict access to their products.

In addition, for each firm to have their own proprietary security stack, the rate at which vulnerabilities are detected scale proportionally with the number of products sold with the same architecture. This is a growing problem for companies that scrape sensitive information like biometric data. If this data was not, by default, secured, it would not take independent repair shops with authorized tools to breach these security protocols. Scaling and popularity are the main factors that correlate to the number of hacks because it is simply the most efficient use of resources. There may be cases where these security flaws can be kept a secret to extend the lifetime that an exploit is used, but it is often by sharing these tools that it becomes profitable since a security firm always runs the possibility of finding it and patching it. Thus, industry should utilize security standards to provide an efficient means of ensuring data security and privacy.

3. Public Policy Recommendations

3.1 Recommendation for Government

Such initiatives require all three branches of government to work conjunctively to implement a framework capable of restoring the right to repair. Federal laws and regulations are hard to pass and enforce respectively in a technologically innovating environment. Thus, the types of cases that are brought in court will have a greater short term impact on the state of repair until substantial changes can be made into law or be better enforced. The beauty of this approach is that all contracts and standards are worked out within industry as long as they do not infringe on antitrust or consumer protection laws. Congress's degree of reparability must call for a baseline standard that industry is willing to agree to. This industry-led effort should become a part of the government's regulatory or legislative framework through incorporation by reference such as through directly copying and modifying. This is in compliance with OMB

Circular No. A-119 and the 1995 National Technology Transfer and Advancement Act that states that commercial standards should be evaluated before the federal government can use their own [42].

Legislation that secures the right to repair has been introduced in many different states, but adoption can only bring about the proposed benefits to all if manufacturers will update their business models rather than simply not conducting business in select states [43]. Implementing this provision within federal law can help expedite manufacturers' efforts to improve their sustainability targets to retain access to the US markets. Moreover, a lack of a degree of reparability can permit corporations to over-engineer needlessly and increase the electronic complexity of their devices. In addition, forcing uninterested parties into doing things that have a meaningful impact on society is not an unrealistic idea. In fact, the government has established laws for worker protections and patient privacy in response to the industry's lack of consideration of these fundamental rights.

All other derivative standards can be worked out in their respective fields that should incorporate perspectives from both large firms and small inventors. Different types of technologies can work out the best way to achieve this near universal design goal for sustainability with the support of experts in their relative fields. Tax credits or other financial tools used to move capital and other resources should be monitored carefully. Legislation like the carbon tax runs the risk of passing these fees to the consumer by marking up the price of goods that firms produce. In fact, all changes to the business models and structures of firms are likely to increase prices which may decrease demand for products. However, this effect will likely help reprioritize the features consumers expect in new generations of products, which will be discussed in more detail below.

The current work of regulatory agencies like the Federal Trade Commission have included outlining a plan forward in regards to repair. The FTC issued a report called "Nixing the Fix," and the Biden administration's executive order has called for an investigation to re-evaluate the government's efforts to bolster repair [44]–[46]. These measures are a step in the right direction and can help expedite the government's response to this overarching issue. The next step would be to deal with noncompliance that should force manufacturers to disclose warnings about how long such a product will last based on normal usage like how food has an expiration date. These products should also have a tax hike to better inform the consumer about the costs associated with negative externalities and to steer customers in the path of more sustainable products that are in compliance. Electronic consumables like AirPods are fundamentally a product that cannot be shared with others. Thus, it should be considered a modern luxury with a price that reflects that principle. This allows the full price to be understood by the consumer and to reincorporate the negative externalities that allow such products to exist in their target price bracket. Congress should give the FTC the power to impose fines based on a percentage of sales volume of noncompliant items. Take-back laws will also not meet this paper's proposed degree of reparability because they reduce the availability of compliant products or simply are shipped

elsewhere for resource extraction to the detriment of the communities these items are exported to. However, startups and other firms that attempt to deal with the repair or recycling of electronics should not be penalized. Thus, exemptions should also be made to companies that contribute to this paper's sustainability goals.

3.2 Impact on Secondary Markets

In order to improve the health of the secondary markets, indoctrinating a degree of reparability must be accomplished to drive economic growth for the market of used electronic goods. A potential solution is to have a tiered model based on a firm's market cap that determines the changes firms must incorporate to remain in compliance with this degree of reparability. Industry-led efforts by nonprofit organizations such as IEEE can help to provide transparency on how standards and other agreements are arranged to meet this design goal to reach an achievable target of sustainability through prolonging the product life cycle within the secondary markets. These points of consensus are more binding than laws such as France's 2020 Anti-Waste and Circular Economy Law that mandates reparability scores or the Hamon Law that bans planned obsolescence [10]. These types of laws are hard to get passed and even harder to enforce due to the variation with which companies can remain in compliance. In addition, violations often are resolved with companies paying fines after these cases can no longer be appealed. Standards are a more efficient way of reaching industrial consensus, of which there is only a single criteria to consider that will have a cascade effect into all other facets related to repair. Updating such a standard will be based on the capabilities of the current tools utilized within industry as research and development propels innovation towards more consumer-friendly practices. As will be explained below, these standards are for companies looking to scale up. Smaller firms should not undergo the same level of scrutiny as larger firms; however, it remains something they should keep in mind if they are to scale productions. And there is no discussion of royalties or standard essential patents within the scope of this paper since incorporating specific technologies is something industry will have to deal with through greater transparency such as balancing views from the largest to smallest companies in producing a standard, which can be further refined with judicial processes [47]. To design without a degree of reparability in mind would be gross negligence within the courts and illegal if implemented in law.

Independent repair shops are critical to the secondary market as they function as hubs where devices can enter the secondhand market while also preventing manufacturer's from having a monopoly on repair. Sourcing parts will not be an issue for independent repair shops if protections are in place from limiting the scope of design patents and trademarks. For the former, conceptions of design are fundamentally about the entire product as they all contribute to the single aesthetic experience that consumers have. This emergent property does not exist within each part but rather is found in the sum of these parts that gives a product its advertised aesthetic function. However, opening these doors may provide an avenue for imitation

products to undercut the sales of the original patent holders if priced lower. But achieving lower cost points demands for lower quality materials, which can be affected by this paper's sustainability standards and, therefore, be subject to fines. By incorporating these changes into patent law, the principle of exhaustion can be used to reclaim the right to fix any product to its original specification such as in situations where third-party parts are used to fit the precise form factor of a device. Trademarks can also prevent the exchange of replacement parts or refurbished products because of the broad coverage of grey-market goods that prevent the sale of products with regional discrepancies, which firms can elect nonjudicial processes to block their imports. Congress should change the scope of trademark infringement by considering how large firms can maliciously utilize their complex supply chains to reduce access to parts. These changes are meant to increase the quality of services consumers can expect from independent repair shops. This is a high priority because a study shows that consumers are less likely to repair their devices if it is more inconvenient than replacing them [48]. Thus, to support competition within the repair market through lower prices and timely repairs, independent repair shops must have access to the parts and tools they need for the repair process of any device, a battle which remains almost entirely within intellectual property laws.

With such changes, devices can be easier to repair or have their parts harvested to service other functional devices. If the need arises, the government could potentially offer their stamp of approval through a safety and testing certification process or requiring greater transparency about independent repair shops' inventory manifest. However, such assistance would not be required once the repair process is secured for most independent repair shops and consumers as this enables local businesses to set competitive prices when compared to the services offered by authorized repair shops, essentially placing a price ceiling above which businesses can no longer remain competitive. By evening the playing field, the free market can help lower costs and improve the quality of service. With more devices being repaired, the secondary market will experience a greater influx of inventory that would not have been possible with manufacturer's controlling the volume of their devices circulating in the current market. Moreover, such an environment fosters greater trust in local businesses and communities enthusiastic about old and new technologies. These same communities, whether online or in-person, can help support many devices past their end of life dates, perhaps by sharing security patches and other repair tools. This hinges upon the exemptions in section 1201 of the DMCA, a precarious arrangement that must be renewed every three years and does not provide full coverage over all electronic devices. A more permanent and holistic solution is preferred to reduce the risk of such critical exemptions from being denied by the Librarian of Congress. In general, not having access to software tools and information is mainly a restriction due to inconsistencies between copyright and contract laws. The End-User License Agreement (EULA) prevents access to software as part of contract law which supersedes any guarantees offered by exemptions to section 1201. The interplay between the two must

be worked out within the courts or in law, which can start from understanding how sustainability is incorporated within each position.

The government should generally not be involved in the market unless the market discourages competition or companies do not assume responsibility for issues that they should be held liable for. Specifically, firms should not pose an obstacle to transactions that transfer ownership of electronics goods, where this process serves as another indicator of the health of the secondary markets. Consumers are free to keep or sell their devices, but they should be able to do so without being taken advantage of, especially within online marketplaces [49]. Nevertheless, used electronic goods present a value proposition for those that currently do not have reliable access to such technologies that would increase one's standard of living, allow them to communicate with loved ones, and improve their education.

These changes help put downward pressure on the market for new goods by reducing demand for products that are not drastically different from existing products. Innovation is not hindered in so far as minor iterative changes are not considered technological leaps. The reduction of profits of the most valuable companies due to people not buying the latest and greatest or buying secondhand will present the opportunity for consumers to spend elsewhere or to invest in their future, perhaps in company stocks that contribute towards climate change solutions or cancer research. This paper's recommendation maintains that such an environment fosters research and development in fields where priority is given to the most pressing matters, not trivial ones. It redirects the cash flow from alleged monopolies to other areas of interest that offer greater functionality, changing the narrative of consumer culture to value function over form and gimmicks.

Additionally, for companies in the prototyping phase, it is often beneficial to rapidly develop their technologies and to generate interest from those who are willing to invest in their technology. There are also community-funded businesses that allow individuals with less resources than a typical venture capitalist to fund technologies that interest them. Imposing this paper's design constraints on these products that have not produced a sales volume worth investigating should be avoided. However, proposing such an exemption should be carefully evaluated to prevent companies from exploiting it. Ideally, this exemption should apply to companies that have a market cap of less than \$1 billion, the threshold where many startups achieve "unicorn" status and are viewed as incredibly profitable. When companies turn profitable, they are better positioned to secure more advantageous contracts and arrangements to scale their operations. It is this threshold where accounting for sustainability is critical, as the capabilities for increasing the company's assets unlocks potentially exponential growth and capturing greater market share. This paper agrees that risk takers should still be able to assume any amount of risk they are comfortable with. Another concern presents itself when these companies are bought up, formed into a subsidy, or forms a contract with a company with a market cap greater than the threshold. Public disclosure about the value of these arrangements or partnerships should be carefully monitored to prevent loopholes.

These changes inevitably will benefit the average consumer. They are free to keep devices themselves whether as mementos or to replace them as they see fit as participants in the primary market. However, lowering the barriers that allow the influx of goods from these primary markets to secondary ones allows owners to transfer ownership of goods to those who would value their functionality and cannot afford new goods. One's relationships to their devices in the secondary market are noticeably different than their counterparts in the primary market because of this reprioritization of value. The important thing for consumers to keep in mind is to value reuse over recycling. In addition, consumers are not expected to understand how every aspect of their devices works. But repairing one's devices can be perceived as a sort of tradecraft that could be a valuable way of spending one's leisure time.

3.3 Alternative: Subscriptions Models

Subscription models, particularly hardware ones, offer an alternative solution to the issue of maintaining one's devices that could have certain advantages such as greater flexibility, portability, and variety in the way customers access new technologies [10], [50]. But there exists a fundamental difference between enterprise and consumer grade versions since the business models behind each inherently offer different value propositions depending on the client's needs. Businesses would subscribe as a means to generate their own capital whereas consumers would view the subscription's included equipment as ends themselves. For example, in industrial cloud computing, businesses can save the costs associated with running their own servers for deploying an IT platform and, instead, focus on their products that are not directly tied to the physical infrastructure. An example of a consumer grade subscription would include services that offer equipment such as air conditioners that come with the latest features to improve one's comfort within their homes or potentially ones that offer electric cars [51].

Thus, for personal licenses, the value proposition consists mainly of greater convenience and the reduction of responsibility of maintenance. In exchange for physical ownership of their equipment, a customer is given a product that will receive firmware updates, free repairs, and a future replacement as long as they remain subscribed. Indeed, it offers a compelling solution to the problem of repairing one's own devices, but it fails to capture other values such as the freedom associated with owning property. For instance, the functionality of devices as part of a subscription is not fundamentally owned by the person using them. This problem is often exacerbated when there are delays in customer support of such subscription services, potentially due to the instability of the economy and disruptions in the supply chain. These products would generally have free warranties included with the subscription, and any attempt to repair them could void the contract of their subscription since these types of businesses would not want consumers to inadvertently damage their equipment. In these situations, a consumer could be left with a dysfunctional product with no alternative means of securing a working device if the cost of buying or financing a retail

unit is too expensive, if even available. Thus, such subscription models expose consumers to greater risk in exchange for lower upfront costs and convenience.

There is also something that is lost when one is not an owner of a product but simply has the license to use it. Less care is taken to treat these devices well and to integrate them within people's lives. As a result, people lose a sense of conservation and preservation of the things they use the most. In addition, when compared to leasing or renting, buying helps build wealth by allowing the owner to associate a monetary value with the assets in their possession similar to that of a mortgage, and these assets can be sold just like any other commodity. On the other hand, what subscription models offer are essentially consumable products that expire if one unsubscribes. In a subscription model, the responsibility of upkeep falls squarely on the manufacturers, but they may not be compelled to make their devices more repair-friendly or to reduce the electronic waste they produce. With enough potential subscribers, manufacturers can maintain their production volume and save costs by not considering alternative solutions and elect to replace defective units with minor adjustments to their existing business models. Externalization of costs and potential monopolies of markets remain serious issues that would be exacerbated by subscriptions. Subscription models also carry the risk of software locking features posing serious concerns when these products are unsupported by manufacturers or are sold on the secondhand market. These types of problems share a common base with the growing platform of Internet of Things (IoT) devices like smart home electronics, especially those that are produced at scale and potentially sold at a loss [52]. These devices work by consulting remote servers that house most of the functionality that is advertised in their marketing. But if the connection between a device and these servers are severed, the consumer's device will be unable to fulfill basic functions despite the hardware being in optimal condition. Unsupported IoT devices are, therefore, the most vulnerable to being forced into obsolescence without recourse. Therefore, ensuring functionality at the point of sale should be a key consideration when determining what would constitute a sustainable design.

4. Final Notes

By implementing a degree of reparability within law through a bill introduced by Congress, the design of products and the market they are introduced to are able to change by establishing a framework from which court precedents and industrial consensus through standards can be generated. A degree of reparability assumes the acknowledgement that a device is constructed and designed with repair in mind. To enforce this notion of a degree of reparability that carries with it a level of sustainability, Congress should also give the FTC or EPA the power to fine corporations in order to better enforce this law. This could even be a percentage of the sales volume of noncompliant products. Compliance would require manufacturers to distinguish their products from being acceptable within the secondary market for used goods or being consumable products like wireless earbuds. Products like AirPods are hard to repair and have small batteries that degrade over a few years that reduces their functionality, essentially coming with an expiration date. Industry is left to figure out the best sustainability standards to meet this federal requirement which should prevent companies from over-engineering their products needlessly. This law would enable antitrust and consumer protection laws to factor sustainability within their burden of proof since firms that do not comply are positioning themselves against the public and the environment by not considering negative externalities. Environmental impact can be addressed by reducing demand or investing in new technologies such as with tax incentives. More has been done on the latter, but it serves as an indirect way of addressing the emissions and other hazardous wastes from resource extraction and manufacturing. In addition, imposing taxes runs the risk of passing these costs to the consumer, which could also reduce demand. In general, letting demand drop is not a bad outcome for the economy because it serves as a market signal to corporations to innovate in other more meaningful ways than the minor iterative changes that are typically introduced. Innovation would proceed faster in technologies with greater interest.

Following this federal degree of reparability, the government can help secure the repair process that requires parts and tools for independent repair shops and consumers by changing IP laws. The problem with design patents is that the scope with which they are granted is too broad, which typically cover non-functional aspects of inventions. Individual parts of a product can have a design patent despite the fact that this overall product is intuitively perceived as the whole design. Design should also be considered an emergent property where the individual parts contribute to the product's

aesthetic function, which may be grounds for exempting parts. Thus, Congress should revise the minimum criteria for the patentability of the design of parts. In the realm of trademarks, grey-market goods are those produced by manufacturers that may have regional discrepancies such as different warranties when comparing devices from Japan to the US. These goods can undergo nonjudicial processes where manufacturers can claim they are counterfeit and seize replacement parts or refurbished products at the border. Congress should change the scope of trademark infringement by considering how large firms can maliciously utilize their complex supply chains to reduce access to parts. These changes in patent and trademark law can help increase access to replacement parts. Copyrights and trade secrets can also affect access to software tools and information. Exemptions to section 1201 of the Digital Millennium Copyright Act allows for software circumvention for the purpose of repair but does not exclude all electronics. In addition, it must be renewed every three years by the Librarian of Congress. A more permanent solution is to narrow the DMCA or to repeal it [10]. Problems may also come about if information about proprietary information is circulated. But the federal Defend Trade Secrets Act has provisions that permits using information for “fair use” as part of one’s constitutional rights in support of the public good. Repair for secondary markets is certainly considered a public good and should therefore be an adequate argument for the legal distribution of information related to repair. Repairing devices that are no longer officially supported by manufacturers should also be allowed as a result of changing these laws.

Additionally, the secondary markets can serve as an indicator of the health of repair. Here, sustainability standards and agreements, due to a federal degree of reparability and its enforcement by the FTC or EPA, can help promote more repair-friendly practices. Industry will have better compliance rates than with laws that demand reparability scores or outright ban planned obsolescence, like France's 2020 Anti-Waste and Circular Economy Law and Hamon Law, because of the variability with which firms can go about achieving these targets. Firms can gather all the pertinent information they deem to be critical to understanding the reparability of their devices to produce a score that is all relative to current offerings of an industry. A federal degree of reparability is inherently more binding than these types of laws that would require a taskforce to vet the information put out by firms. In addition, a standard derived from this federal mandate must exhibit a degree of transparency that incorporates both large and small firms to earn endorsement from the government. These standards will help improve the reparability of future products. In the secondary markets, independent repair shops also serve the role of price ceilings above which

authorized repair shops and other firms cannot remain competitive, allowing the free market to help keep repair costs lower than if firms had a monopoly on repair in a market saturated with their products. Such a monopoly over repair can serve as a constant revenue stream that allows firms to hedge risk in their stocks and improve shareholder confidence. Furthermore, the increase of devices within the secondhand market can also help put downward pressure on the price of new goods. In the end, consumers can choose between keeping or replacing their devices. The idea is to remove barriers to the reuse of devices by repairing them and transferring ownership through the secondhand market, presenting consumers with more options depending on their malleable perspective of value. By changing laws, the markets and the design of devices can be improved, giving more freedom and power back to consumers and securing the right to repair for future products.

5. References

- [1] S. Hollister, “The era of fixing your own phone has nearly arrived,” *The Verge*, Apr. 09, 2022.
<https://www.theverge.com/23017361/ifixit-right-to-repair-parts-google-samsung-valve-microsoft> (accessed May 29, 2022).
- [2] K. Wiens, “The Right to Repair [Soapbox],” *IEEE Consumer Electronics Magazine*, vol. 4, no. 4, pp. 123–135, Oct. 2015, doi: 10.1109/MCE.2015.2463411.
- [3] “What You Should Know About Right to Repair,” *Wirecutter: Reviews for the Real World*, Jul. 15, 2021. <https://www.nytimes.com/wirecutter/blog/what-is-right-to-repair/> (accessed Jun. 19, 2022).
- [4] K. Wiens, “The Right to Repair Should be Protected by Law,” *Scientific American*.
<https://www.scientificamerican.com/article/some-electronics-repairs-are-illegal-federal-law-could-change-that/> (accessed May 29, 2022).
- [5] D. A. Hanley, C. Kelloway, and S. Vaheesan, “Fixing America: Breaking Manufacturers’ Aftermarket Monopoly and Restoring Consumers’ Right to Repair,” p. 37.
- [6] B. X. Chen, “Why You Should Care About Your Right to Repair Gadgets,” *The New York Times*, Jul. 14, 2021. Accessed: Jun. 23, 2022. [Online]. Available:
<https://www.nytimes.com/2021/07/14/technology/personaltech/right-to-repair-iphones-android.html>
- [7] “Why We Must Fight for the Right to Repair Our Electronics,” *IEEE Spectrum*, Oct. 24, 2017. <https://spectrum.ieee.org/why-we-must-fight-for-the-right-to-repair-our-electronics> (accessed Jun. 26, 2022).
- [8] K. Wiens, “John Deere Just Cost Farmers Their Right to Repair,” *Wired*. Accessed: Jan. 23, 2022. [Online]. Available: <https://www.wired.com/story/john-deere-farmers-right-to-repair/>
- [9] M. Park, “Sustainable shopping: if you really, truly need a new phone, buy one with replaceable parts,” *The Conversation*.
<http://theconversation.com/sustainable-shopping-if-you-really-truly-need-a-new-phone-buy-one-with-replaceable-parts-93069> (accessed Sep. 07, 2022).
- [10] A. Perzanowski, *The right to repair: reclaiming the things we own*. Cambridge, United Kingdom: Cambridge University Press, 2022.
- [11] “People Want to Get Phones and Appliances Fixed—But Often, They Can’t,” *Consumer Reports*.
<https://www.consumerreports.org/consumer-rights/people-want-to-get-phones-appliances-fixed-but-often-cant-a1117945195/> (accessed May 29, 2022).
- [12] E. Roth, “Today I learned Amazon will recycle small electronics for free,” *The Verge*, Jul. 16, 2022.
<https://www.theverge.com/2022/7/16/23205725/today-i-learned-til-amazon-recycle-small-electronics-free> (accessed Jul. 19, 2022).
- [13] M. S. Smith, “Gizmo: A Laptop That’s Fit to be Fixed: Dell’s Concept Responds to the ‘Right to Repair’ Movement,” *IEEE Spectrum*, vol. 59, no. 3, pp. 22–22, Mar. 2022, doi: 10.1109/MSPEC.2022.9729954.
- [14] R. Zhang *et al.*, “Compositionally complex doping for zero-strain zero-cobalt layered cathodes,” *Nature*, pp. 1–7, Sep. 2022, doi: 10.1038/s41586-022-05115-z.
- [15] “Is There Any Way to Measure Whether a Laptop Is Truly ‘Sustainable’?,” *Wirecutter: Reviews for the Real World*, Jun. 30, 2022.

- <https://www.nytimes.com/wirecutter/blog/measuring-laptop-sustainability/> (accessed Jun. 30, 2022).
- [16] M. Wirz, “K2 Launches Certification Against Investment Greenwashing,” *WSJ*. <https://www.wsj.com/articles/k2-launches-certification-against-investment-greenwashing-11657062719> (accessed Jul. 06, 2022).
- [17] “Does Buying a Carbon Offset for Your Laptop Really Help the Planet?,” *Wirecutter: Reviews for the Real World*, Jun. 30, 2022. <https://www.nytimes.com/wirecutter/blog/does-buying-carbon-offset-help-the-planet/> (accessed Jun. 30, 2022).
- [18] *The Story of Electronics*, (Nov. 04, 2010). Accessed: Jul. 05, 2022. [Online Video]. Available: https://www.youtube.com/watch?v=sW_7i6T_H78
- [19] “How One Small Startup Is Tackling Apple’s Big AirPods Problem,” *Wirecutter: Reviews for the Real World*, Mar. 09, 2022. <https://www.nytimes.com/wirecutter/blog/podswap-refurbished-airpods/> (accessed Jul. 25, 2022).
- [20] Australian Productivity Commission, “Inquiry report - Right to Repair,” Dec. 01, 2021. <https://www.pc.gov.au/inquiries/completed/repair/report> (accessed Sep. 19, 2022).
- [21] K. Steenmans, P. Taylor, and I. Steenmans, “Regulatory Opportunities and Challenges for Blockchain Adoption for Circular Economies,” in *2021 IEEE International Conference on Blockchain (Blockchain)*, Dec. 2021, pp. 572–577. doi: 10.1109/Blockchain53845.2021.00086.
- [22] “Events for the Artificial Intelligence and Emerging Technologies Partnership,” *Federal Register*, Jun. 07, 2022. <https://www.federalregister.gov/documents/2022/06/07/2022-12139/events-for-the-artificial-intelligence-and-emerging-technologies-partnership> (accessed Jul. 15, 2022).
- [23] M. Kaste, “Cryptocurrency tech is vulnerable to tampering, a DARPA analysis finds,” *NPR*, Jun. 21, 2022. Accessed: Jun. 22, 2022. [Online]. Available: <https://www.npr.org/2022/06/21/1105815143/cryptocurrency-bitcoin-blockchain-security-tampering-darpa>
- [24] “A copyright lawsuit threatens to kill free access to Internet Archive’s library of books,” *Popular Science*, Jul. 11, 2022. <https://www.popsoci.com/technology/internet-archive-lawsuit/> (accessed Sep. 26, 2022).
- [25] N. A. M. * 105 I. L. Rev. 2393, “Defending the Right to Repair: An Argument for Federal Legislation Guaranteeing the Right to Repair,” *Iowa Law Review*. <https://ilr.law.uiowa.edu/print/volume-105-issue-5/defending-the-right-to-repair-an-argument-for-federal-legislation-guaranteeing-the-right-to-repair/> (accessed Jul. 03, 2022).
- [26] B. T. Yeh, “Repair, Modification, or Resale of Software-Enabled Consumer Electronic Devices: Copyright Law Issues,” p. 26.
- [27] N. Deleon, “Right-to-Repair Laws Could Make It Easier to Get a Phone or Laptop Fixed,” *Consumer Reports*. <https://www.consumerreports.org/consumer-protection/right-to-repair-laws-could-make-it-easier-to-get-a-phone-or-laptop-fixed/> (accessed Jun. 26, 2022).
- [28] C. Lloyd, “What Are ‘Right to Repair’ Laws, and What Do They Mean for You?,” *How-To Geek*. <https://www.howtogeek.com/339925/what-are-%e2%80%9cright-to-repair%e2%80%9d-laws-and-what-do-they-mean-for-you/> (accessed Jun. 26, 2022).

- [29] A. Klobuchar, “S.2992 - 117th Congress (2021-2022): American Innovation and Choice Online Act,” Mar. 02, 2022. <http://www.congress.gov/> (accessed Sep. 11, 2022).
- [30] R. Blumenthal, “S.2710 - 117th Congress (2021-2022): Open App Markets Act,” Feb. 17, 2022. <http://www.congress.gov/> (accessed Sep. 11, 2022).
- [31] M. Kelly, “Progressives pressure Schumer to call a vote on tech antitrust bills,” *The Verge*, Jul. 22, 2022.
<https://www.theverge.com/2022/7/22/23273924/progressives-antitrust-reform-bills-klobuchar-chuck-schumer-aico> (accessed Jul. 22, 2022).
- [32] M. Gault, “A New Senate Bill Would Give Farmers the Right to Repair Their Own Tractors,” *Vice*, Feb. 02, 2022.
<https://www.vice.com/en/article/4aw4jb/a-new-senate-bill-would-give-farmers-the-right-to-repair-their-own-tractors> (accessed May 29, 2022).
- [33] M. Potuck, “Apple comes under fire for Independent Repair Program contract that lawyers are calling ‘crazy,’” *9to5Mac*, Feb. 06, 2020.
<https://9to5mac.com/2020/02/06/apple-independent-repair-program-criticism/> (accessed Jul. 14, 2022).
- [34] G. Bensinger, “Opinion | How Illinois Is Winning in the Fight Against Big Tech,” *The New York Times*, May 30, 2022. Accessed: Jun. 23, 2022. [Online]. Available: <https://www.nytimes.com/2022/05/30/opinion/illinois-biometric-data-privacy.html>
- [35] M. Gault, “Auto Industry TV Ads Claim Right to Repair Benefits ‘Sexual Predators,’” *Vice*, Sep. 01, 2020.
<https://www.vice.com/en/article/qj4ayw/auto-industry-tv-ads-claim-right-to-repair-benefits-sexual-predators> (accessed Jul. 23, 2022).
- [36] M. Chin, “Apple’s repair program creates ‘excruciating gauntlet of hurdles,’ iFixit says,” *The Verge*, Aug. 24, 2022.
<https://www.theverge.com/2022/8/24/23319881/apple-macbook-repair-program-ifixit-complaints> (accessed Aug. 28, 2022).
- [37] B. X. Chen, “I Tried Apple’s Self-Repair Program With My iPhone. Disaster Ensued.,” *The New York Times*, May 25, 2022. Accessed: May 29, 2022. [Online]. Available: <https://www.nytimes.com/2022/05/25/technology/personaltech/apple-repair-program-iphone.html>
- [38] “Coalition Letter in Support of California SB 983 (Right to Repair),” *CR Advocacy*.
<https://advocacy.consumerreports.org/research/57804/> (accessed Sep. 26, 2022).
- [39] “Guarding Against Physical Attacks: The Xbox One Story — Tony Chen, Microsoft - YouTube.” <https://www.youtube.com/watch?v=U7VwtOrwceo&t=1514s> (accessed Jun. 19, 2022).
- [40] O. Shwartz, A. Cohen, A. Shabtai, and Y. Oren, “Shattered Trust: When Replacement Smartphone Components Attack,” p. 13.
- [41] D. Parker, “Executive Summary: An assessment of the greenhouse gas emissions and waste impacts from improving the reparability of Microsoft devices,” p. 12.
- [42] “National Technology Transfer and Advancement Act of 1995,” *NIST*, Jun. 2016, Accessed: Sep. 26, 2022. [Online]. Available: <https://www.nist.gov/standardsgov/national-technology-transfer-and-advancement-act-1995>
- [43] “Pennsylvania Legislators Address Right to Repair,” *IEEE-USA InSight*, Sep. 08, 2021.
<https://insight.ieeeusa.org/articles/pennsylvania-legislators-address-right-to-repair/> (accessed Jun. 15, 2022).

- [44] A. Kavi, “The F.T.C. votes to use its leverage to make it easier for consumers to repair their phones.” *The New York Times*, Jul. 22, 2021. Accessed: May 29, 2022. [Online]. Available: <https://www.nytimes.com/2021/07/21/us/politics/phones-right-to-repair-FTC.html>
- [45] “Nixing the Fix: An FTC Report to Congress on Repair Restrictions,” *Federal Trade Commission*, May 06, 2021. <https://www.ftc.gov/reports/nixing-fix-ftc-report-congress-repair-restrictions> (accessed Sep. 19, 2022).
- [46] “Right to repair movement gains power in US and Europe,” *BBC News*, Jul. 07, 2021. Accessed: Jun. 26, 2022. [Online]. Available: <https://www.bbc.com/news/technology-57744091>
- [47] *American Soc. of Mechanical Engineers, Inc. v. Hydrolevel Corp.*, vol. 456. 1982, p. 556.
- [48] Consumers, Health, Agriculture and Food Executive Agency., LE Europe., VVA Europe., IPSOS., ConPolicy., and Trinomics., *Behavioural study on consumers’ engagement in the circular economy: final report*. LU: Publications Office, 2018. Accessed: Jul. 27, 2022. [Online]. Available: <https://data.europa.eu/doi/10.2818/956512>
- [49] “How to Sell and Buy Secondhand Things Online Without Getting Scammed,” *Wirecutter: Reviews for the Real World*, Mar. 11, 2020. <https://www.nytimes.com/wirecutter/blog/how-to-sell-and-buy-secondhand-things-online-without-getting-scammed/> (accessed Aug. 16, 2022).
- [50] A. Bourne, “Comment: Legislation requiring manufacturers to maintain support for their products and make it easier to repair them will reduce their environmental impact, but doesn’t go far enough,” *Engineering & Technology*, vol. 16, no. 10, pp. 1–1, Nov. 2021, doi: 10.1049/et.2021.1001.
- [51] B. News, “A California Startup Is Selling Electric Vehicle ‘Subscriptions’ - BNN Bloomberg,” *BNN*, Aug. 13, 2022. <https://www.bnnbloomberg.ca/a-california-startup-is-selling-electric-vehicle-subscriptions-1.1805217> (accessed Aug. 28, 2022).
- [52] S. Hollister, “Amazon doesn’t sell Echo speakers at a loss, says Bezos — unless they’re on sale,” *The Verge*, Jul. 29, 2020. <https://www.theverge.com/2020/7/29/21347121/amazon-echo-speaker-price-undercut-rivals-loss-sale-antitrust-hearing> (accessed Jul. 31, 2022).