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The Sharing Economy and Environmental Sustainability

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3.1 INTRODUCTION

Sharing economy organizations advertise many types of benefits to users and society, including advancing environmental sustainability. A basic premise of sharing economy services is that they convert private, under-utilized assets into resources that are shared among a pool of users. From an environmental perspective, sharing is assumed to reduce private consumption and attendant energy use, resource demands, and emissions, thus allowing people to live 'low-impact' lifestyles. These benefits are influential, and the promise of efficient use of resources and environmental sustainability have been identified as important motivators for consumers' participation in the sharing economy (Bocker and Meelen 2017).

Meanwhile, the sustainability orientation of sharing economy companies varies dramatically. As manifested by the companies' taglines and branding, housing and mobility platforms have typically framed themselves in terms of economic opportunity: 'Airbnb: Earn money from your extra space', 'Uber: Get behind the wheel and get paid'. Among mobility platforms, Lyft stands out by investing in environmental sustainability through promoting hybrid and electric car rides and buying carbon offsets: 'Every Lyft ride is fully carbon neutral'. Interviews of free home-sharing companies such as 'Couchsurfing', 'Trustroots' and 'BeWelcome', Voytenko Palgan, Zvolska, and Mont (2017) found that environmental sustainability is a core value for these businesses, but that there was no explicit message of environmental sustainability motivation on these companies' websites. Instead, trust was emphasized as the core value.

On the other hand, goods sharing platforms are more often grounded in environmental sustainability, with taglines such as: 'Our mission: save the world and enjoy delicious food in the meantime' (https://medium.com/resq-club), 'OLIO can help create a world in which nothing of value goes to waste', 'Rent instead of buying. Hygglo is good for environment' (hygglo.se). These general observations have recently been confirmed by a systematic analysis of sustainability claims in the online and social media content of 121 sharing platforms (Geissinger et al. 2019),

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which found that all of the thirty-five identified sustainability-oriented platforms were focusing on goods sharing. In another study, 61 per cent of the food-sharing platforms in 100 cities made statements about environmental benefits. Yet, even in the goods-sharing sector, only a few platforms provided any evidence to substantiate achievement of these benefits (Davies et al. 2017).

As with many efforts related to environmental sustainability, in practice the reality is much more complicated than these straightforward claims suggest. The predicted environmental benefits are by no means assured and need to be researched carefully (Frenken 2017, Frenken and Schor 2019). Several observed consequences involve trade-offs between avoided consumption (e.g., from resources and pollution avoided in manufacturing) and increased use (e.g., energy use and emissions from traffic congestion). In some cases, preliminary estimates have been made to quantify such environmental sustainability trade-offs using tools such as life-cycle assessment (LCA) combined with real data from sharing economy platforms (Mi and Coffman 2019). Some estimates have also considered the rebound effect, where savings due to avoided purchases are actually applied to more consumption, which can be either less or more emissions-intensive than the original environmental savings (Plepys and Singh 2019).

This chapter will document the types of unintended consequences that have been observed for different sharing platforms, including for mobility, housing, and second-hand goods, many of which are mediated by the economic rebound effect. This chapter will also present the arguments and evidence to date on the question of how and whether the sharing economy is environmentally beneficial in its current manifestation, and what might be done to improve environmental outcomes. Section 3.2 will describe how sharing systems affect the environment, both directly and indirectly. Sharing systems are often characterized in economic terms; here the focus will instead be on physical consequences, such as shifts in consumption of materials and energy. Section 3.3 will review the nascent literature assessing the environmental sustainability of different sharing systems and identify patterns, both in terms of the methodologies underlying the studies as well as their findings. Based on past results and lessons learned from cases around the world, Section 3.4 will highlight further research opportunities and suggestions that have mitigated some unintended consequences and helped to advance environmental sustainability. Environmental sustainability is multi-factorial, encompassing many types of earth and environmental systems and resources. For simplicity, we will restrict the discussion of environmental sustainability to four aspects: material use and waste, energy use, and emissions.

3.2 THE PHYSICAL SHARING ECONOMY

One way to assess the environmental impact of sharing systems is to describe sharing transactions in physical terms by mapping their associated material and energy flows, to quantify unintended consequences and avoided emissions of manufacturing

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additional products, and to compare against conventional private consumption. The field of industrial ecology (IE) has long been applied to investigate these types of problems. From its founding, IE has used natural ecology as a metaphor for inspiring human systems of production and consumption, including the features of community, connectedness, and cooperation that describe many sharing economy activities (Ehrenfeld 2000). IE research is well developed in its investigation of shared *production*, particularly the inter-firm sharing of by-products or collective services, called 'industrial symbiosis' (Chertow 2000). Using by-products such as fly ash, for example, as a substitute for cement in concrete, avoids the need to dispose of the by-product and simultaneously reduces the amount of virgin production of cement. In physical terms, this means avoiding resources, energy, and emissions from quarrying, transportation of raw materials, cement production, transportation to the disposal site, as well as reducing burden on infrastructure such as roads, landfills, industrial equipment, and so on. Quantifying resource and emissions savings through avoided materials and energy is often done using the systems modelling tool of LCA, which is designed to capture environmental burdens of goods and services over their 'life cycles', that is including their production, use, and end-of-life (Eckelman and Chertow 2013). With the advent of large-scale, technology-enabled sharing economy platforms, IE and LCA are now being used increasingly to analyse shared *consumption*, again starting from the first principle of quantifying material and energy flows.

In transportation, the major physical flows associated with human mobility are the energy needed to move vehicles and the materials in the vehicles themselves. Shared transportation services can directly reduce these resource requirements in a number of ways. In terms of material resources, the availability and convenience of sharing services allows some people to forego the purchase of their own individual vehicles, which in turn avoids energy, water, and emissions associated with materials production and vehicle manufacturing. Shared transportation increases vehicle intensity of use and may cause vehicles to deteriorate faster. This can have both negative effects (physical vehicle must be replaced) as well as positive (new vehicle may be more efficient). For fuel, if each passenger is alone in a ride share vehicle all the way from origin to destination, then there is no clear energy advantage over using a private vehicle, assuming the two vehicles have comparable fuel economies; there may instead be a disadvantage due to additional driving in between hired rides. But, if the rideshare picks up or drops off additional passengers en route (as with UberPool), or if using a rideshare eliminates the need to search for parking at the destination, then some fuel use, associated emissions, and congestion may be avoided.

These shifts may have indirect benefits for health, particularly through reduced emissions and congestion that will be felt predominantly in urban areas, where the majority of ridesharing is occurring. Reduced emissions lower levels of hazardous urban air pollution, especially ozone to which automobile emissions are important

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precursors, with attendant health benefits from cleaner air. Reduced congestion has beneficial implications for pedestrian and bicycle safety, urban noise, road maintenance, worker productivity, and stress. However, unintended consequences may offset some or all of these direct and indirect benefits. Most notably, rideshare drivers who stay on the roads while waiting to respond to ride requests will contribute to fuel use, emissions, congestion, and ageing of their vehicles. This phenomenon would be the same compared to taxis trolling for fares but would not take place compared to private vehicles that remain in parking places when not in use. This raises the vital question of what transportation mode is actually being substituted by ridesharing. Is it taxi or private vehicle? Or (where available) is it public transit, bicycling, walking, or not taking the trip at all? When utilized at high capacity, buses and trains are much more energy efficient modes of transportation per passenger than private vehicles on a life-cycle basis (Chester and Horvath 2009), so a shift away from public transit toward ridesharing will likely increase energy use, in addition to reducing fare-based funding for infrastructure improvements.

Shared housing presents different physical flows and different types of direct and indirect consequences of sharing. Platforms such as Airbnb allow people to rent out a spare room or an entire apartment or home on a short-term basis, presumably substituting for staying in a hotel. In theory, this could lead to direct substitution of hotel goods and services, such as room air conditioning and lighting energy, consumables, and services associated with cleaning and turning over the room. However, these goods and services would be used in the shared housing instead, perhaps with lower efficiency due to smaller economies of scale. On a macro scale, shared housing could shift the market for hotels, leading to fewer being constructed, but the land parcels in question would presumably be used for other productive developments. Another potential direct physical effect relates to energy use: Hotels are frequently located in central, convenient locations, whereas shared housing is more spatially distributed, potentially leading to more transportation energy used when travelling to and from the shared housing site. Indirect environmental concerns are also primarily related to shifts in transportation. When many centrally located properties are used primarily for shared housing rather than residences, the people who previously lived there may move to locations outside of the city and become commuters, potentially increasing fuel use and congestion.

Finally, shared goods such as surplus food and materials represent another type of implicit environmental trade-off between direct and indirect benefits and costs. Surplus food or materials are themselves a physical flow whose sharing prevents their collection, saving fuel energy, and disposal in landfills or waste incinerators, saving valuable space and energy and avoiding landfill leachate and other types of waste management pollution. Goods sharing could contribute to the 3Rs (Reduce, Reuse, Recycle) principles of waste prevention by reducing packaging waste of new products and reusing products that are in good condition. Sharing is also a strategy under the Circular Economy concept that aims to maximize utility and value of the resources in use (Kalmykova, Sadagopan, and Rosado 2018). In addition, their sharing means that receivers do not have to purchase as much new food or materials, with savings of resources all the way up the supply chains of those goods. As with shared housing, the locations of the substituted and shared goods are a critical consideration. If the sharing location is closer than the primary store where goods would ordinarily be bought, then transportation energy could be saved. However, for food in particular, the variety that is available through sharing may not be adequate to cover dietary needs, and participants may end up making trips to primary stores anyway. So, while food and materials sharing appears to have clear avoided materials and waste management emissions benefits, the trade-offs associated with transportation are unclear and likely to depend on origin–destination locations, travel modes, and consumer shopping behaviour.

3.3 Evidence of Environmental Benefits or Disadvantages

A bevy of new data-driven research has emerged recently on the environmental implications of sharing economy practices, supplementing the mostly small-scale, anecdotal or model-based studies in the existing literature. This Section will review findings to date that have been published in open literature (as opposed to studies conducted or commissioned by companies themselves) and how they incorporate (or don't) the relevant physical considerations outlined in Section 3.2.

3.3.1 *Transportation*

The most active research area on the sustainability of the sharing economy has been shared transportation. An early life-cycle impact study of car sharing (business-to-consumer, with fixed parking locations, as opposed to ride sharing) in the United States by Chen and Kockelman (2016) reported reduced car ownership, a decrease of vehicle-kilometres travelled (VKT) of 30–70 per cent, and reduction in greenhouse gas (GHG) emissions of approximately 50 per cent when compared to the car-sharing members' travel before joining the sharing service or in comparison to their non-sharing neighbours. Among other environmental benefits were reduction in parking space demand and increase in use of public transit and non-motorized modes of travel, such as walking and bicycling. The greater intensities of use of the shared vehicles also led to a faster turnover, and subsequently to better fleet fuel economy as more efficient models are adopted. Similar results were found in a study of hundreds of car-sharing participants in the Netherlands (Nijland and van Meerkerk 2017). Importantly, the US study also examined rebound effects, which offset approximately 40 per cent of the environmental benefits as household cost savings were spent on other energy- and emissions-intensive goods and services (Chen and Kockelman 2016).

In contrast, studies of ride sharing have mostly found environmental costs rather than benefits. Ride sharing has been connected to the decline in public transit system ridership (Graehler, Mucci, and Erhardt 2019) and increased congestion in cities (Erhardt et al. 2019). A major study of ride sharing by the Union of Concerned Scientists (UCS 2020) found an average increase in emissions of 70 per cent compared to the trips that ride sharing is replacing, mostly due to excess driving between hired rides. Pooled ride sharing was found to have approximately the same emissions as private vehicle use, but when pooled ride sharing is paired with public transit use, this option was found to decrease emissions to less than half that of private vehicle use. The report also notes that transitioning to electric vehicles will have major benefits for ride sharing and should be a priority. Ride sharing now greatly exceeds taxi ridership in the United States, but because of their decentralized ownership, ride-sharing systems cannot directly take the same fuel efficiency-oriented purchasing decisions as taxi companies or car-sharing systems. However, ride-sharing companies can incentivize their drivers to invest in high-efficiency or electric vehicles, through cash incentives, preferential pricing, and partnerships for vehicle charging. For their part, some governments have taken action through differential fees for pooled rides or rides in downtown areas that compete with public transit, or through direct regulation of ride-sharing emissions, such as California's Clean Miles Standard and Incentive Program (UCS 2020).

Sharing systems for other transportation modes such as bicycles and e-scooters have also been studied. Bike sharing is present in many urban areas around the world, and can include fixed station locations, demarcated parking areas, or no fixed locations at all. Bike sharing in the United States was found to decrease ridership on buses (for which bike trips substitute) but increase ridership on light and heavy rail, as commuters combine bicycling and trains in order to address the 'last-mile' problem often associated with public transit (Graehler et al. 2019). In terms of energy use and emissions, Zhang and Mi (2018) examined a large dataset from bike share trips in Shanghai and concluded that sharing programmes resulted in savings in fuel use and decreases in harmful air pollutant emissions in the city. Similar studies have investigated health benefits, both directly from increased exercise but more significantly indirectly from a decrease in vehicle emissions and pollution that benefits all surrounding residents (Mueller et al. 2018; Woodcock et al. 2014,). On the other hand, these sharing systems require collection and re-distribution or balancing of where bicycles and e-scooters are located, which is typically done with vans or trucks running on conventional fuel. Poor operational management or sprawling low-density systems have the potential to lead to overall increases in emissions which can occur when vehicle use from redistribution exceeds that which is being substituted by bike or e-scooter use (Fishman, Washington, and Haworth 2014, Hollingsworth, Copeland, and Johnson. 2019). Environmental and health benefits are largely predicated on the fact that users are switching away from driving, rather than from public transit, private bike use, or walking; benefits of bike or e-scooter sharing may then not materialize in cities where the share of car trips is already low, as was found for London (Fishman et al. 2014).

3.3.2 *Housing*

Home-sharing platforms are the least researched in terms of environmental impact, despite their popularity. Among different vacation housing options, home sharing has been assumed to cause no additional environmental impact in comparison to the option of staying at home, while an average of 20 kg additional carbon dioxide (CO_2) per person per night at a hotel room was estimated in several studies (Chenoweth 2009). The hotels impact is in part because hotel premises continue to be heated, cooled, and air-conditioned regardless of whether they are occupied or not, and these energy demands are higher than those of a typical home, which may or may not have mechanical ventilation. Airbnb produced a report claiming substantial energy and water savings, as well as reductions in CO_2 emissions and waste due to Airbnb stays instead of staying in hotels (Airbnb 2017), building on an earlier comparison commissioned from the Cleantech Group. The report found that Airbnb stays require substantially less energy (~80 per cent) and generate lower GHG emissions (~90 per cent) than conventional hotel stays. However, the full methodology with which environmental benefits were calculated has not been made available and the results have not been independently verified. Nevertheless, a subsequent report by the Nordic Council of Ministers used the same percentage reductions to approximate potential emissions reductions from home sharing in their region (Skjelvik, Erlandsen, and Haavardsholm 2017). These results are only meaningful if home sharing is substituting directly for hotel stays.

The other consideration is whether the convenience, choice, and typically lower costs of home-sharing platforms induce additional travel. Studies of the direct rebound effect of home sharing, namely whether it promotes more travel (including longer stays) entailing corresponding emissions, showed disparate results. A survey of 450 respondents with experience of using home sharing showed that use of peer-to-peer (P2P) accommodation expands destination selection (65 per cent positive responses) and may increase travel frequency (40 per cent positive responses) (Tussyadiah and Pesonen 2016). It should be noted that over 30 per cent of the respondents used home sharing only once, while 40 per cent of respondents have experience of up to five visits. In another questionnaire involving twenty-four users of a home-sharing platform, all but one user responded that they would conduct their travels independently of access to a home-sharing option (Voytenko Palgan et al. 2017).

3.3.3 *Goods*

It is often assumed that, as a consequence of using a sharing platform, the purchase of new products may be avoided or replaced by the sharing of products with the same functionality, thereby avoiding the environmental impacts of virgin production. Again, this simplistic assumption needs to be tested, as avoided production may not be the driving contributor and rebound effects may negate any potential savings. However, at the time of this review, there were few publications with comprehensive assessments of the environmental benefits of sharing goods such as surplus food, products, or building materials.

One of the most comprehensive was that of Martin, Lazarevic, and Gullstrom (2019), who assessed CO_2 emissions of durable-goods sharing and potential savings in emissions, compared to the baseline (no sharing) scenario, based on transactions from the sharing platform Hygglo.se. Hygglo.se facilitates transactions between the user and provider for P2P sharing of about 7,000 listed products and services. In order to investigate the benefits of this sharing platform, three scenarios were analysed for an urban district with a population of 25,000 in Stockholm, Sweden: (1) a baseline scenario that assumed that no sharing service was available and all products were purchased new by the residents; (2) a scenario of products sharing assuming patterns of Hygglo.se transactions during 2017; and (3) the same sharing scenario as (2) but supplemented with a lockers-and-delivery system in order to reduce transport emissions of transactions. The analysis considered environmental impacts of goods production (due to raw materials extraction and manufacturing), distribution (for example, transportation, retail operations, energy use, and impacts from digital infrastructure), and use (for example, energy consumption) but excluding impacts of goods disposal. The study found that sharing scenarios reduced GHG emissions by about 77–85 per cent, with the results varying according to the average roundtrip travel required to complete the transaction. In this case, environmental impacts associated with avoided goods production were in fact the dominant factor in reducing emissions, since there were fewer products circulating in the district through sharing, providing the same level of service that newly purchased products would have provided. The study also showed how introducing a system with lockers and delivery could additionally reduce the transportation emissions of sharing transactions, though other work has shown that such reductions depend on characteristics of the logistics system, demand, and locker locations.

The garment industry is another sector that has received recent criticism for its environmental impacts, particularly from the rise 'fast fashion', where garment use is extremely short-lived (Niinimäki et al. 2020). There have been calls to transform the industry toward a circular economy model, including mechanisms for sharing via platforms (Ellen MacArthur Foundation 2017), with the implicit assumption that such sharing will lead to environmental benefits such as reduced emissions. To test this hypothesis, Son et al. investigated different scenarios for garments, in which both second-hand purchases and sharing in the community were found to cause similar GHG emissions (1 kg CO_2/garment usage), lower than a new purchase or online/offline rental (2.5–4 kg CO_2/garment usage) (Son et al. 2019). In the case of rental, however, the impacts of cleaning and transportation brought the CO_2/usage above that of owning an item. Another study focused on waste reduction found that, operated under favourable conditions, sharing could potentially reduce household waste by 20 per cent overall (Demailly and Novel 2014).

In general, transportation mode and distance are critical considerations for assessing the emissions associated with product-sharing transactions. For example, for food products, which can have relatively low embodied emissions compared to durable goods, the transport emissions from travelling to and from the point of sharing may offset the environmental benefits of avoiding new food, but the balance depends on how and how far individuals must travel. Proximity and access to low-emission transport options led to favourable results for sharing models. In a study in the United Kingdom, based on records from the OLIO food-sharing app, it has been found that 92 per cent of transactions occur within 10 km and 76 per cent of transactions occur within 5 km (Harvey et al. 2019). For the Greater London area, with high population density and proximity of sharing pairs, Makov et al. found that food sharing through OLIO led to net environmental benefits for all transportation options, though the benefits were greatly reduced when a two-way dedicated car trip was used (Makov et al. 2020).

Emissions are just one measure of environmental performance. For many studies describing the environmental benefits of goods sharing, another common metric is quantity (mass) of the avoided waste. This trend is especially evident in the literature on food waste (Davies and Legg 2018). Two studies involving Craigslist, a popular US-based P2P sharing platform for second-hand goods, found an estimated mass reduction in solid waste generation by 2–6 per cent per capita annually (Dhanorkar 2019; Fremstad 2017). But in these studies, neither the benefits of saved methane emissions, landfill space, and transport for waste collection have been assessed, nor has the alternative of anaerobic digestion of food waste to produce fuel and fertilizer been considered. This indicates that the use of different environmental metrics to assess environmental benefits of goods sharing is far from comprehensive and there is significant scope for expansion in research in this area, as few studies take a life-cycle approach.

Goods sharing is also potentially susceptible to the rebound effects, where savings from avoided purchases are applied to more consumption. For example, usage of second-hand P2P platforms has been connected to buying unnecessary items, both new (due to the ability to easily resell them later) and used (because of the low price). In addition, the results of an empirical study on consumer behaviour pointed out that consumers with materialistic traits and environmental consciousness were both more likely to engage in impulse buying of unnecessary items on P2P platforms (Parguel, Lunardo, and Benoit-Moreau 2017). The suggested mechanism of such behaviour is moral self-licensing, since platforms offer numerous justifications for purchases, including the common belief that buying second-hand is virtuous in terms of savings and environmental benefits. It has also been shown that consumers' propensity to replace goods that are still in working condition has increased due to consumer participation in P2P platforms, thus potentially increasing the consumption of new goods. Unnecessary consumption of products shared for free may be even larger, leading to acquisition of products that are ultimately not used, but disposed of, negating any potential environmental benefits of their sharing.

3.4 OPPORTUNITIES AND CONCLUSIONS

The overall message of the research to date is that sharing is not an environmental panacea and should not be used as a heuristic for sustainability. Whether sharing produces environmental benefits or not depends on many factors, especially the quality of the item or service being shared, its intensity of use, the distances involved, and the severity of rebound effects. As seen in Section 3.3, research on the environmental sustainability of sharing platforms is uneven and there is much we don't know. Transportation continues to receive significant attention, in part because of the public data infrastructure available from detailed travel surveys. On the other hand, there is relatively little research to date on P2P sharing of accommodation and goods, and therefore ample opportunities for improving our understanding of potential benefits and disadvantages.

For all three sharing types considered in this chapter, research has identified opportunities for improvements, regardless of whether the baseline comparison was positive or negative. Such research has also made clear that pursuing these opportunities changes the overall calculus of whether sharing is environmentally beneficial. In general, recommendations have fallen into four major themes:

1. *Design algorithms to emphasize proximity*. For goods especially, the benefits or disadvantages of sharing were found to be highly sensitive to transportation considerations. This suggests that grouping or even restricting sharing to the neighbourhood level, as many platforms already do, may be an effective way to avoid unintended environmental emissions.
2. *Encourage low-carbon transportation options for sharing transactions*. In general, ride sharing was generally found to have higher GHG emissions than personal vehicles, but it could be lower if pooling and vehicle electrification were pursued aggressively (UCS 2020). For accommodation, home sharing was generally found to have lower GHG emissions than hotel stays, and especially so if located in public transit areas where additional car transportation could be avoided, such as city centres. For food, relying on bus travel or trip chaining with a personal vehicle greatly increased the environmental benefits of sharing (Makov et al. 2020).
3. *Model the system and mitigate unintended effects*. Sharing has large-scale implications for both private consumption and public infrastructure, with many knock-on effects that are poorly understood. For example, the emergence of home sharing in some city centres has caused rents to become unaffordable and forced long-time residents to move out of the city. These people must then commute back into the city for work, inducing additional emissions that can eclipse any environmental benefit of the home sharing itself. In response to turmoil in local housing and rental markets from home sharing, major cities such as Los Angeles have passed ordinances regulating home sharing, including by requiring registration of allowed locations, which may

enable the cities to shape where and what types of home sharing are allowed. Such policies could also include environmental motivations. Environmental economics and consequential LCA provide tools for examining the extent of rebound effects and the unequal distribution of benefits and costs.

4. *Focus sharing on transactions with the highest environmental benefit*. Items that are energy- or emissions-intensive to produce, such as like high-end tools or machinery, have a large benefit for avoided production when they are shared. If they are durable items and can be shared among a large group, these benefits will compound. Transactions can also have a large benefit because they avoid the environmental impacts associated with disposal, such as shared food avoiding the emissions from decomposition of food waste in a landfill. Estimating a ranking of sharing benefits by item type using tools such as LCA would be a useful area of future research.

While this chapter has focused on environmental benefits in physical terms, perhaps the most important sustainability opportunities afforded by sharing economy platforms are indirect, through the data that they can provide for consumption-related research and policymaking. For example, shared-ride information can be analysed by municipal transportation departments to identify demand for last-mile transportation, with the purpose of designing public infrastructure and services that operate synergistically with ride-sharing and can satisfy demand in an environmentally sound and safe way (Fishman and Schepers 2016). The levying of occupancy taxes on home-sharing by municipalities allows them to collect data on P2P supply and demand for accommodation that can be useful for urban zoning and development planning (Coles et al. 2018). Identifying the most commonly shared foods may help develop information campaigns for residents on best management practices as well as design of municipal organic waste management systems. Also, areas with food shortages may be identified and assisted. Knowledge about popular items for goods sharing and their end-of-life can inform design of more robust shareable goods by manufacturers (Wastling, Charnley, and Moreno 2018), thus further reducing demand for manufacturing through product lifetime extension. One example is high-quality durable clothing. The sharing economy may help in reaching several United Nations Sustainable Development Goals (SDGs), including SDG #11 (Sustainable Cities and Communities) and SDG #12 (Sustainable Consumption and Production). Enabled by collaborative consumption, reductions in emissions from goods production, long-range transport, and waste management could also contribute to achieving climate goals. If these potentials are found to be considerable, it may warrant political and legislative support of sharing initiatives.

As sharing economy platforms continue to evolve, there are numerous opportunities to improve their back- and front-end design in order to incentivize beneficial environmental outcomes. Thanks to their digital basis, sharing platforms are well suited for evaluation of their environmental costs and benefits at a transaction level using tools like LCA, though this opportunity that has been underutilized so far. Just as some airlines now show passengers the carbon footprint of their trips (and offer the opportunity to purchase carbon offsets), sharing platform algorithms can estimate the environmental benefits due to the avoided manufacturing and transportation, using positioning services or customers' addresses (Martin et al. 2019). Such a feature will allow users to make informed decisions on transactions, such as choosing a pool ride, instead of a single-person ride, or avoiding food pick-up that entails generating high transport emissions. Environmental characteristics of shared items could be communicated to users, such as embodied carbon or product durability. Encouraging sharing of the most robust goods will extend the lifetime of these products while further reducing demand for new goods manufacturing. Sharing economy platforms can also be engineered for the entire user base such that the objectives of the optimization routines they use include minimization of environmental impacts.

Finally, we can think of the design of the physical systems within which sharing economy companies operate, most notably by promoting urban design that enables the sharing economy. For example, what would an effective 'sharing district' look like? Is there a bundle of shared services that can be provided to the residents that would allow them to forego private consumption entirely? Several examples are already common, such as subscriptions to a shared ride service in lieu of private parking spaces, or shared appliances and tools instead of private storage spaces. Safety and security will always be important concerns for consumers; for some sensitive items, can a system of lockers for exchanged goods make transactions more trusted?

In conclusion, the rise of sharing economy platforms has upended many markets for goods and services. From an environmental perspective, there is growing quantitative evidence about the consequences of these shifts, both positive and negative. Many sharing economy participants cite environmental sustainability as a motivator for engagement, but as this chapter has shown, the scale of environmental benefits depends on operational circumstances such as travel distance, substitution, and rebound. This is still an emerging area of investigation, particularly for accommodation and goods, using LCA and other assessment techniques. Harnessing data collected by or in response to sharing economy platforms will enable a clearer picture of environmental benefits and disadvantages, which can in turn inform actions that the platforms and public authorities can take to incentivize more environmentally sustainable outcomes.

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