CARSHARING'S LIFE-CYCLE IMPACTS ON ENERGY USE AND GREENHOUSE GAS EMISSIONS

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ABSTRACT

This paper examines the life-cycle inventory impacts on energy use and greenhouse gas (GHG) emissions as a result of travelers adopting the carsharing mode in US settings where shared-car use is reasonable. Here, households already residing in relatively dense urban neighborhoods with good access to transit and traveling relatively few miles in private vehicles (roughly 10 percent of the U.S. population) are considered good candidates for carsharing. This analysis recognizes the cradle-to-grave impacts of carsharing on vehicle ownership levels, travel distances, fleet fuel economy (partly a result of faster fleet turnover), parking demand (and the associated infrastructure), and alternative mode use. Analytical results suggest that current carsharing candidates reduce their average individual transportation energy use and GHG emissions by approximately 49% upon joining a carsharing organization. Collectively, these individual-level effects translate to roughly a 5% savings in all household transport-related energy use and GHG emissions in the U.S. These energy and emissions savings can be mostly attributed to mode shifts and avoided travel, followed by savings in parking infrastructure demands and fuel consumption. If indirect rebound effects are taken into account (where individuals' travel-cost savings is then spent on other goods and services), these savings may fall to as little as 3% across all U.S. households.

INTRODUCTION

In 2009, for the first time since World War II, the U.S. vehicle fleet diminished in size, as 14 million vehicles were scrapped and 10 million new vehicles were sold (Brown 2010). Alongside a U.S. trend toward lower private-vehicle ownership (Cohen 2012) and a growing popularity of the shared-use economy (Botsman and Rogers 2010), carsharing is emerging as an alternative travel "mode" that is both more flexible than transit and less expensive than traditional ownership. Both peer-to-peer carsharing (through organizations like Getaround and Relayrides) and business-to-consumer carsharing (through operations like Car2Go and Zipcar) are gaining ground in urban areas. Worldwide, carsharing organizations operate in over 1,100 cities across at least 27 countries (Shaheen and Cohen 2013).

In North America alone, carsharing systems exist in more than 20 metropolitan areas (Martin and Shaheen 2011b) and membership levels are over 1 million persons (Shaheen and Cohen 2013). Shared mobility innovations are rapidly growing, and policymakers may want to incentivize this special mode far more than we have seen to date. Carsharing generally reduces automobile dependence and lowers emissions while benefitting its users via lowered travel costs (Litman 2000) For decision makers to better appreciate carsharing's contributions, it is useful to quantify the life-cycle implications of a shift toward shared-car use. A life-cycle inventory (LCI) analysis quantifies the complete energy and atmospheric emissions for the lifetime effects of a product, process, or activity (USEPA 1995), allowing decision makers to compare alternative activities and products via common metrics.

This paper quantifies life-cycle energy and greenhouse gas (GHG) emissions for the carsharing mode as compared to one equivalent person-kilometer traveled (PKT) under the traditional (private vehicle ownership) approach. The calculations recognize the vehicle replacement rate changes that come with sharing, as well as the fuel efficiency improvements from faster fleet turnover, travel distances changes, reduced parking demands, and shifts in the use of alternative modes.

PRIOR RESEARCH

Existing studies have examined the environmental impact of carsharing operations to various extents. Martin and Shaheen (2011a) estimated GHG reductions at the household level via an analysis of 11 carsharing organizations in North America and found that, while some carsharing members increase and others decrease their annual emissions, the net impact is an estimated annual reduction of -0.58 tons of GHG emissions (CO_2-equivalent, per member household, per year) due to observed changes in household driving for North American member households and -0.84 tons of GHG emissions in full impacts (including foregone vehicle purchases). This reduction roughly translates to 11% to 16% of the average American household's transport-related GHG emissions per year (USDOT 2009). Using stated preference survey data from Bremen, Germany and Brussels, Belgium, Ryden and Morin (2005) estimated emissions savings per new member to be 54% in the former and 39% in the latter, based on lower VKTs, increased fleet fuel economies, and increases in public transit use.

Martin and Shaheen's (2011a) and Ryden and Morin (2005)'s emissions reductions estimates did not reflect any land use impacts of carsharing. Switzerland's Mobility Carsharing operation has developed an environmental inventory tool to assess their fleet's consequences - from vehicle manufacturing and maintenance, to road use, infrastructure provision, and land use effects. As compared to the average Swiss passenger car, they estimate that the Mobility Carsharing fleet reduces overall environmental burdens (including exhaust emissions, fuel consumption, material use for car and road infrastructure, health damages from road noise, and motor vehicle accidents) by 39% per vehicle-kilometer travelled (VKT)(Doka and Ziegler 2001). For modern cars with low emissions, carsharing did not provide significant reductions of NO_x, HC, CO, and PM10 (as compared to clear benefits in CO_2, noise, accidents, and fuel production. The authors noted that as vehicles become more fuel efficient, land use aspects (e.g., transportation infrastructure requirements) become a more significant percentage of the total environmental burden reduction. While Doka and Zielger (2001) includes land use and infrastructure impacts of carsharing in their LCA analysis, the study only looks at environmental impacts associated with carsharing vehicle and ignores the effect of changing traveler behavior (e.g., reduced vehicle kilometers traveled and increased use of other modes of transportation).

Briceno et al. (2004) have extended the scope of LCA for shared-vehicle systems by anticipating rebound (in consumption) effects, via the use of input-output analysis (to derive emissions from added non-transport consumption that comes from the average member's travel cost savings). They found that if car-sharers in Norway spread their transportation savings uniformly across non-transport items, the overall rebound effects are small. However, if the travel-cost savings were spent on air travel, the added (rebound) GHG emissions are high, demonstrating how moves towards ostensibly more sustainable consumption patterns can have rather unintended consequences. As Hertwich (2005) notes, carsharing typically reduces local travel expenditures, but use of those savings in other expenditure categories can have negative environmental impacts.

CARSHARING'S IMPACTS ON ENERGY USE AND GHG EMISSIONS

Life-cycle analysis offers a systematic approach to evaluating the environmental consequences of carsharing. This "cradle-to-grave" process recognizes resource extraction to produce the vehicles and fuels, and resource depletion through the vehicle use and disposal phases. Environmental impacts are numerous along the way: First, vehicle "ownership" (in terms of vehicles per person) generally falls with carsharing membership, offering environmental benefits from vehicle production and parking infrastructure savings. Second, carsharing has impacts on VKT and vehicle utilization rates (and thereby fleet replacement rates), which tends to reduce fuel consumption (as well as, arguably, road infrastructure needs, though this potential savings is generally not assessed). Lastly, carsharing shifts many trips previously carried out by private automobile to transit and non-motorized modes (as well as some trips previously carried out by non-auto modes to shared cars).

Candidate Households for Carsharing

However, carsharing is not a reasonable option for every traveler. Carsharing membership is more appealing for those who travel fewer kilometers and reside in higher-density neighborhoods with good walking, cycling, and transit options (Litman 2000). Thus, carsharing programs tend to concentrate in metropolitan cores, well served by other modes, where travelers can and do rely less on private car use than the average traveler (Stillwater et al. 2009). In an analysis of 13 U.S. regions with carsharing programs, Celsor and Millard-Ball (2007) found that carsharing neighborhoods are more likely to have higher shares of one-person households and residents with Bachelor's degrees, more workers commuting by transit and non-motorized modes, lower vehicle ownership levels, higher density, and more walkable environments than non-carsharing neighborhoods.

Thus, while carsharing is not an omnipresent and universally feasible travel option, it does appeal to various populations. Frost and Sullivan (2010) estimated that car owners who drive 12,000 miles

(7,460 km) per year at an average speed of 30 mi/hr can save $1,834 by switching to a carsharing service (with those driving less than 12,000 miles reaping even greater savings). Looking specifically at the San Francisco Bay Area, Duncan (2011) estimates that as much as one-third of those households have vehicle usage patterns that would save money via carsharing. Others are not as optimistic: Schuster et al. (2005) estimate that in Baltimore, Maryland, 4.2% to 14.8% of vehicles would be less expensive to share than to own. If estimates from the Bay Area and Baltimore are applied to urban areas throughout the US (taking into account that 80% of the US population now resides in urban areas (Census 2010), the range of potential carsharing members nationwide covers a wide spectrum: from 3% up to 26% of persons. Surveying 26 existing organizations in North America, Shaheen et al. (2006) estimate that market potential for carsharing is 10% of adults 21 and older.

For members who actively participate in carsharing, the adoption of carsharing behavior has quantifiable effects on vehicle ownership rates, VKT, and modal shift to and from transit and non-motorized modes. The energy and GHG impacts of these vehicle ownership and travel behavior shifts are discussed in detail below.

Vehicle Ownership Impacts

Within carsharing households, early studies estimate that vehicle ownership can be reduced by about 40% to 44% (Whitelegg and Britton 1999, Meijkamp 1998). Zhou and Kockelman (2011) surveyed Austin, Texas households in 2008 and found that 21% of those surveyed (following population correction) would expect to give up/release at least one of their private held vehicles upon joining a carsharing organization. A 2008 nationwide survey found that after carsharing, US households reduced their overall vehicle ownership by 49%, with most of this shift from one-car households to no-car households (Martin and Shaheen 2011b). In the San Francisco Bay Area, Cervero et al. (2007) looked at the longer term effects of membership in City Carshare and found that vehicle shedding effects level off with length of membership. A survey 4 years following the program’s establishment found that the net vehicle shedding effects (as compared to non-member households) is about 10 vehicles per 100 households. Martin et al. (2010) also concluded that the combined effect of vehicles shed and vehicles avoided translates to each carsharing vehicle serving in lieu of 9 to 13 privately owned vehicles. A first-year look in Philadelphia estimates that each PhillyCarShare vehicle replaced, on average, 23 private vehicles (Lane 2005). Other North American studies have estimated the vehicle replacement rate closer to one carsharing vehicle per 15 privately owned vehicles (Millard-Ball et al. 2005, Econsult 2010, Frost & Sullivan 2010, Stasko et al. 2013).

Impacts on Vehicle-Kilometers Traveled (VKT)

Upon joining a carsharing operation, households typically travel by car less than prior to joining carsharing. When use of a vehicle involves reserving a vehicle in advance and the costs of operating a vehicle are made more apparent (generally with a by the minute charge in most car-share operations), households tend to decrease their use of vehicles. Comparing similar households in Montreal, Sioui et al. (2012) found that households who subscribe to and active use a carsharing organization utilize a car 3.7 times less than neighbors who do not subscribe to these services.

However, estimates of how much households reduce their auto travel distances vary greatly. Sperling et al. (2000) estimate carsharing reduces VKT by 30-60%. Frost & Sullivan (2010) estimate carsharing members drive 31% fewer kilometers upon joining a carsharing service. Cervero et al. (2007) looked at members of City CarShare in San Francisco and found that in the long term, carsharing members reduced their annual VKT by 67%. Martin and Shaheen (2011) found through a North American survey that the average VKT by respondents decreased 27% after joining carsharing (from 6468 km/year to 4729 km/year). In Europe, these impacts seem to be even greater as Muheim (1998) estimates that members of Mobility Carsharing Switzerland drove 72% fewer kilometers after their first year of joining the program and Meijkamp (1998) reports that members of carsharing organizations in The Netherlands drove 33% fewer miles after becoming car-sharers. Ryden and Morin (2005) used stated preference surveys and found that, on average, carsharing members in Bremen, Germany and Brussels, Belgium reduced their VKT by 45 and 28%, respectively.

Impacts on Energy Consumption During Use Phase

In addition to reducing use phase energy demand by reducing VKT, members of car-share operations also tend to drive more fuel efficient vehicles than non-car-share members. Meijkamp (1998) estimate that shared cars are approximately 24% more fuel efficient than the average car in the Netherlands. Martin and Shaheen (2011a) also found that carsharing vehicles are more fuel efficient than the vehicles they replaced, with the carsharing fleet averaging 13.9 km per liter (32.8 mpg) and the vehicles they replaced averaging 9.8 km per liter (23.3 mpg). Using stated preference data from Germany and Belgium, Ryden and Morin (2005) estimated that the average carsharing vehicle is 17% more fuel efficient than the average privately owned vehicle. This phenomenon can probably be attributed to the faster replacement rate of car-share vehicles since they have higher utilization rates. The average privately owned new vehicle in the U.S. is owned for 71.4 months (or approximately 6 years) before being "replaced", which may be via sale as a used vehicle, trade-in (when acquiring a newer or different vehicle), shedding an unneeded vehicle, or a serious crash (Seng 2012). On the other hand, due to more VKT and faster wear and tear, the commercial car-share operations replace cars every 2 to 3 years (Mont 2004). With government mandates like CAFE standards and increasing fuel prices, newer vehicles, on average, are more fuel efficient (and smaller) than older fleets, contributing to a more fuel efficient shared fleet compared to a privately owned fleet.

Impacts on Parking Infrastructure Demand

Reduced car ownership has potential impacts on infrastructure requirements, particularly parking. Most governing authorities' interest in promoting carsharing is motivated by parking demand reduction (Millard-Ball et al. 2005). While numerous studies qualitatively link reduced vehicle ownership and parking demand (see, e.g., Millard-Ball et al. [2005] and Martin et al. [2010]), few studies have quantified the magnitude of that impact. The 1-to-15 shared-vehicle-to-private-vehicle replacement rate discussed earlier does not directly translate to a parking impact in high-demand areas, since many car-share participants use transit and other non-auto modes for commute trips (Celsor and Millard Ball 2007), and hence much of the parking reduction would occur in private garages and parking lots. A 2004 study in the U.K. surveyed employers and found that spaces fell from 0.79 spaces per staff member to 0.42 spaces per staff member after starting a carsharing program (Department for Transport 2004). Looking at carsharing and parking at the building scale in Toronto, Engel-Yan and Passmore (2013) found that buildings with dedicated carshare vehicles required 50% fewer parking spaces than those without such dedications. Using survey data from Ithaca Carshare, Stasko et al. (2013) estimated that program participants' on-street parking needs or demands fall by 26 to 30%, depending on day of week and time of the day.

Impacts on Other Modes of Transportation

So how do car-share members pursue trips while reducing vehicle ownership and cutting VKT? Overwhelming, studies point to increase use in non-motorized modes and transit. In the Netherlands, Meijkamp (1998) reports 14% increase in bicycling, 36% increase in rail transit use, and 34% increase in bus transit use among carsharing members. In Germany and Belgium, Ryden and Morin (2005) estimate that carsharing members use public transportation 35 to 47% more during weekdays. In Montreal, Canada, households who subscribe to carsharing services use public transportation 55% more often than neighbors who own one private vehicle (Sioui et al. 2012). In the US, a second year evaluation of CarSharing Portland found members reporting 25% increase in walking, 10% increase in bicycling, and a 14% increase in public transit use (Cooper et al. 2000). Similar results can be seen in Philadelphia after one year of joining Philly CarShare, 19% of members reported more walking, 8% reported more cycling, and 18% reported more transit use (Lane 2005). In a survey of 13 car sharing operations in North America, Martin and Shaheen (2011c) found the impact on transit use was statistically insignificant after joining car sharing programs but net use of walking, biking, and carpooling modes increased 2%, 7%, and 3%, respectively.

ANALYSIS AND RESULTS

The total impact of carsharing on energy use and GHG emissions as compared to an equivalent PKT in a private automobile (the functional unit in this study) is the combined effect from all of these different dimensions of travel behavior, vehicle technology, and infrastructure change. This analysis presents three different scenarios to examine the sensitivity of reduction in total life-cycle energy and GHG emissions for a candidate household member (one who travels shorter total distances and resides in higher-density urban neighborhoods, with good walking, cycling, and transit services) upon joining a carsharing organization. Table 1's results for low-impact (pessimistic), medium-impact (likely), and high-impact (optimistic) scenarios are based on multiple input factors (as shown in Table 1's first column). The values and ranges of these inputs come from the studies previously discussed in this impacts section.

Table 1. Effect of Carsharing on Travel Behavior, Infrastructure Demand, and Other Modes

Input	Low Impact	Med Impact	High Impact
Carsharing Market Potential (% of US Households)	3.0%	10.0%	26.0%
% Reduction in Private Vehicles Owned	10.0%	21.0%	49.0%
Private Vehicle Replacement Rate for Each Carshare Vehicle	9	15	23
% Reduction in VKT	27.0%	31.0%	60.0%
% Fuel Efficiency Improvement	17.0%	24.0%	43.5%
% Reduction in Public Parking Demand	26.0%	38.0%	50.0%
% Increase in Rail Transit Use	0.0%	17.0%	36.0%
% Increase in Bus Transit Use	0.0%	17.0%	34.0%
% Increase in Bicycling	6.0%	10.0%	14.0%
% Increase in Walking	3.0%	19.0%	25.0%

The energy use and GHG emissions impacts are estimated relative to the base case ("Before" scenario) of private vehicle ownership (prior to joining a car-share organization). As discussed previously, potential carsharing participants exhibit different travel behaviors than the average motorist. The calculations on energy and emissions impacts as a result of mode shift are based on initial mode shares of "likely" candidates for carsharing membership, based on findings in Celsor and Millard-Ball (2007) and Cervero et al. (2007).

Table 2. Base Mode Split for Candidate Carsharing Members

	Mode Split
Private Car	33.6%
Rail Transit	19.4%
Bus Transit	11.6%
Bike	3.8%
Walk	31.6%

The impacts of vehicle operation changes are estimated as a result of reduction in VKT in Table 1 and are based on per PKT estimates of a conventional sedan from Chester and Horvath (2009). The impacts of vehicle manufacturing and maintenance changes are a result of the private vehicle replacement rate in Table 1 and are based on per PKT estimates of a conventional sedan from Chester and Horvath (2009). The impacts of parking infrastructure demand decrease is a result of percent reduction in public parking demand in Table 1 and are based on the per PKT estimates of a total inventory of 820 million parking spaces in the US including for-pay parking spaces, commercial spaces, and on-street parking from Chester et al. (2010). The impacts of decreased fuel production are a result of the percent fuel efficiency improvement in Table 1 and are based on per PKT estimates for a conventional sedan in Chester and Horvath (2009). The impact on energy and GHG emissions from increased rail transit use is based on CalTrain operations in the Bay Area, and for bus transit use is based on diesel bus operations during peak congestion hours as reported in Chester and Horvath (2009). Lastly, the impacts of increased use of walk and bike (assumed non-electric) modes are from per PKT estimates in Dave (2010).

Table 3. Energy and GHG Emissions per Equivalent Private Vehicle PKT

	Energy (MJ)				GHG ($g\ CO_2$ equiv)			
	Before	**After-Low**	**After-Mid**	**After-High**	**Before**	**After-Low**	**After-Mid**	**After-High**
Vehicle Operation	2.1	1.53	1.06	0.42	144.15	105.23	72.61	29.04
Vehicle Manufacturing & Maintenance	0.37	0.04	2.74E-3	1.19E-4	29.76	3.31	0.22	0.01
Parking Infrastructure	0.5	0.37	0.23	0.11	46.6	34.48	21.38	10.69
Fuel Production	0.24	0.20	0.15	0.09	24.18	20.07	15.25	8.62
Increased Rail Transit Use	0	0.00	0.14	0.29	0	0.00	10.43	22.09
Increased Bus Transit Use	0	0.00	0.04	0.08	0	0.00	3.04	6.08
Increased Bike Mode Use	0	0.00	0.00	0.00	0	0.14	0.23	0.33
Increased Walk Mode Use	0	0.00	0.01	0.01	0	0.58	3.68	4.84
Total	*3.21*	*2.15*	*1.63*	*1.01*	*244.69*	*163.81*	*126.85*	*81.70*
Total % Reduction		*33.1%*	*49.2%*	*68.5%*		*33.0%*	*48.2%*	*66.6%*

As seen in Table 3, for a traveler who drives relatively few miles each year and lives in a denser urban neighborhood with good access to transit and non-motorized modes, joining a carsharing organization can reduce his/her energy use and GHG emissions 33 to 69%. In the most likely scenario, both inventories are reduced about 48% after a candidate traveler joins a carsharing organization. However, each component of travel behavior change, infrastructure demand change, and technology change impacts the total reduction differently, as seen in the tornado graphs shown below.

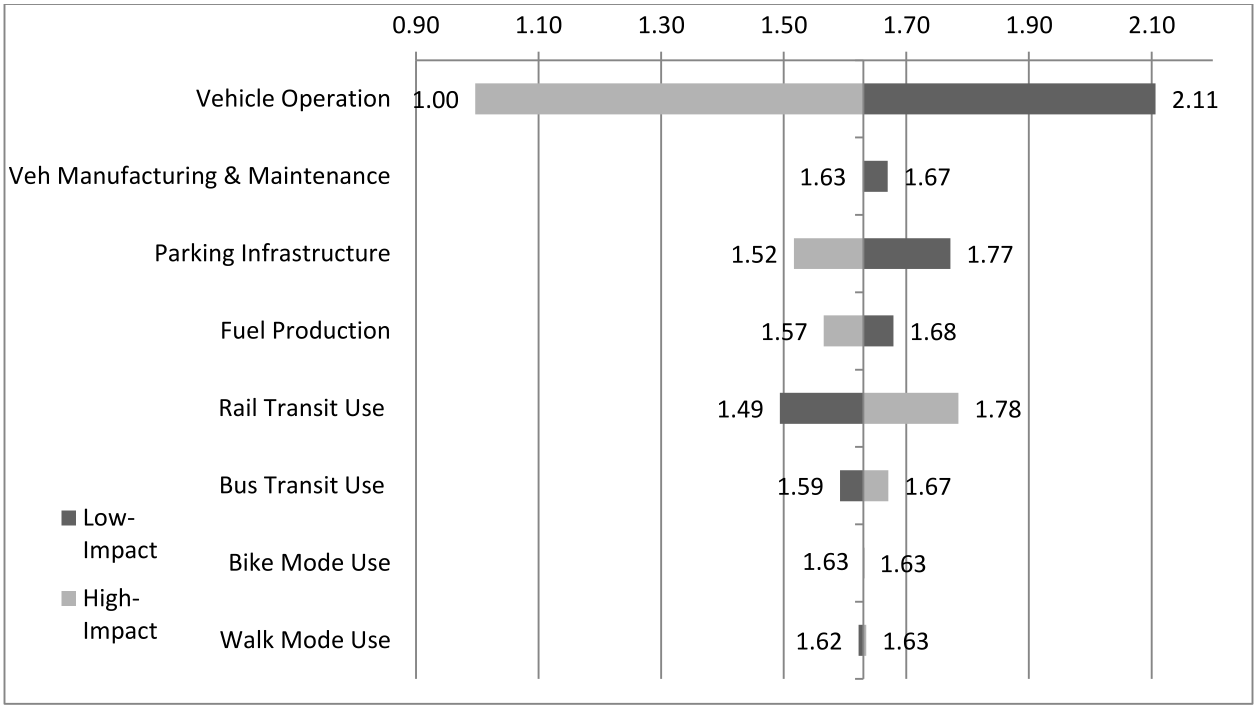

Figure 1. Impact of Inputs on Energy Use (MJ) per Equivalent Private Vehicle PKT

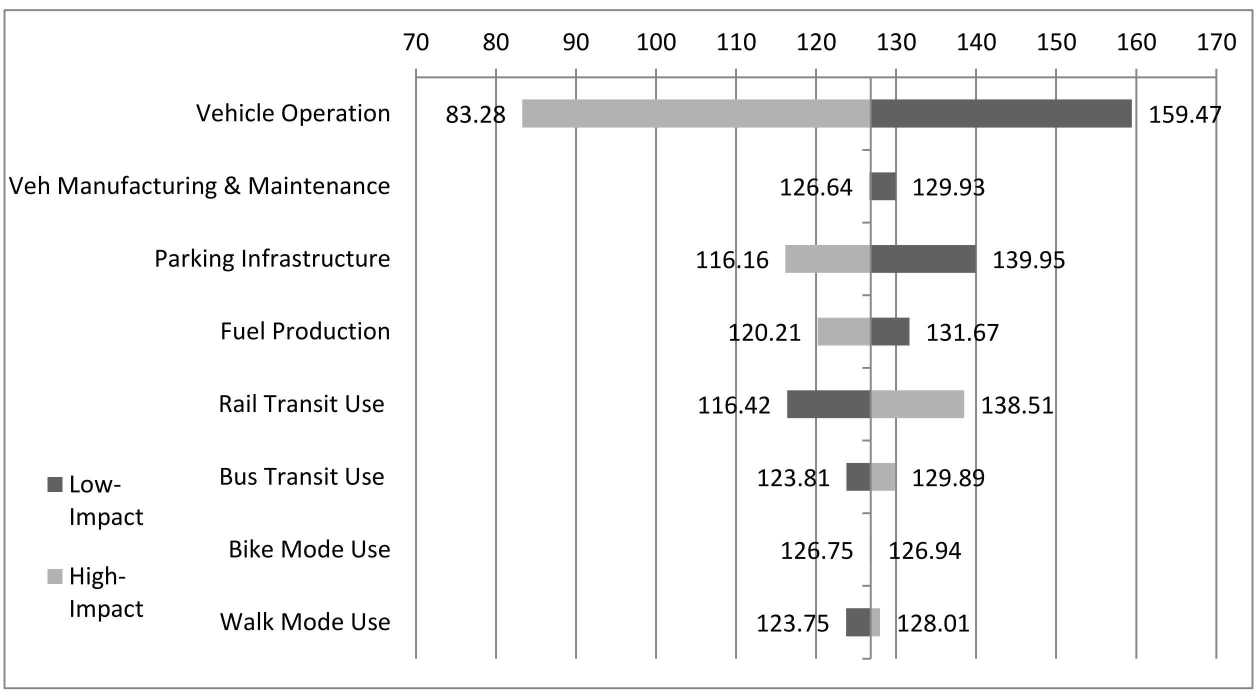

Figure 2. Impact of Inputs on GHG Emissions (g CO_2 equiv) per Equivalent Private Vehicle PKT

It is apparent that the energy use and GHG reductions are dominated by changes in vehicle operations, which is a result of reduced trips and travel distances in an automobile. In other words, the most important factor in carsharing's lowered impacts comes from avoided travel and shifted travel to non-auto modes. The biggest impacts on these inventories from trips to non-auto modes come from transit use, particularly the rail mode, as seen in Figures 1 and 2. Even accounting for the increased energy use and emissions from additional rail and bus transit use, the savings over private vehicle operation is still large. While carsharing can increase the service of underutilized vehicles (with more vehicles replaced due to miles driven rather than age-related factors like rust or outdated design), the primary driver behind environmental benefits seem to arise out of a traveler's need to plan for travel and awareness of the cost of automobile travel, as most carsharing services require reservations and operate on a pay-by-the-minute basis.

Following vehicle operations, the biggest reductions can be seen in parking infrastructure demand followed by fuel production decreases, which are results of reduced auto ownership, shifted modes, and vehicle technology improvements. Even accounting only for impacts to public parking infrastructure, life-cycle inventory energy and emissions savings are substantial. Despite the emphasis on vehicle ownership reduction and car-share vehicle to private vehicle replacement ratios in the literature, vehicle manufacturing and maintenance has a relatively small impact on reducing total energy and GHG emissions per equivalent private vehicle PKT.

Potential reductions in energy use and GHG emissions across all US households as a result of all candidate households joining carsharing organizations are in the range of 1 to 17% based on the nationwide carsharing market potential presented Table 1, with the most likely scenario showing an approximate net 5% reduction in energy use and GHG emissions in household transportation if all candidate households joined carsharing organizations as compared to all households using private, non-shared vehicles. While this analysis assumes that 3.0 to 26.0% of US households could be candidate members for carsharing organizations, as of 2013, there are only about 800,000 carsharing members in the United States (Steinberg and Vlasic 2013), constituting less than half of one percent of the nation's 210 million licensed drivers, and their 246 million registered (non-commercial) vehicles (USDOT 2011).

It is important to note that while these calculations include direct rebound effects as a consequence of joining a carsharing organization in the form of increased transit and nonmotorized trips, they do not account for indirect, economy-wide rebound effects of the avoided and shifted mode trips. From a household perspective, the savings in transportation expenditures will likely be allocated to other household expenditure categories which also have environmental impacts. Since indirect rebound effects are difficult to calculate (as a result of a whole host of second-order effects), estimated impacts from energy and GHG emissions indirect rebound vary widely. Experts estimate these effects to be as little as 5 to 15% (Thomas and Azevedo 2013, Druckman et al. 2011) to as much as 35 to 40% (Sorrell 2007). Thus, with indirect rebound effects considered, the likely total life-cycle inventory energy and GHG emissions savings from all U.S. candidate households joining carsharing organizations is in the range of 3 to 5%.

CONCLUSIONS AND EXTENSIONS

The benefits of carsharing have been touted in many previous studies from reduction in vehicle ownership to increased transit use. However, not many studies have examined the life-cycle impacts of carsharing, and the limited LCA studies on carsharing exclude infrastructure and/or shifted mode components. Using estimates from a wealth of previous carsharing studies, this study quantifies the life-cycle reductions in energy and GHG emissions of carsharing as compared to an equivalent PKT in a private vehicle, combining the effects of reduced vehicle ownership, reduced vehicle distance traveled, fleet fuel efficiency improvements, reduced parking infrastructure demand, and trips shifted to no-auto modes. For a traveler that meets the criteria of a good candidate for carsharing, joining a carsharing organization is predicted to decrease his/her transportation energy use and GHG emissions by 48%, with the biggest reduction coming from decreased vehicle operations as a result of avoided or shifted mode travel. Across all US households, this translates to a total energy use and GHG emissions reduction of approximately 5% within household transportation.

While this study accounts for sensitivity of the results to each of the impact factors, there are still other elements not accounted for. Carsharing has potential impacts on transportation infrastructure outside of parking, including roadway construction, lighting, and maintenance. However, the impacts on roadway capacity demand is likely to be small due to the large marginal capacity addition of each roadway lane compared to the relatively small decrease in total vehicles on the road as a result of carsharing. Nonetheless, in dense urban centers where carsharing has the potential to reduce the already limited numbers of car trips, roadway infrastructure can be impacted by carsharing. This study also does not take into account vehicle technologies outside of fuel efficiency that can also reduce GHG emissions, such as improved catalytic converters. This study is also limited to comparing a carsharing fleet of traditional internal combustion engine sedans. With smaller hybrid and electric vehicles growing in popularity, the magnitude of the energy and GHG emissions reduction from vehicle operations would likely decrease.

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LIST OF TABLES

LIST OF FIGURES