BSR

Advancing Environmental Sustainability in the Transportation Sector

The Role of Wireless Technologies

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About This Report

The report highlights several wireless integrations and applications that have potential to minimize the environmental impact of the transportation industry, with a particular focus on road transport in the United States. These solutions range from enterprise fleet management systems to consumer smartphones applications that simplify the use of public transit. Wireless technology is also enabling improvements in parking infrastructure and support for electric vehicle adoption. The report was commissioned by The Wireless Foundation, a 501(c)3 non-profit organization dedicated to demonstrating the power of wireless technologies to change lives through its innovative programs and initiatives.

METHODOLOGY

The report is based on a review of publicly available information and discussions with select experts from the wireless industry and transportation sector, among others. A full list of interviewees and sources is available at the end of the report. The applications detailed in this report were included on the basis of two key criteria: They include a clear wireless-enabled technology (specifically, licensed-spectrum wireless, such as that provided by AT&T, Sprint, T-Mobile, and Verizon), and they have documented potential for positive environmental impacts in the U.S. transportation sector. The applications listed here are not meant to be exhaustive. Rather, they represent a selection of current wireless applications that are advancing environmental sustainability in the transportation sector.

The authors would like to thank the interviewees and reviewers for their review of this report for accuracy. Please direct comments or questions to Aditi Mohapatra at amohapatra@bsr.org.

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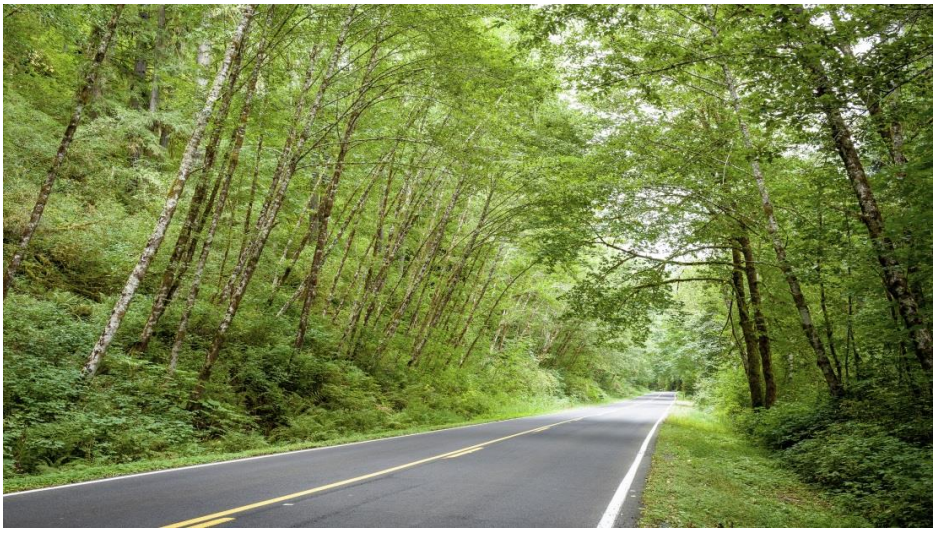
Introduction

Wireless technologies are starting to enable substantial efficiencies in the transportation sector. The use of real-time data can enhance vehicle and fleet operations and improve consumer transportation decisions. Various wireless integrations offer flexibility in routes and modes of transportation, including new opportunities to incorporate environmentally friendly choices into everyday transport decisions. In this report, we identify several of these wireless integrations and review their potential to drive environmental sustainability in the transportation sector.



The transportation sector, including cars, trucks, commercial aircraft, and railroads, among others, represents one of the largest sources of greenhouse gas (GHG) emissions and other air pollutants in the United States. The sector accounted for 27 percent of all GHG emissions in 2011,[1] while cars are the largest contributor to an average U.S. household's carbon footprint, accounting for 55 percent of CO_2 emissions in a typical two-car home.[2] Transport sources are a leading contributor to carbon monoxide, nitrogen oxides, volatile organic compounds, and other air pollutants.[3] Air pollution from road transport in particular caused 53,000 premature deaths in the United States in 2012—more than any other source of air pollution.[4]

Emerging wireless technologies and applications are increasingly used to reduce these environmental impacts. They can both replace the need for transportation by creating opportunities to connect remotely and help transform the current transportation system. In this report, we focus on wireless integrations that can minimize waste and reduce inefficiencies within the transportation sector. These include fleet management and connected car technologies, smartphone applications that support the use of alternative transportation, smart parking systems, and electric vehicle infrastructure analytics.

Wireless Fleet Management Solutions

Verizon's Networkfleet telematics solution transforms the way fleets operate by providing actionable data to improve efficiency and trim costs. For example, Simplot Grower Solutions, a California-based retailer and wholesaler of fertilizers, chemicals, seed, and a variety of on-farm services, needed a solution to track idle time and monitor the location of its fleet of more than 250 vehicles. The inability to locate trucks sometimes caused them to pick up pesticides from the same location six to seven times per day, leading to unnecessary fuel consumption and GHG emissions.

Through the integration of a wireless solution, dispatchers were able to receive daily and weekly activity reports showing vehicle location and start and stop information. They also received email alerts with vehicle arrival time and length of stay at specific locations. As a result, Simplot was able to reduce idle time by 30 percent, lowering its carbon footprint and saving thousands of dollars on fuel costs. Furthermore, the company increased its equipment productivity and utilization.

Improving Efficiency: A Focus on Fleets

Fleet operators integrate wireless technologies to optimize route planning, monitor performance, and minimize idle time, thereby reducing their environmental impacts.

Key Findings

- Wireless systems allow fleet managers to optimize their route planning by combining real-time data for vehicle location, fuel efficiency, idle time, engine performance, and other key diagnostics, all of which drive positive environmental impacts.
- The deployment of wireless fleet management systems could save up to a total of 80 million metric tons CO_2e (carbon dioxide equivalent) globally by the year 2020.[5]
- In the United States, the market for wireless fleet management systems is experiencing a growth period with the number of installed fleet management systems predicted to increase at a compound annual growth rate of 12.6 percent (from 2.1 million units in 2010 to 3.8 million units by 2015).[6]
- Addressing concerns about network security and privacy will be important to increasing adoption of these services.

Environmental Impacts of Fleets

As noted in the introduction, road transport is one of the leading causes of GHG emissions and air pollution in the United States. A significant component of this category, fleets provide day-to-day services ranging from waste collection to emergency services and the transportation of goods. Fleets may comprise 30 percent of vehicles (about 75 million) in the United States,[7] and these are often among the largest and most heavily used vehicles on the road.

A significant cause of environmental impact from road transport is simply sitting in traffic, for example, taking inefficient routes or idling a vehicle unnecessarily. Other causes include poor maintenance or poor driving techniques, which can significantly decrease fuel efficiency.

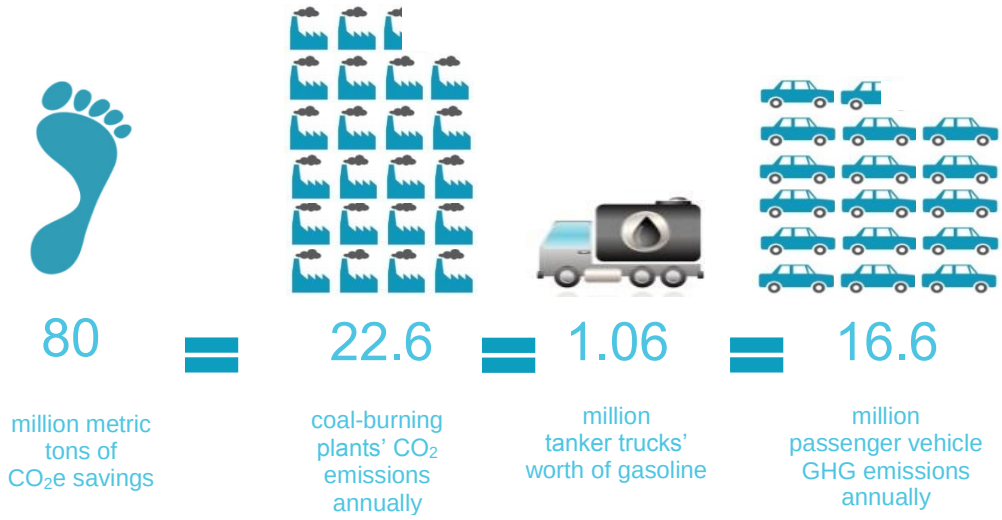
Wireless and Fleets

The market for wireless connectivity in vehicles and fleets is growing rapidly, generating significant opportunities to reduce their environmental impacts. It is estimated that the deployment of wireless fleet management systems and telematics could save up to a total of 80 million metric tons CO_2e globally by the year 2020.[8] As shown on the next page, this savings is equivalent to the CO_2 emissions produced by 22.6 coal-burning plants annually, 1.06 million tanker trucks' worth of gasoline in the United States, or 16.6 million passenger vehicles on a yearly basis.[9]

The number of installed fleet management systems is predicted to increase at a compound annual growth rate of 12.6 percent (from 2.1 million units in 2010 to 3.8 million units by 2015).[10] Their use in non-privately-owned commercial vehicles is forecast to rise from 16.3 percent to 29.5 percent by 2015.[11] Wireless fleet management systems include Networkfleet from Verizon, Omnitracs from Qualcomm, XATA, and PeopleNet.

Wireless fleet management solutions and telematics can save up to a total of 80 million metric tons of CO_2e globally by 2020.

Source: Global e-Sustainability Initiative (GeSI), "SMARTer2020: The Role of ICT in Driving a Sustainable Future," 2012, p. 36.



Case Study: The Smithsonian

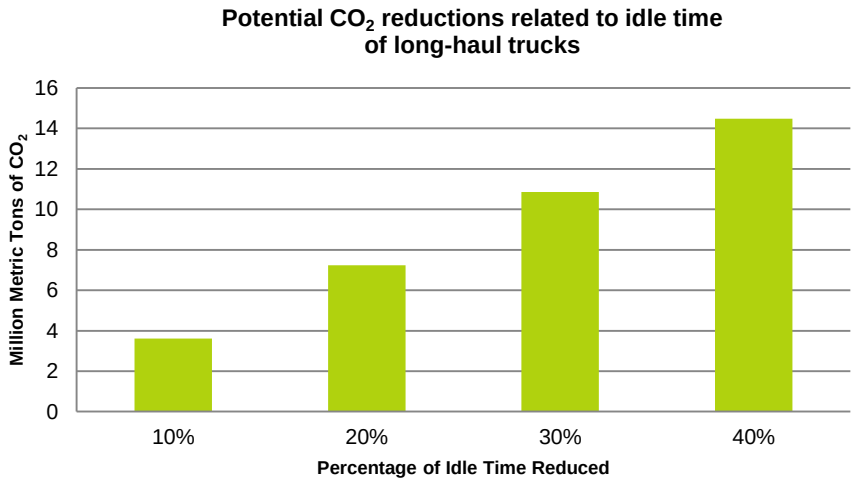
The Smithsonian Institution, which operates a wide range of facilities including museums, zoos, and educational centers, introduced the use of a wireless fleet management system to optimize the operation of its fleet of more than 1,500 vehicles. As a result, the Smithsonian decreased fuel consumption by 44 percent, optimized routing and deliveries to achieve a reduction of 12 full-size vehicles, reduced vehicle idle time by 40 percent through telematics, and avoided unscheduled maintenance by 15 percent through preventative maintenance.

Source: Ye, Jason, and Stephen Seidel, "Fleet Management and the Smithsonian: Using New Tools to Advance Sustainability and Efficiency," *Leading by Example: Using Information and Communication Technologies to Achieve Federal Sustainability Goals*, Center for Climate and Energy Solutions, 2012, pp. 31-36.

These wireless management systems enable the following opportunities and potential benefits:

» **Drivers and fleet managers can optimize routing.** Connected vehicles embed operating systems, applications, and other services that deliver real-time information to drivers,[12] who can use the information to navigate around traffic, anticipate red lights, and optimize their overall route planning. In larger fleets, machine-to-machine devices attached to vehicles collect and communicate data in real time through wireless networks to a centralized fleet management software system. The fleet manager can then calculate the quickest and most efficient route for vehicles on the road, and adjust these routes according to road conditions and unexpected events, such as adverse weather conditions. If wasted "out of route" miles could be eliminated on every long-haul truck in the United States by alerting drivers to delivery locations or fleet managers to errant behavior, fleet management systems could reduce GHG emissions by up to 13 million metric tons of CO_2 annually and provide US$4.9 billion in fuel savings.[13]

» **Drivers and fleet managers can optimize vehicle operations** by combining real-time data for vehicle location, fuel efficiency, idle time, engine performance, and other diagnostics**.** A typical long-haul truck, for example, idles as much as 1,400 hours per year. Applied to every long-haul truck in the United States, the wasted fuel and resulting GHG emissions could total as much as 36 million metric tons of CO_2 emitted per year.[14] As shown in the graph below, using wireless solutions to reduce this annual idle time by as little as 20 percent would lead to savings of 7.2 million metric tons of CO_2.



» **Fleet Managers can identify mechanical problems before they cause equipment breakdowns.** By collecting a variety of data, such as tire pressure, engine efficiency, and emissions of CO_2 or other pollutants, connected car infrastructures and wireless fleet management systems allow for constant monitoring of vehicle performance. As a result, they enable real-time monitoring of emissions levels and preventative maintenance resulting in reduced costs and less need for back-up vehicles.

Moving Forward

Although wireless fleet management systems are growing, there is still additional opportunity for deployment. Deploying such systems could help companies meet mandated GHG reduction requirements. For example, U.S. federal government agencies are required to cut fuel consumption, develop sustainability performance plans, set targets for GHG emission reductions, optimize the number of vehicles in their feet, and collect various data relating to vehicle performance.

Addressing concerns about network security may be needed to encourage adoption of fleet management systems. Connecting vehicles to networks makes them tempting targets for malicious hackers, while the inherent scalability of software means that a single security attack can spread quickly.[15] Providers of fleet management systems need to ensure that the networks they use are as secure as possible.

Next Generation: Connected Cars

According to research conducted by SBD, most, if not all, new cars will have some form of internet connectivity by 2025. As costs decrease and connectivity capabilities improve, several of the fleet vehicle capabilities discussed in this section are being made available in personal vehicles. Connected cars or cars that are equipped with internet access and wireless technologies are increasingly bringing traffic, weather, and vehicle diagnostic intelligence to car owners. For example, the Sprint Velocity connected vehicle platform offers in-vehicle connections, such as weather, navigation, emergency services, and engine diagnostics. Although they may be more limited than those installed in fleet vehicles, these tools bring comparable benefits like efficient route finding that avoids traffic or other slowdowns and optimization of vehicle maintenance and driving practices.

The capabilities of such connected cars, while impressive today, are likely to increase as more cars embed these technologies. As a greater number of vehicles are able to communicate with one another using wireless technologies, these vehicles could alert drivers to potential accidents, exchange safety and operational data, and share road and highway information intended to avoid accidents and improve overall traffic flow.

While such technologies are new to the market, they represent an opportunity for individual drivers to more effectively minimize their fuel consumption and optimize travel patterns. Increased direct vehicle-to-vehicle communication could also help improve overall traffic patterns.

The Sharing Economy

Wireless-enabled car and bike-sharing applications provide commuters with access to common goods and services, and they can encourage a shift in behavior from a singular to a shared ownership of resources. According to a member survey report conducted among subscribers to Capital Bikeshare, a bike-sharing service in Washington, D.C., 5 percent of all subscribers surveyed had sold their private car since joining the program, and 81 percent claimed that bike sharing was a factor in their decision to get rid of their car.

Changing Behavior: Alternative Transport Modes

From public transit to car and bike sharing, smartphone applications allow commuters access to a variety of transportation options, many of which represent environmentally friendly alternatives to traditional commuting.

Key Findings

- Smartphone applications provide accessible real-time information about transit schedules and transportation options and enable vehicle sharing. Access to this information gives commuters an opportunity to make greener choices and could even reduce individual vehicle ownership.
- Each car-sharing vehicle is estimated to remove 9 to 13 privately owned cars,[16] equivalent to eliminating 43 to 62 metric tons of CO_2 emissions annually.[17]
- Open data regarding transportation options, which can be accessed via wireless devices, is unavailable in many locations. Access to this data is essential to developing applications that enable smart commuting.

Environmental Issues and Alternative Transport Modes

The environmental impacts of vehicle transport, whether for personal or fleet vehicles, are discussed in the introduction and previous section. One of the simplest means of reducing these impacts may be to remove vehicles from the roads. Carpooling is one traditional example. If two or more commuters share a vehicle to and from work each day, they cut the number of single-occupancy vehicles on the road during peak driving times and reduce congestion, allowing all traffic to flow more freely. Public transit is another classic example; the environmental impacts of subways, buses, and commuter rail per passenger mile are far below those of single-occupancy vehicles. In fact, two-car households could shrink their carbon footprint 25 to 30 percent by giving up their second car and using public transit when possible.[18]

One of the greatest barriers to wider adoption of alternative transport modes has been that they are often seen as less convenient than single-occupancy car trips. Limited ability to change plans (for example, to get home early or pick up children in an emergency), uncertainty about bus or train schedules, and lack of options all make people less likely to carpool or take public transit.

Wireless and Alternative Transport Modes

Wireless information technology systems enable real-time, on-the-go access to data that can make alternative transport modes (including public transit and emerging forms of ride sharing) significantly easier to use and, therefore, support their adoption. Some of these systems' opportunities and benefits include:

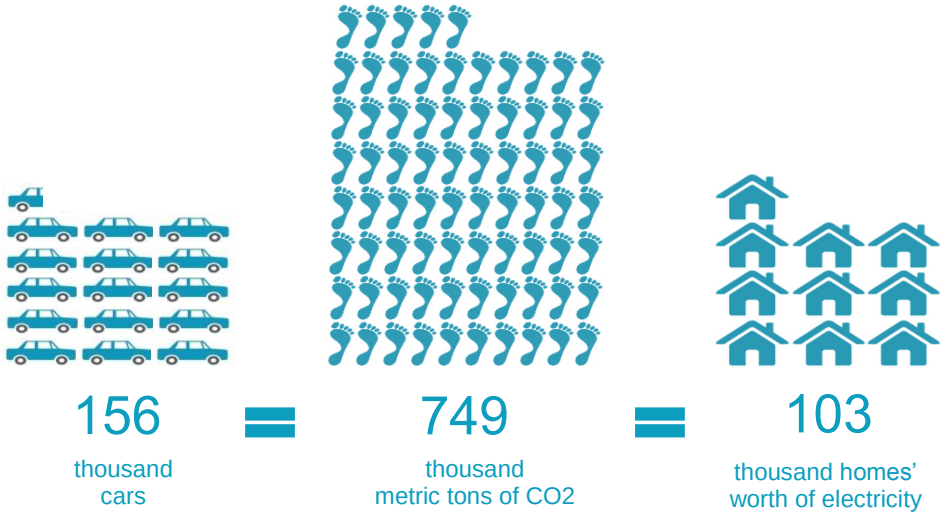
- **Enabling the transportation sharing economy.** The critical underlying technology that makes car, ride, and taxi sharing widely possible, the smartphone overcomes communications barriers and connects those needing rides with those who can offer them in real time and on the go. Applications that allow commuters to share cars, bikes, and rides (including Zipcar, Lyft, Uber, RelayRides, GetAround, and JustShareIt) owe their emergence and growth to the widespread use of smartphones. Vehicle sharing may reduce individual car ownership and use: According to some estimates, every car-sharing vehicle replaces 9 to 13 privately owned cars.[19] In early 2013, the total number of car-sharing subscribers was estimated at 800,000 who collectively used a fleet of around 12,000 vehicles.[20] As shown

Public Transit Opportunities

The HERE Transit application provides commuters information about various public transit options and compares routes, departure times, arrival times, and walking distance for each route option. The application is available in more than 740 cities globally and more than 100 cities in the United States. Developed by HERE, a Nokia company, the application has been scaled up rapidly over the last two years to cover 280 cities in China and significant parts of Australia, South America, and Europe.

Providing commuters with the information they need to weigh timing and transit options helps show that public transport offers viable alternatives to using cars, which carries an inherent benefit for the environment. Assuming that one-third of the total number of requests per month represent a unique trip, HERE Transit already enables around 500,000 public transit trips per month. Thus, when compared to driving a car, the application contributes to savings of more than 5 million pounds of CO_2 per month.

in the illustration below, assuming that each vehicle in this fleet replaced 13 privately owned cars, removing 156,000 cars from American roads would reduce annual CO_2 emissions by 0.749 million metric tons—the equivalent of the electricity use of 103,027 homes for one year.[21]



» **Improving access to and information about public transportation.** Most U.S. public transit systems now make schedule information publicly available, and in many cases, they provide real-time location and estimated arrival times for buses, trains, and other vehicles. Smartphone applications in turn provide commuters with easy access to this information. Social networking platforms serve as an additional source of information, enabling commuters to share real-time user-generated information, such as train arrival times and delays. As a result, commuters can reduce their wait times, choose the best transit route, and otherwise improve their ability to use public transit. If this increased convenience allows travelers to shift away from private cars to public transit or other modes of transport, it can have a large positive environmental impact. A single individual commuting alone by car 20 miles round-trip who switches to public transportation can lower their CO_2 emissions by 4,800 pounds per year, which is equivalent to a 10 percent reduction of all GHG emissions produced by an average two-adult, two-car household in the United States.[22]

Moving Forward

Open access to transit schedules and operations data, wireless network coverage on transit vehicles, and the integration of various transit modes and options are essential to spur the future development of innovative transportation solutions, including multimodal transit applications, mobile fare payments, and navigation maps. In this context, greater collaboration among stakeholders, including application developers and public transport authorities, would allow greater uptake of these wireless solutions and help make them more useful.

There are also questions regarding the calculation of environmental benefits of car sharing; in some cases, these applications may encourage an increase in miles driven by shared vehicles even as they decrease the total number of vehicles in use. More detailed study of these applications' long-term effects is needed to understand the full scope of their environmental effects.

Pilots Underway

Pilots for wireless-enabled parking guidance and information systems have begun. Two examples include SFpark in San Francisco (7,000 of the city's 28,000 meters) and LA Express Park in Los Angeles (6,000 spaces).

Partners in these initiatives include the U.S. Department of Transportation, Streetline, and StreetSmart Technology. These initiatives provide important opportunities to understand how smart parking can work to reduce congestion and increase environmental sustainability.

Making the System Work: Smart Parking

Effective parking systems are a key lever for reducing the environmental impacts of transportation. Using wireless technology, smart parking systems employ a combination of inventory and pricing information that influences and improves the flow of traffic by guiding those desiring parking to available spaces faster and more efficiently.

Key Findings

- Smart parking systems can reduce GHG emissions and air pollution by reducing traffic congestion and shortening the search for parking. In addition, land used for parking infrastructure can be minimized by decreasing the need for surplus spaces, which currently number four for every one car.[23]
- Wireless solutions can significantly reduce the number of cars looking for parking. If these solutions can eliminate a third of such "cruisers," it would reduce traffic in some neighborhoods by at least 10 percent.
- Smart parking pilots in the United States are identifying how to use this technology to reduce congestion and unnecessary travel. These pilots are also projecting the associated GHG emissions reduction potential.
- In order for smart parking to be widely deployed, the public will need to trust and accept the new technology, and effective partnerships with local governments and planners will be necessary for implementation.

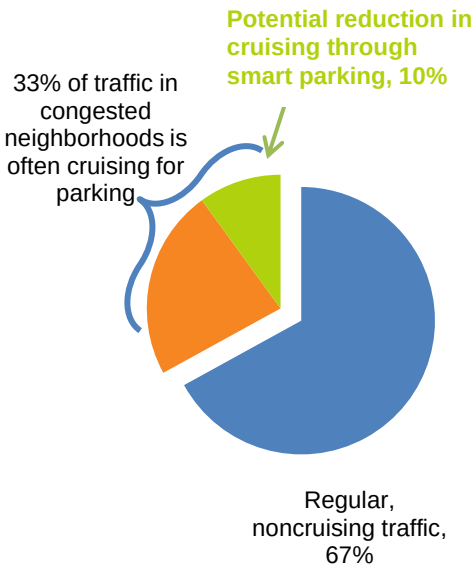
Environmental Issues and the Relevance of Wireless

Parking is one of the key areas of inefficiency in modern urban transportation infrastructure, leading to avoidable travel and significantly and unnecessarily oversized parking facilities:

- **Traditional parking practices cause unneeded travel and congestion.**[24] Between 1927 and 2001, 16 studies found that an average of 30 percent of cars in congested downtown traffic were looking for parking ("cruising")[25]—a figure corroborated by a 2006 study in Manhattan's SoHo district that found that 28 percent of cars were on the hunt for parking[26] and a similar study in Brooklyn that found the number to be 45 percent.[27] While these areas might be exceptional, such parking inefficiencies create an astounding number of unnecessary vehicle miles traveled—a million miles a year, for example, spent cruising in a single neighborhood in Los Angeles,[28] resulting in increased GHG emissions, air pollution, and wasted time.

- **Inefficient parking systems require vastly oversized structures.**[29] To assist with the parking problem, planners have responded by increasing the scale of parking lots rather than trying to understand the underlying traffic flow and resulting needs. For this reason, there are now more than four parking spaces for every car in the United States, translating to a total of more than 1 billion spaces.[30] In some areas, one-third of the land is covered by parking complexes.[31] This extensive infrastructure disrupts natural ecosystems and communities, generates urban sprawl, and often reduces community livability.[32]

Wireless and Parking



Wireless technology plays a key role in addressing the problems of parking by enabling better decision-making and infrastructure management.

» **Real-time data exchange to inform drivers about the number and location of available spaces reduces cruising.** It helps drivers find parking faster and discourages attempts to park in areas where spots are difficult to find. The exchange of data among individual parking spaces, a centralized control system, and drivers with mobile devices are at the heart of smart parking. Mobile applications like Streetline's Parker and Fybr's Park Genuis provide customers easy access to this information. This mapping can help drivers navigate to the best spot based on an array of preferences, including location, cost (e.g., less than $5), or communities of like-minded travelers (e.g., fans of the same sports team). As illustrated in the pie chart on the left, these solutions could reduce cruising by one-third in congested neighborhoods like those noted above, which would likely cut total traffic in those areas by at least 10 percent,[33] significantly reducing air pollution, GHG emissions, fuel use, and time wasted.

» **With wireless information flow that enables drivers to interact with a central control system, less physical parking infrastructure is needed.** In addition to more effectively routing traffic, smart parking can shrink parking's physical footprint by making the market more efficient. This shift in efficiency can cut the need for surplus parking, which currently stands at more than four spaces for every car.

Moving Forward

As smart parking is in its infancy, further testing and research is needed to show its specific economic and environmental benefits. Additional information will help determine what prices and information are most effective and will improve the quality and accuracy of specific parking systems.[34]

Given the lack of information on pricing effects to date, skeptics may perceive smart parking as possibly leading to higher prices or more competition. As a result, there is an opportunity to increase public familiarity with these efforts and highlight their benefits while addressing challenges.

Upgrading Infrastructure: Electric Vehicles

Wireless technologies offer solutions to address two of the primary challenges associated with the increased adoption of electric vehicles (EVs): a perception of having short driving range and the potential to create enormous draw on energy grids. These issues need to be addressed to enable a shift to EV adoption in place of their gasoline-powered counterparts, a migration that could radically lower GHG and other emissions.

Key Findings
» Wireless technology can facilitate the adoption of EVs through enhanced charging infrastructure, improved access to information, and an easier experience for drivers. EVs, in turn, offer the potential to dramatically lower the emissions impact of the nation's transportation systems.
» If wireless solutions facilitated the purchase of EVs in place of even 1 percent of cars purchased in the United States in 2012, emissions would be reduced by than 70 thousand metric tons of CO_2 annually.
» Charging standards and services remain fragmented, affecting the interoperability of charging systems and potentially the extent to which wireless technology can direct users to charging options.

Environmental Issues of Grid Electricity and Transport

Electricity generation and the transportation sector together account for more than 60 percent of U.S. GHG emissions.[35] EVs provide a new transportation paradigm that can significantly reduce the GHG emissions of transportation. At the same time, without proper management, EVs could cause major increases in electricity usage and negatively impact the stability of the electrical grid. While the U.S. transport system is well developed for petroleum-based vehicles, EVs require new infrastructure, new consumer information, and new driver habits.

Wireless and Electric Vehicles

Information technology systems using wireless to share data among drivers, vehicles, and utility providers (using both smartphones and machine-to-machine interfaces) can make EVs significantly easier to use and, therefore, encourage their adoption. Several significant examples include:

» **Wireless networks and smartphones make it easier for users to monitor their vehicles, as well as to find, reserve, and pay for vehicle charging.** Many potential EV buyers remain wary about switching from traditional vehicles to an EV because of concerns about vehicle range and availability of charging, but mobile applications can help overcome these issues. For example, mobile applications for Ford and Nissan EV owners, powered by the AT&T network, provide owners with information, such as battery charge status, how far the vehicle can drive on its current charge, and the locations of nearby charging stations.[36] In addition, ChargePoint, a membership-based service, maintains a network of charging stations and allows subscribers to use their smartphones to find and reserve charging slots and to track usage.[37]

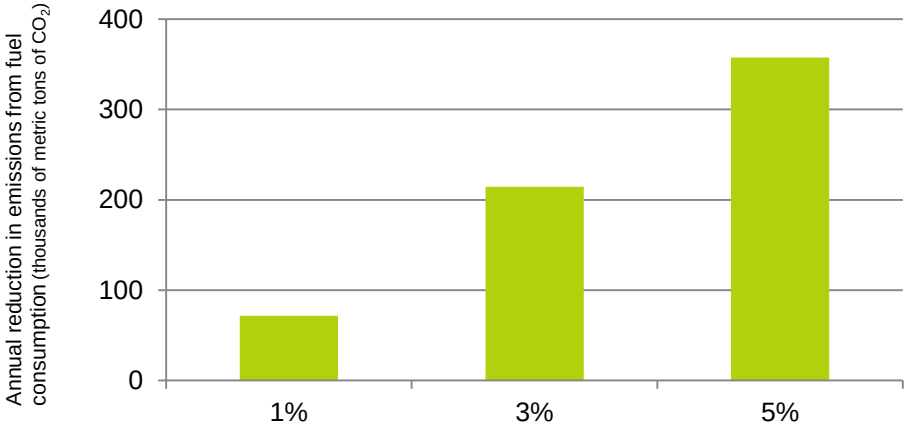
» **By facilitating the purchase of EVs, wireless solutions can have a significant environmental benefit.** The Union of Concerned Scientists has found that grid-powered EVs produce between 19 and 77 percent lower emissions per mile than the average new compact car, depending on the grid's electricity sources.[38] The same study found that switching from the

average new compact car (at 27 miles per gallon) to an EV saves 6,100 gallons of gasoline over the lifetime of that vehicle. For a sense of the potential impact: If the wireless solutions discussed above had facilitated the purchase of EVs in place of even just 1 percent of new cars purchased in 2012, GHG emissions could have been reduced by more than 70 thousand metric tons of CO_2 per year.[39]

» **Wireless technology and EV charging solutions can improve the economics and grid dynamics behind EV charging.** Solutions from companies like IBM and Microsoft enable drivers to use mobile devices to "set and forget" charging systems for their vehicles. Owners using a smartphone application can set charging parameters (how much, by when, etc.), and then the system automatically looks for times of day when electricity costs are low and charges the vehicle during those windows.[40] This off-peak charging saves EV owners money. One assessment found that drivers could save up to 50 percent of charging costs through such smart charging.[41] These improved economics of EV use may also support their wider adoption.

» **Wireless remote charging and support for vehicle-to-grid energy supply can smooth out electricity demand peaks and valleys.** Utility providers must constantly adjust the grid's electricity supply to meet consumer demand. Excess supply can lead to imbalanced grids and wasted energy, while insufficient supply can lead to service interruptions. As EV adoption increases, simultaneous charging of EVs (when commuters return from work, for example) could add to these strains by creating spikes in energy demand. Remote applications can enable off-peak charging to limit these spikes, as well as offer the potential to use EV batteries as a source of electricity in times of high demand and as a place to store renewable energy sources that have variable output, such as wind and solar. These attributes can reduce the need for utility providers to construct new power plants and maintain "spinning reserves" that generate backup electricity supplies.[42] By reducing demand peaks, smart EV charging can serve as a shock absorber for grids,[43] thus addressing one of the main concerns related to widespread use and even perhaps paying EV owners for these services. The effects would likely reduce overall GHG emissions and other air pollutants, as well as the landscape and other impacts of power plant construction.

Potential Annual GHG Reductions from EV Adoption



Note: This is meant to illustrate a switch to EVs from gasoline-fueled vehicles due to wireless technology's ability to facilitate ease of ownership.

Moving Forward

Despite the support that wireless technologies provide for EV adoption, these technologies cannot eliminate the vehicles' typically long charge times. In addition, fragmented, proprietary charging standards can limit drivers' charging options. To address the latter concern, the Open Charge Alliance, which includes such members as the Eaton Corporation, is working to increase the interoperability of charging systems and the software systems that underlie them.[44]

Finally, some aspects of the environmental benefits of EVs are still open to debate. While using EVs avoids the need to burn gasoline, their manufacturing and battery production still have large environmental impacts. In addition, the net benefits of EV operations depend on the grid's sources of energy.

Conclusion

While the solutions presented in this report hold significant promise, many are still in pilot phases or being used by early adopters. Concerted efforts should be made to increase adoption of these technologies and measure their environmental benefits. There are several areas where further development and understanding will be helpful:

» Many of these technologies are still in early implementation stages, so **sharing information generated by pilot studies** about their successes, limitations, and opportunities for improvement will be crucial to encouraging adoption and improving them over time.

» ICT and transport companies should work together to **ensure network security and privacy** of information and maintain the ability to transmit it securely. In particular, ICT companies have significant experience in this arena and could support transport companies that may be new to handling large amounts of sensitive personal data.

» Because many of these technologies provide information to vehicle drivers that they might use while en route, continued **attention to concerns about distracted driving** from both transport and telecommunications companies will be important for their safe implementation.

» The **full implications of incorporating complex electronics into vehicles** and transport systems warrants further study, particularly to ensure that manufacturing and disposal systems can deal with these materials without creating additional environmental concerns.

» **Realistic measurement of environmental benefits** will be important to ensure that they are neither discounted nor exaggerated in a way that might damage the credibility of those promoting the solutions. These measurements should include an understanding of conditions like “rebound effects” in which, for example, improvements in the efficiency of transport may encourage increased transport volume and negate some of the environmental benefit.

Given the large environmental footprint of the transportation sector there are significant opportunities to minimize inefficiencies and provide smart alternatives to current transportation methods. The wireless integrations profiled in this report showcase several wireless solutions that have the potential to considerably minimize the sector’s environmental footprint:

» Fleet operators can use wireless systems to **optimize route planning, fuel efficiency, idle time, and engine performance**, which could minimize the emissions of fleets by up to a total of 80 million metric tons of CO_2e globally by the year 2020. In the years ahead, similar technologies in connected cars will provide individual drivers with intelligence to reduce their fuel consumption and manage vehicle operations.

» Smartphone applications can **promote greener commuting options and reduce individual vehicle ownership** by providing access to real-time, on-the-go transit options and scheduling and by enabling the shared ownership of transportation resources.

» Current parking systems could benefit from the integration of wireless solutions which provide inventory and pricing information and can **reduce traffic congestion, GHG emissions, air pollution, and land used** for parking infrastructure.

» Wireless solutions also play a key role in **facilitating the switch from gasoline-fueled to electric vehicles** due to the technology’s ability to simplify EV charging and improve the grid management of electricity demand.

Appendix: Interviewees and References

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