Innovative solutions for e-Mobility and their potential impact on climate change

Introduction

A perfect storm of events is transforming mobility and modes of personal transportation. For the past several decades, (carbon-based) mobility has mostly entailed automakers producing ever larger and more powerful cars and governments building newer and larger roads to accommodate them. This mobility model has defined our society, the economy and the environment for decades. However, as global population and income levels grow, extending the current system to another 2 to 3 billion people is not feasible for a number of reasons. Peak oil, geopolitical tensions in oil producing states, urbanization of society, demographic factors and climate change are forcing us to rethink our mobility systems. This paper examines current mobility and e-mobility trends as well as some of the technologies that will be integral to future mobility systems.

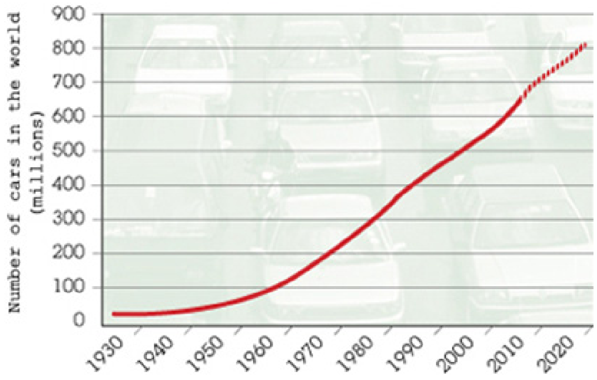
Motorization and the carbon-based society

Since our ancestors first ventured from the forests into the plains of Africa, mobility has played a key role in our success as a species. Mobility has allowed us to populate the farthest reaches of the globe and become the cornerstone of our economies and civilization itself. Ironically, today's mobility based on fossil fuels and the societies that it has defined now threaten our very existence through their impact on the global climate. This is not the first time our transportation mode has adversely affected our environment, however. At the end of the 19th century, horses and overcrowding were a key source of pollution and disease in our cities. At that time, cars and mechanized transit were viewed as our society's environmental saviors.[i]

Source: www.lowtechmagazine.com

Horses' first competitors were motorized bicycles, which were also the precursors to automobiles. In fact, bicycle advocates spearheaded the good roads movement that ushered in the age of motorization. Electric vehicles appeared on the scene around the same time as internal combustion engines. In 1882, Werner Siemens drove the first electric vehicle – the Elektromote – along a 540 meter test track in Germany. The Elektromote was followed in 1905 by the Electric Victoria which rolled through Berlin as a taxi and delivery vehicle. Although these vehicles and others like them were ahead of their time, "their low battery capacities, speeds, and range couldn't compete with internal combustion engines."[ii]

By the end of World War 2, the combustion engine and motorization became the defining factors in shaping our communities and the automobile "had become universal, inexpensive, and above all a symbol of modern 'urban' culture." Master planning for the car and the auto-centric society had taken hold in North America and also spilled over into Europe. By the 1970s, this form of development began



Source: http://www.globaltrees.co.uk/facts_.php

to define middle income countries as well.[iii] For the past several decades, the number of motor vehicles has been rising steadily as has the amount of land devoted to highways and parking lots. Today, road and highway mileage has dramatically increased and there are over 600 million motor vehicles in the world.[iv]

The distance that people travel has also increased steadily. Today, Americans living in urban areas travel approximately 45 km per day, Europeans about 30 to 35 km. In China, where motorization is not yet widespread, data from the China Transport Association indicate distances travelled of only 2.8 km/day.[v] However, "China's spectacular economic growth over the past two decades has resulted in high rates of industrialization, urban development, and motorization." China's motorization is still not widespread, but its impact - in the form of congestion, pollution and traffic-related fatalities - on the major cities of eastern China is clear."[vi]

Impacts of motorization and future outlook

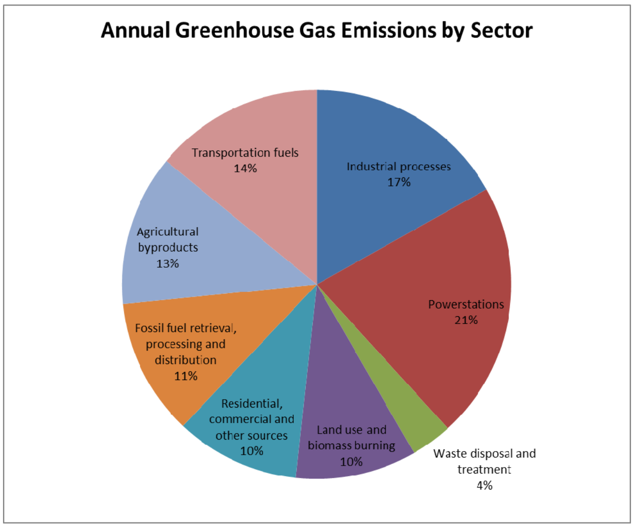
From the 1940s on in the U.S. where motorization first took hold, neighborhood streets have grown wider, densities have decreased, and zoning has resulting in the strict regulation of land uses. Cul-de-sacs emerged as the basic organizing principle of the emerging suburbs.[vii] The subsequent suburbanization process has since eaten up thousands of acres of land. "By the late 1990s, the rate of open land that was being lost to development had grown by 50 percent over the previous decade. More than three million rangeland acres, seven million cropland acres, and 10 million forestland acres were lost in just 15 years."[viii]

Source: Photo by Carnotzet from the Torontoist Flickr Pool.

Suburbanization and sprawl has not been limited only to North America. In Europe from 1990 to 2000 large amounts of new urban area have been developed in formerly rural areas , particularly in Germany, Northern Italy, Portugal, and in some parts also Ireland, France and Spain. The same patterns of sprawl are also significant in the Benelux countries, in some areas of England, France, Poland, Austria, and Hungary.[ix] Although many have benefited from the effects of this rapid suburbanization in the form of "large yards, proximity to open space, new schools, increased mobility, and the financial appreciation of home values", these benefits have not been universal.

Indeed, suburbanization carries many unintended consequences. Wide streets that have inadequate street crossings and lack bike lanes and even sidewalks endanger drivers, cyclists and pedestrians alike.[x] "Low densities and segregated land uses put people farther from work, play, school, and daily errands, making cars necessary for most trips." The cul-de-sacs isolate local residents. Although people can and do walk in their neighborhoods, it is difficult to actually get anywhere.[xi] As suburbs and exurbs spread out, less land remains to replenish aquifers for clean drinking water, to prevent erosion, to reduce greenhouse gases, and to support the biodiversity that is vital to ecosystems and to people. The septic systems and manicured lawns of these new subdivisions pour toxins into the ground further degrading the environment and threatening water supplies.[xii] As suburbanization eats up farmland, crops and foodstuffs must be shipped over longer distances – consuming more fuel. People must also travel further as connectivity is designed out of our neighborhoods. Today, Americans drive twice as many miles as they did in 1970. Sprawl and congestion are also causing Europeans to spend more time behind the wheel. As a consequence, Americans waste over 3.5 billion hours a year in traffic tie-ups, and since the early 1980s, these delays have consumed more than two billion gallons of fuel — this not only pollutes the air and contributes to global warming, but also greatly adds to the cost of the products and services we buy.[xiii]

Global oil consumption has increased 10-fold since World War 2 – about half of this consumption stems from mobility.[xiv] Many geologists believe oil production will soon peak and subsequently reserves will slowly, irreversibly decline. As a result, at current consumption levels these reserves will not last past 2050. The U.S. currently imports 60 percent of its oil. Europe imports the vast majority of its oil. Cars account for much of this demand (60 percent in Germany).[xv] Until only a decade ago, China was virtually self-sufficient in energy and oil. Now, owing to its rapid industrialization and motorization, China has also joined the list of oil-importing nations.[xvi] All of this oil consumption is leading to increased carbon dioxide emissions – the chief culprit behind global warming. Moreover, the afore-mentioned suburbanization processes have resulted in a significant increase in our society's mobility needs – leading to yet more cars and more driving.[xvii] As a result, whereas during the past decade CO_2 emissions have increased by 13 percent, carbon emissions by vehicles have increased by 25 percent.[xviii]



Source: Wikipedia

By comparison, motorization and mobility levels are still far lower in Asia than in North America and Europe. Unfortunately, the U.S. in particular has "virtually created the transportation model that China, India and others seem likely to imitate..."[xix] As these developing countries seek similar levels of motorization, the number of cars in the world could soon double or even triple. [xx] [xxi] This process is already underway. China is already the world's second largest car market after the U.S., "and its leaders have promised that the country will soon have 34,000 miles of highways, second only to the U.S."[xxii] China is now poised to become the world's largest automobile market by 2020. Furthermore, like in other countries, the benefits of motorization in China are not equally distributed. Those who can afford to own private cars have benefitted while conditions for pedestrians and cyclists have deteriorated - mainly due to the significant reductions in sidewalks and bike lanes.[xxiii] As a result, "bicycling as a major form of travel in urban China is rapidly declining."[xxiv]

The changing landscape of the Energy sector

Before fossil fuels, our economies were powered by renewable resources: the sun, wind, flowing water, wood, and muscle.[xxv] However, these energy sources and the technologies used to harness them could not meet the energy needs of the industrial age. Coal, oil and gas soon took over as our main sources of energy. Today, peak oil, geopolitical tensions and climate change are causing us to rethink our dependence on fossil fuels. We have come full circle and renewable resources are once again being used for energy. Modern technology is allowing us to capture energy from the sun, wind, biomass, geothermal and other sources with much greater efficiency than in the past. In the hitherto highly fossil fuel dependent United States, by 2030, a fifth of the nation's electricity could be provided by wind.[xxvi] Europe has already made great strides in the area of renewable energy. Denmark produces 20 percent of its electricity by wind power. This figure is set to rise to 50 percent by 2025. And, in terms of producing the technology to capture energy from renewable resources, China has vaulted past its competitors in Denmark, Germany, Spain and the U.S. in making wind turbines and is also the world's largest manufacturer of solar panels.[xxvii]

Source: http://www.sbc-technologies.com/sbc-technologies-renewableEnergy.php

The biggest hindrance to widespread generation of electricity via renewables is the electric grid itself. Often, the most productive areas for generating renewable energy are located far from the population centers where the energy is consumed. Transmission lines must be erected to carry the electricity to consumers – wasting up to two-thirds of the energy along the way. [xxviii]Distributed generation using small-scale renewable energy technologies can utilize resources closer to consumers to reduce these inefficiencies. In this manner, the next generation of photovoltaic and wind power technologies will allow buildings and even roads to become power plants, permitting them to be both self-sufficient and profitable by selling surplus energy back into the grid. In order to achieve this, however, the electric grid must be rebuilt so that it can handle such a network of local generators. “Currently, most electric power grids can't handle 'downstream' sources, so there's no good way to pump excess local power back into the grid.”[xxix] The future grid must be two-way and it must be “smart”. It must carry energy and information — real-time information about energy usage and distributed production – in order to optimize the system. And, the last piece of the puzzle that is missing is the issue of storage. Denmark is a world leader when it comes to producing electricity from renewable energy sources, wind in particular. Unfortunately, unlike countries like Austria where surplus energy can be used to pump water into reservoirs in the mountains that can be tapped later as hydroelectric power, Denmark is flat and has no means of storing its surplus energy. Danish power utilities must send their surplus electricity to neighboring countries - and pay for doing so.[xxx]

The Low Carbon City and e-Mobility's renaissance

The recognition of the role that greenhouse gases emissions from burning fossil fuels play in climate change has led the emergence of the "Low Carbon City" movement. Low carbon cities are proposed as a means of reducing greenhouse gases to avert irreversible and catastrophic changes to our climate. Achieving the low carbon city requires an "integrated and inclusive planning of city, region and human's settlement system". A key element of this effort involves rethinking mobility.[xxxi] With nations and cities across the globe setting ever more ambitious CO_2 goals, and consumers becoming more environmentally conscious, the automotive industry is coming under extreme pressure to innovate. "Although there is room for improvement in combustion motors, they are becoming less economical for car makers and customers – the technology is approaching the end of its potential." [xxxii]

The convergence of the factors described above – increasing mobility in developing nations, rising energy costs and the shift towards renewable energy, the push to reduce carbon emissions and growing environmental consciousness among consumers – underlie electric mobility's current renaissance.[xxxiii] In fact, electric propulsion is nothing new for the transportation sector - trains, trams and buses have relied on it for decades.[xxxiv] Now, many car manufacturers are also recognizing the enormous market potential that lies in electric vehicles, their components and infrastructure.[xxxv] In Germany, BMW, Daimler and Volkswagen are working with major German power suppliers such as E.ON, EWE, Vattenfall and EnBW to develop comprehensive e-mobility solutions.[xxxvi] [xxxvii] Indeed, virtually all major car companies are or will soon be pursuing electric mobility solutions. It is predicted that by 2020, half of all new cars will have electric propulsion either as range extenders, completely electric or plugin hybrids. At the forefront of interest are e-motorbikes, short trip and commercial vehicles, but also electric sports cars.[xxxviii] Evidence of this is the recent disclosure by U.S. sports car maker Tesla Motors of a $100 million deal with Toyota.[xxxix] The U.K.'s Ecotricity also just introduced a sports car, built on the Lotus Exige chasis, the Nemesis which is powered by two 125 kilowatt motors which produce 330 brake horsepower.[xl] It is not just the car-makers that are jumping on the e-mobility bandwagon, however. Other global players include: Siemens, Infineon, Panasonic, Philips, Robert Bosch, EBM-Papst, Johnson Control, Bitrode and AVL List.[xli] Of course, it is not just industry that is behind the push for e-mobility. Governments are also actively supporting such efforts. France, USA, China, Japan and Germany all have outlined goals related to e-mobility. Germany recently passed a National Electromobility Development Plan aiming to speed up research and development in battery powered electric vehicles in Germany with the goal of having one million electric vehicles on German roads by 2020. Within the framework of the Electric Vehicle Deployment Act, President Obama set forth even more ambitious goals for the U.S., calling for one million electric cars on the road by 2015.[xlii] And, in China, 2010's "12th Five-Year Plan" highlights miniaturization and electrification as the future of the Chinese automotive industry.[xliii] The EU and many of its other member states are also following suit.[xliv]

Source: http://green.autoblog.com/photos/ecotricity-nemesis/full/

This push for electric vehicles "will make an important contribution to meeting climate targets around the world.[xlv] "Through electric cars comes the ability to introduce renewable energy into the transportation sector". Thus, vehicles can be completely emission free.[xlvi] Indeed, electric cars can play a vital role in stabilizing the grid when renewables are in the energy mix. As previously mentioned, the problem with the current push for renewable energy generation from sources such as wind and solar is the need to store energy during times of surplus (when the wind is blowing or the sun is shining) for times when these installations are not producing. A solution would be to use the batteries of electric cars as a storage mechanism. "If, for example, a surplus of electricity is available, as is often the case at night or during periods of windy weather, prices could be lowered, making it attractive to 'fill up' at such times. Conversely, if winds were calm, or a lot of electricity was being used during the day, the price might rise accordingly, which would lead many vehicle owners to sell their electricity back to the grid at a profit." In terms of one of today's most widely utilized renewable resources, wind, approximately 300 electric vehicles would be needed as potential energy storage units for every wind turbine with a peak output of three megawatts.[xlvii] It is this vision of electric cars operating both as a means of transport and a mobile energy storage device that is set to transform both the auto industry and the energy sector.

The technologies behind e-Mobility

Electric motors are 3 to 4 times more efficient than combustion engines. This efficiency is because in the case of the latter, 25-30 percent of the energy the engine uses contributes to movement of car, the rest is lost as heat. An electric car, on the other hand, converts 80 percent of its energy to movement.[xlviii]

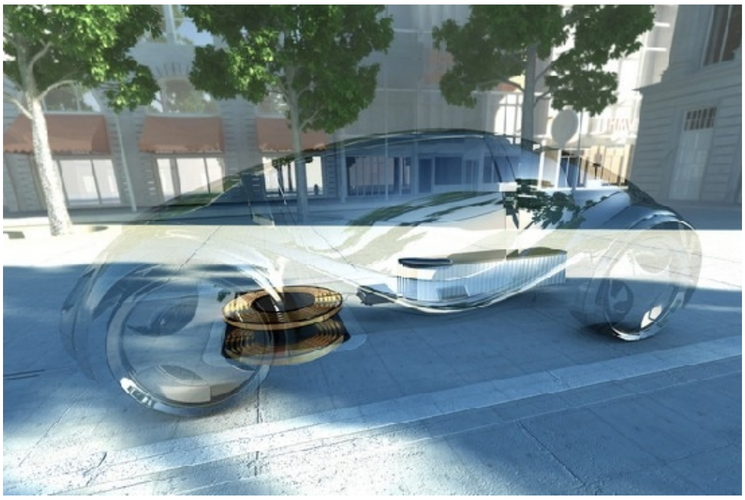
The most important technology for electric vehicles is the battery, which often accounts for 50-80 percent of the added value of the vehicle.[xlix] Lead batteries are commonplace in most two wheel electric vehicles in Asia. Newer vehicles rely on nickel cadmium batteries, which store twice as much energy. Toxicity issues are leading to their replacement with even more efficient metal hydrides. The past decade saw the introduction of Lithium ion batteries including Li-titanate, Li-cobalt oxide, Li-Nickel-Cobalt or Li-iron phosphate that range in toxicity and are expensive to produce. Such batteries are found in cell phones, PDAs, and laptops. Indeed, VW recently began working with laptop maker Toshiba on the development of battery technology.[l] Another IT firm – IBM – has teamed with the University of St. Andrews to develop a new generation of Lithium air batteries that are 10 times more energy dense than today's lithium ion batteries. These batteries could be on market within 10-15 years and will offer a huge boost to e-Mobility.

The battery is also significant because of the weight it adds to the car. To run a mid-sized car 500 km requires 90 kWh, a lead battery with a 30 Wh/kg capacity would weigh three tons, a Nickel metal hydride battery (80Wh/kg) would weigh one-half ton.[li] The extra weight that today's batteries add to a vehicle is between 140-450 kg. Efforts are ongoing to further reduce the weight and increase the efficiency of batteries.

The heavier the car, the larger (and heavier) the battery needed to power it. This has led to a push to also reduce the weight of the car itself. Many car components that hitherto were made of metal can now be made from plastic offering a weight reduction of up to 50 percent per component. [lii] BMW plans to build a battery-powered city car with a lightweight shell made out of carbon fiber - the same material used to protect Formula One drivers. Since such a carbon structure would be 50-60 percent lighter than a conventional body, the added expense of the body would be offset by the concomitant reduction in battery size needed to power the car.[liii]

Students at the Karlsruhe University of Applied Sciences are taking weight reduction one-step further. Their approach is to build a car so light that it can run without a battery. The power would be delivered to the vehicle through cables embedded in the roadway using inductive charging. Such vehicles would benefit “cities that might want to sponsor such vehicles in order to limit access to crowded urban areas or provide small, automatic vehicles as an alternative to buses or other mass transit.”[liv] Nevertheless, this research is still very preliminary and its application would likely be limited and unable to supplant battery driven cars.

With this in mind, another important aspect of e-mobility is the charging infrastructure for recharging batteries. This infrastructure should allow the simple and safe charging of the cars. The plug must be standardized and work flawlessly worldwide – despite different power systems and plug/socket requirement. It must also permit bidirectional flow to allow the e-vehicles to serve as storage for the future Smart Grids.[lv] The charging stations themselves must be located in areas where they make sense and (ideally) where the electricity stems from renewable resources.[lvi] Public charging stations would be best placed where e-vehicles are parked for extended periods - this includes parking lots at shopping centers, rest stops, work places, etc.[lvii] Obviously, homes and residential garages will be where most people will charge their vehicles. Some may wish to use solar carports or even augment them with wind to minimize carbon emissions.[lviii] BMW has recently joined forces with Siemens to develop a magnetic field charging system similar to those used to wireless laptop and cell phone charging pads. Using this solution, a car could simply park above a charging station, at which point coils in both the ground and the vehicle would recognize each other and begin the charge. Such a system could help drivers avoid vandalism or safety issues that might be associated with plug in chargers.[lix]



Source: gizfactory.com

Another approach that is being taken to charging is to set up battery stations designed like gas stations. With this solution, drivers whose batteries are low on energy could stop at such a station to quickly exchange their battery for a fully-charged one. California-based company Better Place has entered a partnership with Renault-Nissan and plans to work with local energy utilities to establish energy infrastructures based on this principle in various countries.[lx]

Regardless of the technology used for charging, the payment systems will need to be fast and easy to use. Users should be able to select from a range of payment options – SMS & charge, RFID or credit cards. They should be able to select clean energy from their provider of choice anywhere, anytime at no extra cost and be able to watch the charging progress on their smart phones.[lxi] [lxii] Payment solutions should also be comprehensive. “We can soon use a credit card to charge our car, use intercity transportation, obtain a rental car or access a car share – payment can be on the basis of previously determined rates or flat-rates from a provider of our choice.”[lxiii]

E-mobility also has its hurdles that must be overcome in order for it to become established. In the foreseeable future, batteries will remain one of the most expensive components of electric cars. For a

Source: Udy 2011

mid-sized vehicle to achieve a range of 100 kilometers would require a battery with approximately 15 kilowatt-hours of energy content. Such batteries currently cost more than €10,000 – significantly adding to vehicle costs. However, it is feasible that such batteries need not be bought, but leased from an energy supplier. "In other words, an energy company would decentralize its energy storage capacity and finance the battery through the latter's 'secondary use'."[lxiv]

Range anxiety is another factor that discourages some drivers from going electric. To overcome this issue, in North America, AAA recently announced it will offer North America's first mobile charging roadside-assistance trucks.[lxv]

The cost of the charging stations themselves is also an issue. According to Germany's Frauenhofer Institute a single charging station can cost up to €17000, while a complete charge of a 55 kWh battery, however, earns such a station barely €10 in revenue. One method to improve the ROI for such a charging station is to combine the sale of electricity with parking payment systems. In this manner, the charging station, which would consist of one master and up to 4 satellite stations, distributes both electricity and parking tickets. [lxvi]

Electric cars are not a panacea

As we learned above, the autocentric society goes hand-in-hand with a host of other problems. In other words, "our car-related environmental and energy problems have a lot less to do with the fuel we use than we might think. The simple truth is that we're not going to drive our way out of these problems."[lxvii]

Today, more than 74 percent of the European population lives in cities. In Asia the urbanization process is also pronounced.[lxviii] Even in the U.S. (owing largely to the recent financial crisis), the suburbanization process has slowed. Moreover, the aging of populations will likely contribute to a reverse migration into cities. A recent study by EnBW found that 70 percent of the day (approximately 17 hours) vehicles are parked at home and effective commuting time for most Europeans is only 50 minutes.[lxix] In consideration of these facts, it is becoming more and more evident that expectations for cars especially in terms of range requirements are changing. Even the 20th century's role of a car as a status symbol is losing sway among younger generations, whose attention is more focused on acquiring the newest handheld

Source: http://www.flickr.com/photos/renaissancechambara/3831219067/

electronic devices than a big flashy car.[lxx] The modal split in many European cities already demonstrates that the car is not the preferred mobility alternative for many urban residents.[lxxi] In the future, young professionals may choose not to own a car, but rent one when they need it paying for the time and distance when they use it.[lxxii]

Thus, instead of waiting expectantly for developments in the area of electric automobiles we should bear in mind that individual mobility consists of a much broader range of vehicles – for many of which electrification is already much more progressed. There is an astonishing diversity of mature technologies for two-wheelers: segways, ebikes, pedelecs, emotorbikes, escooters (of which there are already over 60 million on Chinese streets).[lxxiii] There is also a variety of electric vans and buses that are the logical choice for short distance commercial services in city centers. UPS is already using such vehicles in many cities across Germany.[lxxiv]

The new age of mobility

For many commutes in urban areas, public transportation and bicycles or other two-wheel electric vehicles would be perfectly suited. Most European cities have good public transportation systems and are well-designed for bicycling and two wheel vehicles. Current modal splits in Europe are evidence to this effect. In the U.S., public transportation does not play a prominent role in mobility and safety has been the key deterrent to a boom in bicycling as a cheap, nonpolluting, and healthful alternative to the car.[lxxv] Unfortunately, in Asia the path towards motorization appears to be following the U.S example. In this regard, increased motorization often comes at the expense of bicycles and public transport. Bicycles are effectively (and often literally) being forced off the streets in many Asian cities.[lxxvi] And, if the lessons of the rest of the world apply to Asia, public transportation systems will also soon be exposed to stiff competition from individual cars both in terms of actual trips and from “the impact of congestion slowing buses down, hindering access to rail and metro stations, and ultimately worsening the economics of public transit.” [lxxvii]

Achieving the much vaunted “Low Carbon City” will require a rethinking of auto-centric mobility models. A more holistic view must be taken in terms of mobility and its impact on our communities. Establishing the “Low carbon City” will be contingent on creating the “Pedestrian-City” (mixed uses and mobility based on short distances) and the “Tram-City” (Transit Oriented Development) to enable ecology compatible transport, sustaining mobility, and the “Solar-City” to bring about energy efficiency, sustainable comfortable living in buildings. Automobiles (and electric automobiles) will undoubtedly remain an important form of transportation for many people. However, automobile transportation must be combined with other multi-modal transportation choices (public transportation, bicycling, walking, etc.) and the pooling of automotive resources (ridesharing and car sharing) should also be encouraged.[lxxviii] This paradigm shift will go hand-in-hand with new economic opportunities. The ambitious targets set by governments will attract new investment, renewable energy will be ramped up as energy storage issues are resolved and the smart grid is implemented, businesses and countries pursuing these technologies will achieve more competitive positions, and finally the numerous inefficiencies and externalities associated with fossil fuels can be reduced.[lxxix]

Today, we are witnessing the renaissance of electric mobility and it is up to us planners to rethink our communities and our energy infrastructure so that these new vehicles can take their rightful place in a new age of mobility.

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[i] American Planning Association (2004) "Public Garages: The Dupont Garage, Washington, DC," Horseless Age Microsoft PowerPoint - APA Web Presentation.
[ii] Tschulik, Peter (2010) "Smart Grid and E-Mobility". REAL CORP 2010 Proceedings, Vienna, 18-20 May 2010 p. 1253-8.
[iii] Schipper, Lee; Shiuen, Wei (2004) "Rapid Motorization in China: Environmental and Social Challenges". EMBARQ. World Resources Institute. October 18, 2004.
[iv] (1997) "Cars Emit Carbon Dioxide". Global Warming, Focus on the Future.
[v] Schipper et al.
[vi] Ibid
[vii] Epstein, Lee R. (2005) "The Path to Pedestrianization" Planning — May 2005.
[viii] Goodman, Robert (2008) "The Truth About Sustainability History tells us that smart cars won't solve all our problems." Planning — May 2008.
[ix] Fina, Stefan; Siedentop, Stefan SIEDENTOP (2008) "Urban sprawl in Europe – identifying the challenge". REAL CORP Proceedings 2008, Wien, May 19-21 pp. 489-501.
[x] Krohe, James Jr. (2005) "It's Dangerous Out There Safety and security are becoming planning preoccupations." Planning — May 2005.
[xi] Epstein, Lee R. (2005) "The Path to Pedestrianization" Planning — May 2005.
[xii] Goodman, Robert (2008) "The Truth About Sustainability History tells us that smart cars won't solve all our problems." Planning — May 2008.
[xiii] Ibid
[xiv] Esch, Hans-Jürgen (2010) „Mobilitaet – mit Vollgas in die falsche Richtung",Neue Mobilitaet Vol. 1 October 2010 pp. 48-49.
[xv] Traenckner, Jan (2010) „Mobilitaet – mit Vollgas in die falsche Richtung",Neue Mobilitaet Vol. 1 October 2010 pp. 44.45.
[xvi] Schipper et al.
[xvii] Henkel, Andrea; Haag, Martin (2010) "Sustainable Mobility in Cities: Reducing the Carbon Footprint of Transportation in Tübingen". REAL CORP 2010 Proceedings, Vienna, 18-20 May 2010 pp. 691-700.
[xviii] Zhang, Wentong (2010) "Planning Strategy and Practice of Low-carbon City Construction", 46th ISOCARP Congress.
[xix] Browning, William (2009) "Energy: Where Design Begins: An excerpt from a new APA Planners Press book explains how energy sources shape our communities". Planning — October 2009.
[xx] Traenckner
[xxi] Ibid
[xxii] Goodman, Robert (2008) "The Truth About Sustainability History tells us that smart cars won't solve all our problems." Planning — May 2008.
[xxiii] Schipper et al.
[xxiv] Goodman
[xxv] Browning
[xxvi] Best, Allen (2010) "Transmission Boost - A surge in wind power means the U.S. needs to seriously upgrade its grid. That's easier said than done." Planning — February 2010.
[xxvii] Bradsher, Keith (2010) "China Leading Global Race to Make Clean Energy" The New York Times, January 30, 2010. http://www.nytimes.com/2010/01/31/business/energy-environment/31renew.html
[xxviii] LeCompte, Celeste (2009) "Cisco's Latest Consumer Play: The Smart Grid" GIGAOM April 21, 2009. http://gigaom.com/cleantech/ciscos-latest-consumer-play-the-smart-grid-1/
[xxix] Fehrenbacher, Katie (2009) "How the Smart Grid Could Create a New Market for Energy Goods" GIGAOM March 1, 2009. http://gigaom.com/cleantech/how-the-smart-grid-could-create-a-new-market-for-energy-goods/
[xxx] Tschulik
[xxxi] Zhang
[xxxii] Traenckner
[xxxiii] Tschulik
[xxxiv] German-e-cars (2010) „Vordenker für Morgen German E-Cars setzt Maßstaebe i Markt",Neue Mobilitaet Vol. 1 October 2010 pp. 28-29.
[xxxv] Doll, Birgit; Ebner, Marco (2010) „Das Elektroauto wird das iPhone der Automobilindustrie", Neue Mobilitaet Vol. 1 October 2010 pp. 20-21.
[xxxvi] Tschulik
[xxxvii] Doll et al.
[xxxviii] Ibid

[xxxix] Rooney, Ben (2011) "Tesla shares pop on $100 million Toyota deal" @CNNMoney July 20, 2011. http://money.cnn.com/2011/07/20/news/companies/tesla_toyota_electric_rav4/
[xl] Durgahee, Ayesha; Knight, Matthew (2011) "Former hippy speeds into new energy age" CNN July 25, 2011. http://edition.cnn.com/2011/WORLD/europe/07/22/nemesis.wind.turbine.ecotricity/index.html
[xli] Doll et al.
[xlii] (2010) "Electric Vehicle Infrastructure Planning" Planning March 2010
[xliii] http://www.emobilitychina.com/
[xliv] Korthals, Jan Peter (2010) „Leimarkt Elektromobilitaet – Wie Deutschland an die Spitze faehrt,",Neue Mobilitaet Vol. 1 October 2010 pp. 62-63.
[xlv] Fücks, Ralf (2011) "The Future of E-mobility in Germany and the US", Heinrich Böll Stiftung North America. March 31 2011. http://www.boell.org/web/136-741.html
[xlvi] Rentsch, Stefan (2010) „eMobilitaet – wir machen Zukunft sicher", Neue Mobilitaet Vol. 1 October 2010 p. 7.
[xlvii] Tschulik
[xlviii] Traenckner
[xlix] Korthals
[l] Tschulik
[li] Traenckner
[lii] Dallner, Claus, Zeiher, Volker (2011) "Electric Cars: Lightweight Construction and More", Kunststoffe International 3/2011 p. 39-43.
[liii] Collins, Hugh (2010) "BMW Plans Electric Car With Lightweight Carbon Fiber Shell", DailyFinance July 2, 2010.
[liv] Proefrock, Philip (2010) "Superlightweight Electric Car Doesn't Need Batteries" Ecogeek.org September 29, 2010.
[lv] Mora, Melanie (2009) "E-mobility: First VDE global standard for car plugs", Association for Electrical, Electronic & Information Technologies.
[lvi] Gabriel et al.
[lvii] Fröschl, Andreas (2010) „Status Quo der Elektromobilitaet", Neue Mobilitaet Vol. 1 October 2010 p. 56.
[lviii] Electric Vehicle Infrastructure Planning — Planning March 2010.
[lix] Stevens, Tim (2011) "BMW and Siemens partnering for wireless-charging EVs, cutting the cord this May" Engadget April 14th 2011. http://www.engadget.com/2011/04/14/bmw-and-siemens-partnering-for-wireless-charging-evs-cutting-th/
[lx] Tschulik
[lxi] Fröschl
[lxii] Gabriel et al.
[lxiii] Esch
[lxiv] Tschulik
[lxv] Udy, Jason (2011) "Range Anxiety Reducer: AAA Unveils Mobile EV Charging Trucks". Motor Trend, July 20, 2011 MT1Gabriel, Jürgen; Buchman, Marius (2010) „Interview mit Ronald Große Die ökologische Dimension der Elektromobilitaet", Neue Mobilitaet Vol. 1 October 2010 pp. 58-59.
[lxvi] Hahner, Uwe (2010) „EnergieParken – Parkscheinautomat mit Ladeanschlüssen", Neue Mobilitaet Vol. 1 October 2010 pp. 30-32.
[lxvii] Goodman
[lxviii] Henkel
[lxix] Kretzer, Bianca, Wohlbold, Jadine (2010) „Are you ready for E-mobility", Neue Mobilitaet Vol. 1 October 2010 p. 26.
[lxx] Elektro-Mobilität ist primär ein kulturelles Problem Ohne Abschied von der "Rennreiselimousine" geht es nicht. http://www.heise.de/tp/blogs/2/147474
[lxxi] Schwedes, Oliver; Kollosche, Ingo (2011) "Elektromobilität als technologischer Treiber der Stadtentwicklung". REAL CORP 2011 Proceedings, Essen, 18-20 May 2011.
[lxxii] Fücks
[lxxiii] Rosansky, Thortsten (2010) „eMobility - worauf warten wir eigentlich noch?", Neue Mobilitaet Vol. 1 October 2010 pp. 50-51.
[lxxiv] Sigl, Kurt (2010) „Die Zeit ist reif", Neue Mobilitaet Vol. 1 October 2010 p. 3.
[lxxv] Krohe, James Jr. (2005) "It's Dangerous Out There Safety and security are becoming planning preoccupations." Planning — May 2005.
[lxxvi] Goodman
[lxxvii] Schipper et al.
[lxxviii] American Planning Association (2002) Policy Guide on Smart Growth - Adopted by Chapter Delegate Assembly, April 14, 2002, Ratified by Board of Directors, April 15, 2002 Chicago, IL.
[lxxix] Fücks