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1st Place

Better Place: Shifting Paradigms in the Automotive Industry

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In February 2010, Better Place opened its first demonstration center in Israel, constructed inside a refurbished industrial oil storage tank, with a 1.5km test track allowing visitors to drive an electric car. The demonstration center showcased Better Place's ambitious plan to challenge the status quo in a complex and rigid industry. Its opening was the latest milestone in the company's three-year history, during which it had established partnerships with Israel's national electric utility, venture capital firms, battery companies, car manufacturers, corporate clients and the Israeli government to launch a nationwide network of electric vehicles. In addition, Better Place had announced partnerships with firms and governments in Denmark, the United States, Canada, Australia and Japan and had engaged in conversations with 25 other governments around the world. Along the way, Better Place raised \$200 million in its first round of venture capital funding in 2007, and \$350 million in a second round in 2010, based on a valuation estimated at \$1.25 billion, making it the second largest startup in history. The company's mission was nothing short of audacious - to reduce and eventually eliminate the automobile industry's dependence on oil.

A brief history of the automobile industry

Prior to the emergence of motorized personal vehicles, very few people traversed long distances on a regular basis. For shorter distances, besides walking, horses-drawn carriages had long been the dominant mode of transportation. But around the middle of the eighteenth century, population, especially in city centers, increased sharply. As a result, the use of horses in cities became problematic due to increased street congestion and accumulation of startling amounts of manure in the streets. With animal waste leeching into waterways, health and sanitation problems surfaced, leading to increasing alarm about the future of transportation.

As these concerns mounted, steam engine technology, originally developed for industrial applications, was gradually adapted to personal vehicles, thereby revolutionizing the transportation sector. Although early steamers were too heavy to be used as personal vehicles, ongoing development, mostly in the agricultural sector, eventually led to the development of technology that would enable the steam vehicle to function as a mode of personal transport. Nicolas Joseph Cugnot was the first to apply steam engine technology to a self-propelled mechanical vehicle, in 1769. Water was heated by combusting a source of fuel, mainly coal or wood, expanding the water to create steam, thus propelling the vehicle. It took roughly 20 minutes to start the vehicle because of the time required to heat the engine, and the water tank needed refilling roughly every 50 kilometers.

Yet, in the 1870's, when steam-powered personal transport became technologically feasible, demand for travel was limited, because roads were unpaved and social networks were - in large part - local. In fact, demand for personal vehicles took off only after a short-lived bicycle craze and the emergence of trams, first drawn by horses, then self-propelled. Such modes of transport had encouraged people to relocate to suburban areas, thereby generating demand for convenient personal transportation. As personal vehicles became increasingly popular, they spawned unprecedented opportunities for mobility, fundamentally altering the

way people perceived time and distance. The automobile era, which characterizes society to this day, had begun.

With demand for steam cars increasing steadily, propulsion technologies attracted entrepreneurial attention. Thomas Davenport and Robert Davidson are credited with inventing the first practical application of the electric vehicle as early as 1842. The use of electric vehicles (EVs) expanded in the second half of the 19th century, as they outperformed the steam-powered automobile on several dimensions, including ease of use, cleanliness and near-silent operation. Many inventors made contributions to electric vehicles through improvements in motor technology, battery technology and electricity storage. Early EVs used non-rechargeable batteries, and the energy stored within them was released as electrical current used to propel the car. Typical EVs reached an average speed of 15-30 kilometers an hour and could travel approximately 65 kilometers per charge. Despite being more expensive than steam vehicles, at the end of the 19th century automotive manufacturers sold more electric cars than other types of vehicles, primarily to the upper class. However, EV production, peaking in 1912, began declining with the ascendance of the internal combustion engine (ICE) vehicle in the early 20th century. By 1935, electric car production had declined to virtually zero.

The emergence of ICE can be traced back to 1876, when Nicolaus Otto invented and built the four-stroke engine which is still used in petrol-fueled cars today. These engines used a mixture of liquid fuel and air, ignited by a spark plug. Gottlieb Daimler, later co-founder of Daimler Motoren Gesellschaft, the maker of Mercedes vehicles, contributed to the evolution of the industry with the development of a small, light, fast engine.¹ Its timing was opportune, reaching the market just as familiarity with personal vehicles began to grow, driving rules and regulations coalesced, and the paved road network in and around cities began taking shape. Further, the electric starter, developed around 1910 – ironically, based on electric vehicle technology – had rendered the awkward crank-start obsolete, eliminating one of the main disadvantages of the ICE vehicle. Additional factors, unrelated to intrinsic vehicle performance, helped the ICE win the race to mass adoption, including the production and availability of an energy dense fuel. Moreover, a particularly vocal consumer group, young male drivers, preferred the ICE, whereas EVs were preferred primarily by women. As more people became aware of ICE technology, their preferences shifted from silence and air quality - which characterized the EV - to price, speed and range. Henry Ford's invention of the assembly line, coupled with his eventual decision to embrace the ICE, fueled its meteoric rise. The assembly line process produced a new car every 15 minutes, dramatically reducing labor costs per produced vehicle, making them available for \$850. Consequently, by 1915 there were 1 million ICE vehicles on the road and the number was rising steadily. ICE vehicles became the first global car, produced and driven throughout North America and Europe.²

The development of extensive highway infrastructure, the improvement of fuel efficiency and the rapid evolution and expansion towards a network of 150,000 gas stations in the United States alone, also contributed to the ubiquity of the ICE.³ Detroit, Michigan emerged as the

¹ History of the Automobile

² Auto Atlantic, 2008

³ Electrification Coalition, 2009

hub of the automotive industry, headquartering the big three car manufacturers and many of their suppliers. General Motors, Chrysler and Ford became model companies for the industry while France-based Citroen introduced the ICE prototype to Europe. These companies and others demonstrated that mass-producing vehicles could be a lucrative business while improving the quality of life of people around the world. Major car manufacturers and suppliers appeared and created millions of jobs in Japan, China, Germany, South Korea, Canada and 14 other countries around the world. The ICE led to dramatic economic growth in the fuel extraction, refinement and distribution industries as well.⁴

For many years, consumers and producers alike remained unaware of the associated health, environmental and political issues that would arise from the dominance and ubiquity of the ICE. Lead was one of the first additives in gasoline and was used to increase the level of octane, which allowed gasoline to burn in a more controlled manner. It was first used by GM in the 1920's and the health effects on humans, including lead poisoning and heart disease, were not recognized until the 1960s when Clair Cameron Patterson, an American geochemist, published his research on the increasing levels of lead found in the environment due to its combustion in automobiles.⁵ In response to Patterson's findings, governments began pressuring manufacturers and, subsequently, oil companies to eliminate the use of lead in gasoline. Its complete phase-out culminated in 1986. Additionally, governments pressured manufacturers to install catalytic converters to reduce the emission of hydrocarbons and carbon monoxide and, later, nitrogen oxide, all potent greenhouse gases.⁶ The US government required that, by 1975, all cars manufactured in the US would have a catalytic converter installed, but even today this policy is not enforced globally.⁷

As of 2010, there were nearly 750 million vehicles on the planet, roughly 600 million of which were passenger vehicles.⁸ Together they were responsible for 25 percent of global greenhouse gas emissions,⁹ half of global oil and rubber consumption, 25 percent of glass consumption, 23 percent of zinc and 15 percent of steel production.¹⁰ Oil imports placed a significant burden on many countries' balances of trade. For example, the US trade deficit on oil imports reached \$388 billion in 2008, representing over half the country's deficit.¹¹ With growing populations and personal transportation unlikely to decline significantly in the short or medium terms, the economic and environmental sustainability of an ICE-dominated transportation sector had become increasingly dubious.

⁴ OICA, 2008

⁵ Kitman, 2000

⁶ McCarthy, 2009

⁷ McCarthy, 2007

⁸ Worldwatch Institute

⁹ Moriarty, 2007

¹⁰ Orsato, 2009

¹¹ Electrification Coalition, 2009

The Better Place Model

In 2005, Shai Agassi took part in a Young Global Leaders seminar for young innovators, where the question, “What would you do to make the world a better place by 2020?” was posed. At the time, Agassi was President of the Products and Technology Group at SAP AG, a multinational software development company based in Germany and heir-apparent to the company’s CEO position. Before that, the Israeli high-tech entrepreneur had established and led a software start-up, which he sold to SAP when he was 33 for \$400 million. In the months after the gauntlet was thrown in the Young Global Leaders seminar, the challenge of making the world a better place remained implanted firmly in Agassi’s mind. By 2007, Agassi quit his job at SAP and had founded the Better Place Company with headquarters in Palo Alto, California and an R&D center in Israel.

Agassi’s vision for Better Place was to create linkages between car companies, battery companies, utilities and consumers in a manner that would enable EVs to attain widespread adoption. Agassi believed that the only way to make consumers adopt EVs on a massive scale was by overcoming the most significant hurdle that beset the EV paradigm – limited mobility. While others believed that widespread adoption would not occur until dramatic improvements in battery capacity would enable electric cars to traverse more than the 100 miles currently possible, Agassi sought to develop a comprehensive EV-based solution, suitable for all driving profiles and implementable with existing, off-the shelf technology. Agassi’s fundamental insight was that “the solution to electric cars lay not in re-engineering the battery but in re-engineering the car.”¹²

In essence, the Better Place model could be summed up simply: “We buy batteries and electricity, and we sell miles.”¹³ It was based on the concept that the battery and the automobile would be sold separately. Not having to include the battery in the vehicle purchase positioned the EV, price-wise, on par with an ICE vehicle, with its price projected to be roughly \$20,000.¹⁴ At the time of purchase, the buyer would sign up for a service plan with Better Place – or a competing Electric Recharge Grid Operator (ERGO) – which would provide electric car services that including the energy required for the car’s propulsion. With each car sold, the ERGO – not the buyer – would purchase a battery, estimated at roughly \$12,000. In addition, and unrelated to the ERGO, drivers would pay vehicle maintenance and insurance costs (as with standard ICE cars). Maintenance costs for the EV powertrain, having very few moving parts, were expected to be much lower than for ICE vehicles.

Service plans

As envisioned by Better Place, drivers would sign up for a service plan with an ERGO in which “electricity will be sold in miles as opposed to kilowatt hours.”¹⁵ ERGOs would be able to provide a menu of service plans to their consumers, analogous to those offered by mobile telephony operators. Better Place predicted that its clients would be offered three tiers of service plans – all-you-can-drive, fixed monthly fee, and pay-as-you-go.

¹² Thomsson, 2009

¹³ Goodman

¹⁴ Levinson, 2009

¹⁵ Sandalow, 2009

The all-you-can-drive plan was designed for heavy users, such as taxi-drivers. Better Place market research found that the top 25 percent of drivers consumed 66 percent of gasoline in the US, and believed this ratio to be broadly true in other target countries.¹⁶ Frequent drivers would thus be best suited to a program with a fixed monthly fee based on a locked-in price (meaning they would not pay more if energy prices spiked), for a roughly 4-year contract. Similar to cell phone companies, drivers who chose to sign up for the top tier service plan, estimated to be \$500 per month, would likely obtain a rebate from Better Place, potentially offsetting the entire capital cost of the car.¹⁷

For medium-range drivers that were able to predict their yearly driving range, Better Place created the fixed monthly fee plan, which allocated the driver a pre-determined amount of miles. For example, a driver would be able choose a plan that offered her 12,000 miles for the entire year for a fixed monthly price of roughly \$350 per month.

The third tier to be offered by Better Place was the pay-as-you-go plan, for less frequent drivers. The major advantage of this plan was that drivers would be able to purchase miles in smaller quantities, similar to calling cards. However, the drawback was that, unlike the other two plans, these drivers would be exposed to fluctuating electricity prices.

Software and infrastructure

In order for Better Place's model to work, the company would be required to build and maintain the recharging infrastructure for the EVs. The infrastructure for recharging would be composed of two main components – charge spots and switching stations. Resembling a short post with an electric socket, charging spots would enable drivers to recharge their cars at convenient locations, whenever the car was stationary for some duration, such as at work, while shopping or at a restaurant. Charge spots, with an estimated installation cost of \$1,000, would be abundantly placed in key locations – train stations, malls, offices, grocery stores, parking lots and even along sidewalks. Moreover, for a fee of \$250-\$300, drivers would also have the option to install a charge spot at home.¹⁸

A full recharge of an EV battery with existing technology required several hours of connectivity to a charge spot, thereby significantly constraining mobility. To address this problem, the ERGO infrastructure offered a complementary component - switching stations. Switching stations would be analogous to conventional gas stations, and would serve cars traversing longer distances. Inside these switching stations, robotic arms would automatically replace depleted batteries with fully charged ones. Cars would be moved along a conveyor belt to swap their batteries in less time than it took to refuel an ICE vehicle at a gas station. Every switching lane would have the capacity to swap 12 batteries per hour. Behind the scenes, each battery switching lane would be equipped with ten battery chargers, potentially yielding 20 available batteries per hour, given that it would take roughly thirty minutes to charge each battery.¹⁹ A switching station was forecast to be much more costly than a traditional fuel station, on the order of \$1M fixed cost, and, on top of that, would require cost-effective management and stocking of expensive batteries.

¹⁶ Agassi, 2009

¹⁷ Agassi, 2009

¹⁸ Pogue, 2009

¹⁹ Roth & Gohla-Neudecker, 2009

In the US, 90 percent of car trips are less than 30 miles²⁰, and the average number of miles driven is usually around 12,000 per year.²¹ As a result, Better Place believed that its customers would rely on charge spots for the bulk of their energy needs, using switching stations much less frequently. In the early stages, Better Place expected to build 2.1 charge spots per subscriber.²² Agassi believed that switching stations, intended primarily to support long range driving, needed to be placed roughly 25 miles apart on major thoroughfares.²³ Since a multitude of charge spots substantially reduced demand at switching stations, Better Place believed that one switching station would be able to support 3,000 cars, and planned to install no more than 100 switching stations in each of its primary launch locations. By comparison, there were roughly 1,100 gas stations in Israel²⁴, 2,000 in Denmark²⁵, and 2,100 in the San Francisco Bay Area in the United States.²⁶

Finally, cars would be equipped with computers that would track the time to depletion, the distance the car could drive with remaining power, and the location of switching stations. Additionally, information about driving behavior would be transmitted to ERGOs, enabling them to place cars in priority sequence for charging when demand for electricity was high. Driving patterns would also be analyzed so that, for example, drivers who were typically parked at the office for 8 hours a day would only receive their charge when electricity demand was low, and energy prices were relatively inexpensive.

Renewable Energy

One major criticism of EVs was that, in regions with low levels of renewable energy production, the production of greenhouse gas emissions was merely transferred from the car engine to large energy production facilities that converted carbon-intensive feedstocks such as coal into electricity. For Better Place to really make the world a better place, the company could not simply transfer emissions from car tailpipes to conventional electricity production facilities—the energy source needed to be renewable. Albeit renewable energy production had not passed the 10 percent threshold in most countries, Better Place committed itself to “buying only clean electrons that come from renewable sources.”²⁷ Better Place believed that it would be able to cost-effectively purchase electricity from renewable sources at wholesale prices in the markets in which it operated. In fact, Better Place believed that when renewable energy production had scaled up to meet the increased demand emanating from the transportation sector, the cost to drive an electric vehicle would be equal to or less than driving a gasoline-powered ICE. In the US, the average cost per mile for electricity was \$0.06-0.08 (albeit most electricity was generated by coal-fired plants²⁸), compared to \$0.10-

²⁰ Electrification Coalition, 2009

²¹ Kanellos, 2010

²² Kanellos, 2010

²³ Agassi, 2009

²⁴ Haaretz, 2010

²⁵ Datamonitor, 2010

²⁶ Kanellos, 2010. To put this into perspective, there are roughly 25 million cars and 10,000 service stations in California. On average, a gasoline station services roughly 350 vehicles per day, at 10-20% utilization.

²⁷ Pogue, 2009

²⁸ See appendix

\$0.12 per mile for gasoline. In Denmark gasoline cost as much as \$7 to \$8 a gallon, or roughly \$0.20 per mile.²⁹

Peering into the future, EVs could offer additional value as a way to capture and store renewable energy. One of the greatest barriers with renewable energy was that wind and solar energy are intermittent; therefore, to fully capture these sources, utility companies needed large batteries to store excess energy for use when production was low (night-time and windless periods). Denmark for example, already produced 20 percent of its energy from renewable sources but was required to export electrons when production exceeded demand, due to lack of adequate storage capacity.³⁰ Since the typical vehicle is parked for 90 percent of the day, it constituted a potentially ideal source of renewable energy storage for utility companies. By partnering with an ERGO, a utility would not be required to jettison excess production, because capacity could be stored in car batteries, assuming car owners were given an incentive to provide storage services. And indeed, “smart grid technology”, which utilities had started developing, would allow drivers to buy energy from the grid when their car required recharging and sell to the grid when the battery was full.³¹

Even though the stars appeared to be in alignment for Agassi and his revolutionary model to take hold, industry stakeholders including governments and auto manufacturers were pursuing other initiatives to reconceptualize transportation.

Personal Transportation: An Industry in Turmoil

Governments the world over had developed a mix of incentives and deterrents to reduce the use of personal vehicles, and thereby curb both oil consumption and emissions. These strategies included congestion pricing, highway tolls, parking tolls, car pooling lanes on highways and tax rebates on environmentally preferable vehicle options. The investment and development of sidewalk infrastructure and bike pathways in major cities also influenced public behavior, by providing convenient means of transportation that were not based on motorized vehicles. The development of public transportation, such as buses, trains and subways as well as intermodal transportation (which combined two or more transportation modes) further reduced the use of personal vehicles.

The automotive industry itself responded to the greenhouse gas challenge primarily through development of new technology. Many car manufacturers introduced efficiency improvements and alternative fuel capabilities, all targeted at reducing greenhouse gases and oil dependency. Other investments centered on new propulsion systems, some compatible with the ICE and others requiring entirely new power trains and infrastructure.

In fact, variants of the internal combustion engine had been around nearly as long as the ICE had existed. The Diesel engine was invented in 1897 by Rudolph Diesel, and differed from the petrol-fueled engine because it used a different process to ignite the fuel. It did not require a spark plug, but instead used compression to combust the fuel and propel the car. Although diesel engines produced a persistent knocking sound which drivers found

²⁹ Pogue, 2009 (see appendix for a list of more countries)

³⁰ Coherent Energy and Environmental System Analysis, 2010

³¹ EPRI, 2008

problematic, diesel engines were 20 to 40 percent more fuel-efficient than petrol-fueled ICEs. Diesel fuel was less flammable and had lubricating properties that allowed diesel engines to last longer than regular gas engines. However, the diesel engine did not gain attention until governments set emission abatement requirements and consumers lost confidence in big oil companies during the oil embargo crises of the 1970s. Governments favored diesel engines because they burned much cleaner than gasoline and reduced dependence on foreign oil. Moreover, they produced lower levels of carbon dioxide, carbon monoxide and hydrocarbons. By 1981 diesel engine cars accounted for 10 percent of GMs sales and made up more than half of Mercedes-Benz, Peugeot and Isuzu's sales.³² Yet, diesel engines still produced greenhouse gases and soot, which contributed directly to air pollution.

Other ICEs could operate on liquid fuels other than petrol. A notable example was the Ford Model T, which could run on gasoline, kerosene, or ethanol. More generally, "flex-fuel" vehicles could handle blends from two fuels, whereas "bi-fuel" vehicles could run on two different fuels. Specifically, flex-fuel vehicles could utilize combinations of gasoline or diesel with alcohol derived from a plant base, such as corn, sugar cane or cellulose from sources such as grass, wood and old crops. Methanol, which is alcohol derived from sources such as biomass, natural gas or coal, had also been investigated as an alternative, but ethanol attracted greater attention, partially due to the availability of inexpensive corn.

Flex fuels were measured in ethanol or methanol content. Ethanol blends could range from 5 percent to 100 percent (E5-E100). Ethanol vehicles burned cleaner than pure gasoline vehicles and could provide both better performance and longer life. Since part of the volume of these fuels originated in plant-based carbon, the net greenhouse gases released through combustion could potentially be lower than that of pure petrol-based fuels. As the share of ethanol in the blend increased, the energy density decreased; on the other hand cars burned the fuel more efficiently, the net result being slightly increased energy use on a per-mile basis. A price point at 20-30 percent less than petrol made ethanol economically viable. In Brazil, for example, the widespread availability of arable land and the prominence of agribusiness made ethanol and flex-fuel vehicles particularly attractive, and they comprised over half the country's fleet. Importantly, the use of these fuels did not require a massive shift in fuel supply infrastructure. Moreover, as expertise in ethanol production increased, production costs declined. However, widespread adoption of alcohol-based fuels did face several hurdles. Critics pointed out that, in many instances, ethanol required more energy to produce than it generated, when agricultural inputs such as fertilizer and machinery were factored in. Other critics questioned the appropriateness of growing food for fuel, which put upward pressure on the price of food, thereby affecting distribution and affordability.

Compressed natural gas (CNG) had been used as a fuel source since the 1930s and was pursued as another alternative to the ICE. In 2008 there were 9.7 million CNG vehicles worldwide.³³ These vehicles were concentrated primarily in Pakistan, Argentina, Brazil, Iran and India. Typically, CNG for vehicles cost 30 to 60 percent less than gasoline fueled cars.³⁴ The fuel stock was composed primarily of methane, derived generally from drilling.³⁵ A

³² The History of Diesel

³³ Green Car Congress

³⁴ Gas Fueling Technology, 2006

³⁵ Natural Gas Org, 2004

refining process allowed for removal of toxic substances from CNG, but the main component, methane, was a potent greenhouse gas. CNG was delivered to the engine from large tanks found in car trunks. Fuel availability, however, necessitated a dedicated infrastructure, incompatible with pipelines, storage facilities and fuel stations designed for petrol.

Perhaps the most significant advance in recent years was the rise in popularity of hybrid electric vehicles (HEV). HEVs were equipped with both an internal combustion engine and an electric motor to propel the car. The cars were equipped with a regenerative braking mechanism, which captured energy released when the car braked, thus replenishing the car's battery. The Toyota Prius was the world's best-selling HEV with sales in 40 countries. According to the US Environmental Protection Agency, it was the most fuel-efficient car in the US, offering roughly 45 miles per gallon. It was also rated one of the cleanest by the California Air Resource Board. The car retailed for roughly \$21,000, and average refueling costs were approximately \$900/year, (at \$2.80 per gallon).³⁶

Plug-in hybrid electric vehicles (PHEV) also used a combination of an ICE and electric motor, but in addition could be recharged using energy from the electrical grid. The cost of the battery was added to the cost of the standard car model.³⁷ PHEVs boasted a fuel economy similar to HEVs, but could also drive 40 miles running on pure electricity. Some made the argument that that cost savings in fuel, of up-to 75%, were not sufficient to recoup the higher initial price of the car.³⁸

Hydrogen fuel cell vehicles (HFCVs) had long been pursued as a particularly compelling alternative. In fuel cells, hydrogen and oxygen gases combine to form electricity, and pure water is the only byproduct. The electricity can then be used to propel a car, using the same power train system as an EV. In converting stored energy into electricity, hydrogen fuel cells are similar to batteries but rather than being recharged through electricity, they use hydrogen as input. Hydrogen, being a storable carrier, but not a primary source, can be derived from many sources including renewable energy sources, fossil fuels, electrolysis of water, coal and petroleum. Most early infrastructure focused on natural gas as the primary source, reformed into hydrogen at the fueling station. There were, however, critical growth barriers for HFCVs. Costs for hydrogen "at the pump", in 2010, were roughly \$4-\$9.50 per kilogram in the USA, although this cost was heavily dependent upon the source of energy.³⁹ On the other hand, HFCVs were much more energy efficient than conventional ICE vehicles, making them competitive on a per mile cost basis. Yet low energy density of on-board stored hydrogen meant that drivers would find themselves refueling much more often.

Like many other alternative fuels, hydrogen was incompatible with most existing transmission, storage and retail infrastructure for petrol, and required a dedicated network of hydrogen pipelines and refueling stations. Nonetheless, believing that many of the obstacles could be overcome through cumulative efforts, auto manufacturers including GM, Honda, Daimler AG and Toyota engaged actively in the development of fuel cell cars. The German government was working with RWE, a German utility, and Linde AG, a major producer of industrial gases, to develop infrastructure to support the use of hydrogen fuel

³⁶ 2008 Toyota Prius

³⁷ Electric Power Research Institute **Error! Hyperlink reference not valid.**, 2009

³⁸ Petersen, **Error! Hyperlink reference not valid.**2009

³⁹ Blenco, 2009

cell vehicles.⁴⁰ Similarly, the Japanese government and Toyota were working together to develop affordable hydrogen vehicles as well as an abundant supply of hydrogen.⁴¹ Shell was also investing heavily in research and development as a precursor to installing hydrogen stations in California, estimating the cost at roughly \$1-5 million per station.⁴²

In addition to alternative fuels and power trains, some manufacturers were looking at reducing the weight to be transported, thereby increasing per-person efficiency. For example, lightweight materials, such as carbon fiber body frames, formed an alternative to heavy steel bodies that were the industry standard. By using lighter materials to build cars, less energy would be needed to propel it, thus offering consumers higher fuel efficiency. The cost of carbon fiber was dropping continuously as the material became more commonplace, making it more attractive to use in mass production models. Consumer concerns with safety had inhibited the widespread adoption of carbon fiber models, despite the fact that high performance vehicles such as race-cars were built primarily of carbon and withstood high-velocity impacts extremely well.

Another way of making cars lighter – and thereby more fuel efficient – simply required making them smaller. The Tata Nano, launched in 2008, was the world's cheapest automobile, costing only \$2,000. It was 1.4 meters wide and just over 3 meters long, weighed 1,400 pounds and had a fuel tank capacity of 4 gallons. It was first launched in India and other developing countries with high population densities and lower household incomes. Renault entered the small car industry with the launch of the Logan in 2009. At a price of \$6,000, the car was being launched in the Indian market to compete with the Tata Nano.⁴³ Small cars remained very popular in Europe, where vehicles like the Fiat 500 and the Mini were hugely successful, many decades before global warming was recognized as a threat.

All told, a significant number of alternative designs were being explored by automakers in a quest to reduce petrol dependence. It was within this context of multiple potential alternatives that Shai Agassi and others were attempting to transform the EV into the preeminent choice for consumers.

Establishing the EV market

Although production of EVs had halted in the 1930s, the idea of an electric vehicle lived on. General Motors sparked a short-lived revival of electric automobiles in the late 1990s when the company launched the EV1 in California. The 1,100 cars produced by GM came equipped with the choice of a lead acid battery or a nickel-metal hybrid battery offering drivers a range of anything between 55 and 130 miles per recharge.⁴⁴ The car consumed roughly 11 kWh per 100 kilometers,⁴⁵ where only 10 percent of the energy was lost in conversion, compared to 65 percent energy losses in petrol-fueled ICEs.⁴⁶ GM provided users with EV recharging devices

⁴⁰ Ohnsman, 2009

⁴¹ Adams, 2010

⁴² Ohnsman, 2009

⁴³ Naughton, 2008

⁴⁴ EV1 Specifications

⁴⁵ US department of Energy

⁴⁶ Fung, Derek 2009

installed in their homes, whereby batteries could fully recharge each night, over an 8 hour time span. The EV1 was favored by drivers because it was quiet; did not create tailpipe emissions; and was easy and cheap to maintain, primarily because it contained only one-fifth the number of moving parts found in an ICE. The 100 percent recyclable, lightweight body panels also meant that less electricity was expended to move the car itself.⁴⁷ Even though the EV1 was hailed as a technological success and was popular among users, GM voluntarily recalled its cars in 1999 due to alleged low consumer demand and the company's inability to turn a profit from the initiative.

Although GM's withdrawal from electric vehicle production was a major step back for proponents of the technology, as the new millennium dawned, numerous other, smaller companies began developing new models. Tesla Motors, a California startup headed by Elon Musk, co-founder of PayPal, began marketing \$100,000 luxury electric roadsters. The initial model catered to the high end of the market but Tesla subsequently announced that they would be working toward developing a more affordable model, the Model S. Entrepreneurial EV developers, focusing mainly on micro-cars, sprang up outside the United States, notably the affordable REVA developed in India, Norway's TH!NK city, and an electric version of Daimler's Smart Fortwo. Large manufacturers re-entered the fray with Renault-Nissan, Mitsubishi, Subaru, Toyota, Ford and others all announcing plans to mass-produce electric cars within a few years.

Infrastructure and Standards

Competition began to emerge not only among and within the various vehicle platforms, but around other components of the system. For example, several battery producers ranging from large corporations to startups and auto manufacturers themselves started developing different products for EVs. The Johnson Controls and Saft partnership developed a lithium, nickel, cobalt and aluminum chemistry for Mercedes-Benz. LG Chem, AESC, Bosch-Samsung, Hitachi and NEC were investing in manganese-spinal batteries, attracting the interest of companies such as GM, due to their cost effectiveness and the larger amount of proven mineral reserves used in the production of these batteries.⁴⁸ Nissan announced plans to construct a battery manufacturing facility for their all electric EV, the Leaf, in Smyrna Tennessee.⁴⁹ Although Better Place favored lithium ion batteries, featuring an expected life span of approximately 8 years, several other designs offered alternative price points, energy densities, weights and life spans. As range, safety, recyclability and costs improved and battery standards converged, experts were forecasting a dramatic reduction in the number of global battery manufacturers.⁵⁰

Of course, Better Place realized that the mere provision of an electric vehicle would not fully satisfy consumer needs for a coherent transportation solution. Direct competition had emerged in the form of alternative recharging infrastructures. Through its \$37M "ChargePoint America" program, Coulomb Technologies, an electric car service provider founded in 2007, planned to provide nearly 5,000 charging stations to nine regions in the United States. Pilot charge stations providing free energy had already been unveiled in New

⁴⁷ EV1 Specifications

⁴⁸ Petersen, 2009

⁴⁹ Caolgera, 2010

⁵⁰ Petersen, John 2010

York City, Houston and Seattle, as well as outside the US, in Ireland and Australia. Coulomb Technologies planned on earning revenues based on provision of access to electricity, as opposed to selling the electricity themselves. Every time a driver wanted to use a charge point they would pay a fixed amount, for a certain amount of time, for example \$2 for 30 minutes. On top of that, consumers would pay for whatever electricity they consumed, based on prices charged by the utility company. Elektromotive, a UK company, was pursuing a similar strategy and had established partnerships with Renault-Nissan and Mercedes-Benz to deploy EVs in Europe.

Some auto manufacturers decided to examine the viability of vertical integration, and took on additional roles to ensure that an electricity infrastructure, including batteries and charging stations, would be able to provide the energy needed to propel their customers' cars. Toyota, for example announced that it would be installing roughly 20 solar-powered recharge stations in Toyota City, site of Toyota Motor Corporation's main plant. The stations would be compatible with both PHEVs and EVs and powered by the company's storage batteries as well as energy from the grid. GM was planning to launch its Chevy Volt in the UK (under the Opel Ampera name), together with a number of charging points at work places and in parking lots.⁵¹ Nissan had partnered with Portland General Electric in developing smart grid technology to support a network of electric vehicles in several states, including Oregon, and in the Canadian province of British Columbia.⁵² Nissan's Leaf and the Chevy Volt were featured in the United States Department of Energy sponsored "EV Project", in which some 15,000 fast chargers would be installed in five states with the aim of collecting data on vehicle use and charge infrastructure effectiveness in diverse topographic and climatic conditions.⁵³

Tesla Motors had partnered with SolarCity, a photovoltaic company that installed recharge stations on buyers' roofs to ensure that electricity for vehicle propulsion originated from a clean source. At a cost of \$2,000 to \$6,000, Tesla owners would be able to have the peace of mind of recharging at home, including a free and renewable energy source.⁵⁴ Furthermore, Tesla had announced plans to develop cars with potentially removable batteries. Yet, the company was not deploying its own swapping infrastructure and had mentioned the possibility of integrating recharge ports with other electric car service providers, such as Better Place, to be able to expand its product line and ensure its compatibility with the rest of the EV market. Other manufacturers were trying to bypass the swapping procedure entirely, and were creating partnerships with utilities and governments directly, calling into question the value of ERGOs. Mercedes, for example, who had experimented with battery swapping in the 1970s, decided to pursue a fixed (non-swappable) battery technology.⁵⁵

As the race to establish a dominant infrastructure design heated up, Better Place advocated consistently for EV infrastructures to be completely standardized, and called for utilities, car manufacturers and battery developers to adhere to international standards. Specifically, the International Organization for Standards (ISO) and International Electrotechnical

⁵¹ Pickard, 2010

⁵² Groom, 2008

⁵³ The EV Project, 2010

⁵⁴ Woody, Todd 2009

⁵⁵ Hybrid Cars, 2009

Commission (IEC) were setting standards concerning EV battery modules, plug connectors and communication protocols to accelerate the transition to electric vehicles. As noted by Agassi: “What we ask governments to do is to force everybody that comes into this business, the electric recharge grid networks, to be bound by international standards, ISOIC standards, so we don't use a connector that is unique, that will lock anybody out. And we will provide open access across networks, because we want to optimize for speed of adoption. So, I'd rather have a second competitor that comes in and installs more of the network with their own money but with the same connector.”⁵⁶

Japan was demonstrating leadership in standardization as its top car manufacturers including Toyota, Nissan, Mitsubishi as well as their major utility company, Tokyo Electric Power Co, and battery manufacturer, Fuji Heavy Industries Ltd. engaged in talks to set a national standard. Standardization proceeded more slowly in Europe, and agreement was reached on only two issues – spot connectors and voltage requirements.⁵⁷ However, European Union industry commissioner Antonio Tajani launched an EU green vehicles strategy which attempted to catch up quickly with standards being developed in the US, Japan and China⁵⁸.

Scaling up the EV market

Hurdles in growing the EV market stemmed not only from the challenge of reshaping the supply-side. Questions loomed regarding how fast the demand-side of the market would materialize. Assuming Better Place managed to get the infrastructure and vehicles in place, factors related to consumer adoption could still potentially constrain rapid uptake of EVs. A quick comparison between EVs and iPods illustrated the key challenge facing EV sales. With an average lifespan on the order of 15 years, vehicle turnover is much slower than for MP3 players. Moreover, the single biggest consumer investment - after the purchase of a house - is a car, thereby guaranteeing conservatism in choice for most buyers, unlike the relatively inexpensive iPod. Simply put, to achieve production numbers like those of MP3 players, that would generate economies of scale for producers and accumulate into a large installed base necessary to generate electricity demand and favorable exposure, EV market shares would have to attain critical mass very quickly.

While alternative power train technologies, and especially the various EVs, had received significant media attention, it was far from clear how consumers would respond when products were introduced into the market in large numbers. An Ernst and Young report examining the level of understanding of and interest in PHEVS and EVs in the United States validated these concerns.⁵⁹ The report indicated that familiarity with EVs was based primarily on conjecture, and that consumers had high expectations regarding EVs' increased fuel economy and environmental impact. However, the report suggested that consumer willingness to consider EVs as viable options remained very weak across the United States. Among the most significant concerns were vehicle cost and driving/battery range, even though most consumers did not need to cover long distances regularly. The report concluded

⁵⁶ Steenstrup, 2009

⁵⁷ Better Place, 2010

⁵⁸ Harrison, 2010.

⁵⁹ Ernst and Young (2010) Automotive Survey. Measuring the understanding of and interest in plug-in hybrid and electric vehicles in the US.

that the majority of consumers would not be willing to compromise vehicle capabilities when considering the purchase of an EV. In part to address these psychological barriers and to create greater acceptance of EVs, Better Place launched a pilot project in Japan to demonstrate that the perceived tradeoffs inherent in the EV could be overcome. The project involved 4 taxis driving in Tokyo nonstop for 100 days, with the purpose of showcasing the long-range capabilities of EVs.⁶⁰

The Better Place Rollout Strategy

For its initial launch sites, Better Place had sought regions with high consumer consciousness and strong demand for EVs. In Israel, Better Place's first site, 57 percent of drivers said they wanted their next vehicle to be powered with electricity. In Denmark, Australia, Canada and the US, the numbers were 40, 39, 35 and 30 percent respectively.⁶¹ In order for its business model and technology to be rolled out in the most congenial settings possible, Better Place had selected several small countries and "islands". Islands were conceptualized as regions with high population densities and limited traffic to "off-island" destinations. Israel's population, for example, is concentrated within roughly 10,000 square kilometers. Ninety percent of drivers commute less than 70 kilometers each day and urban centers are generally less than 150 kilometers apart. Vehicle travel outside the country's borders is negligible. Denmark was expected to become the second Better Place island in early 2011. In Denmark, DONG energy was expanding its renewable energy mix while the government had committed to EV incentive programs. The CEO of Better Place Denmark, Jens Moberg, had already announced the company's plans for rolling-out its charging infrastructure in the capital, Copenhagen.⁶²

Better Place had engaged with other islands as well, including Hawaii and the San Francisco Bay Area. Hawaii was importing oil to meet 90 percent of its energy needs and had the highest gasoline prices of any US state. The state had launched its Hawaii Clean Energy Initiative (HCEI) to work with the US Department of Energy to develop clean energy alternatives for meeting 70 percent of the state's energy needs by 2030.⁶³ Australia, the largest island in the world, was also attractive for Better Place, which perceived it to contain three major urban centers connected by a single freeway, making it particularly suitable for the Better Place model. Spain and Portugal were also prospective locations as Better Place projected a demand for 50,000 plug-in electric cars in the region by 2011.⁶⁴ As of early 2010, the company had begun establishing partnerships and carrying out market research to assess the feasibility of entry into regions with fewer boundaries and more factors inhibiting the transition to EVs.

⁶⁰ Agassi, 2010

⁶¹ Better Place, 2009

⁶² Global Progress: Denmark, 2010

⁶³ Barron, Rachel 2008

⁶⁴ Day, 2008

Establishing Networks

“This is a massive integration project; everything needs to happen roughly at the same time. In other words, the cars need to show up at the same time that batteries need to produce in scale, at the same time as the infrastructure is in the ground...”⁶⁵

Better Place envisioned that utility companies would play a key role in mainstreaming EVs and provide much needed support by laying underground electric cables, providing lighting fixtures, and installing other infrastructure. In order for ERGOs and utilities to reap the greatest benefit from the model, ERGO software would need to be synchronized with utility software, allowing the local grid to determine optimal allocation of energy to vehicles during peak and off-peak hours. Better Place had begun developing software to track data, communicate with the grid and dispense electricity as demand fluctuated, thus minimizing costly spikes in electricity demand.⁶⁶ In order to manage this data flow process, the cars’ on-board computers would be linked to a data system that would recognize when a car was hooked up to the grid. By establishing communication, the ERGO would have the capacity to complement the grid so that the bulk of recharging could take place during off peak hours.⁶⁷

Based on its perception that it could add value to utilities, Better Place was working closely with utilities to develop long term investment plans in renewable and clean energy. Israel, for example, had set a goal to have 10 percent of its electricity sourced from solar power and renewable energy by 2020.⁶⁸ Israel Electric Corporation established a committee led by the senior vice president of engineering projects, Yakov Hain, to facilitate ongoing conversations between IEC and Better Place.⁶⁹ Hawaii Electric Company announced a non-exclusive agreement with Better Place to invest in renewable energy and establish a recharging network connected to the grid,⁷⁰ yet the utility noted its open-mindedness to engaging with similar companies. In Toronto, Canada, Better Place held talks with Bullfrog Power, an electricity provider that provided 100 percent renewable and clean energy.

To assist utilities in attaining renewable energy goals, some governments were offering tax rebates on electric vehicles. Israel, which typically taxed ICEs at 70 percent, agreed to tax EVs at 10 percent until 2019. Instead of the 180 percent ICE tax in Denmark, drivers would be able to purchase EVs at zero percent until 2015.⁷¹ As of 2010, the US was offering rebates ranging from \$3,200 to \$7,500, depending on the battery’s capacity.⁷²

Finally, Better Place was in talks with the Big Three auto manufacturers in Detroit, but no partnerships had materialized. Toyota’s manager of environmental communications, John Hanson, went on the record expressing his views on developing a car compatible with Better Place technology. “What good does it do if we only sell 500 a year? We sell 175,000 Priuses alone in North America”⁷³. In fact, Renault-Nissan was the only car manufacturer that

⁶⁵ Pogue, 2009

⁶⁶ Woody, 2009

⁶⁷ See Appendix

⁶⁸ Ritch, 2009

⁶⁹ Baron, 2008

⁷⁰ Markoff, John

⁷¹ Lettice, John 2008

⁷² Voelcker, 2009

⁷³ Thompson, 2009

committed to providing automobiles compatible with Better Place specifications. Renault-Nissan had already started manufacturing an electric version of the Fluence in Bursa, Turkey and had committed to producing 100,000 units by 2016.⁷⁴ The company planned to build a second plant outside of Paris, France when demand increased,⁷⁵ and began designing EV versions of the Kangoo Z.E. Van, and the Laguna Sedan, as well as the new two-seater Twizy.⁷⁶ Flexing its muscles, Renault-Nissan threatened to withdraw from the Danish project if the Danish government reduced the 180 percent sales tax they had previously set on ICE automobiles.⁷⁷ Renault-Nissan was on record, however, suggesting that as production reached 500,000 – 1 million vehicles per year government incentives would become unnecessary.⁷⁸

The Israel launch

Israel's President Shimon Peres; Carlos Ghosn, the CEO of Renault-Nissan; and Agassi announced that Israel would be the world's first Better Place country, and that the venture would launch in 2010. Renault-Nissan would supply the Renault Fluence, compatible with Better Place infrastructure. Agassi claimed that 20,000 Israeli subscribers were already fully committed to purchasing EVs. Better Place planned to install 100,000 charge spots and 100 switching stations in the country and had invested \$200M. At the opening of the demonstration center in February 2010, the company announced the signing of 92 corporate fleet owners as subscribers, including FedEx, IBM, Microsoft, and Orange. Better Place also announced a partnership with Dor Alon, one of Israel's leading gas station operators, for the deployment of battery switching stations at Dor Alon's facilities.⁷⁹

Clearly, Better Place's plan to radically transform personal transportation was revolutionary, and naysayers encountered little difficulty in unearthing potential flaws in the business model. These hurdles included technological obstacles, such as standardization of battery size and location in vehicles, necessary for automated battery switching. Others called into question the freedom of movement that Better Place customers would really enjoy, citing the high costs of roaming that often characterized mobile telephony. Yet others cautioned that widespread adoption of EVs would place unbearable loads on the electric grid, causing large scale power failures. More fundamentally, critics questioned whether Better Place could actually turn a profit, and the extent to which it required subsidization from governments and utilities. By piloting the concept in several small regions, Better Place hoped to iron out the wrinkles that would undoubtedly surface as the first cars were deployed. However, as the launch in Israel loomed near, the main questions the company needed to answer were its capacity to create value and its capacity to capture it, especially over the long term.

⁷⁴ Reed, 2010

⁷⁵ Jolly, David 2010.

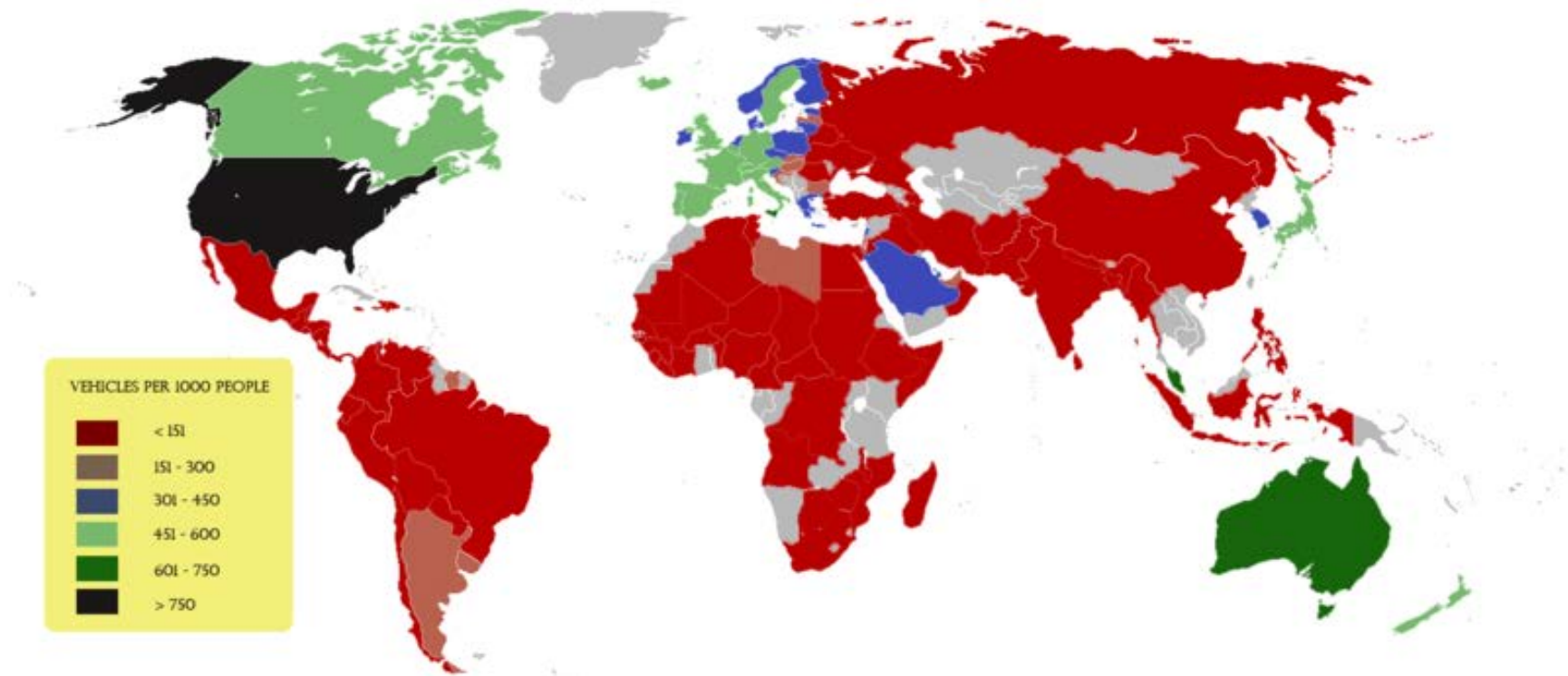
⁷⁶ Better Place, 2010

⁷⁷ Renault Threatens Electric Car Withdrawal, 2010

⁷⁸ Bailey, 2010.

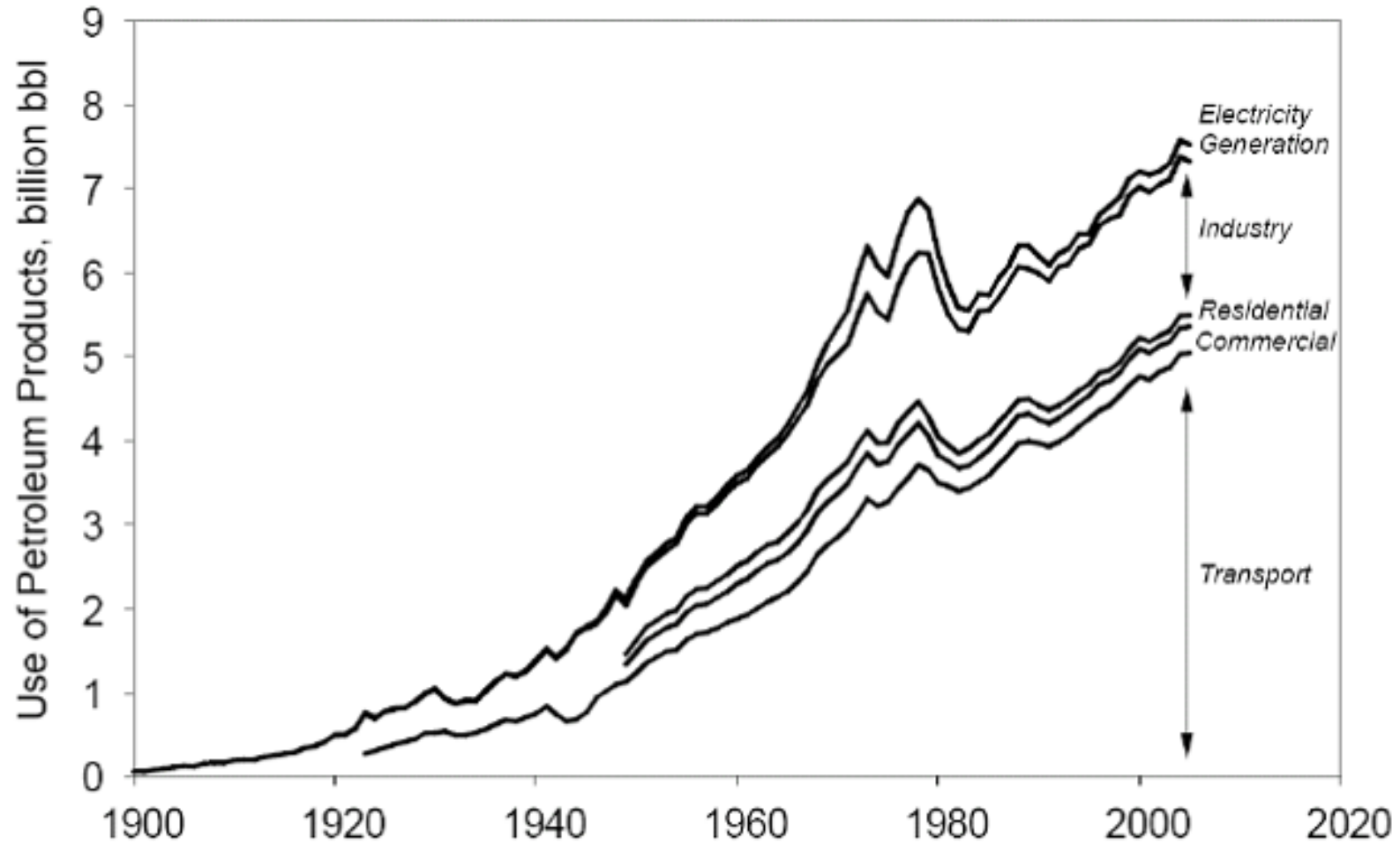
⁷⁹ EarthTimes, 2010

Exhibit 1: World Map of Automobiles per Capita



Source: http://commons.wikimedia.org/wiki/File:World_vehicles_per_capita.png

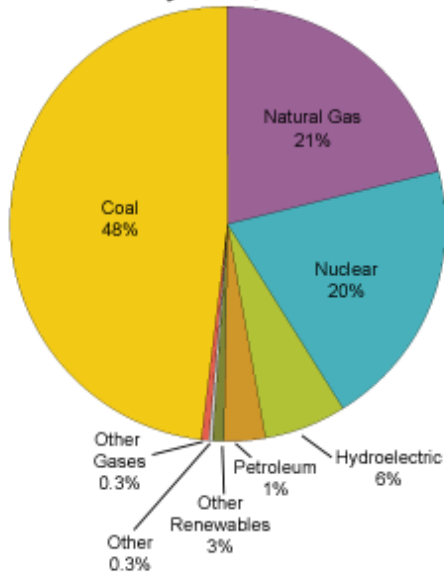
Exhibit 2: Worldwide Petroleum Use by Sector



Source: MIT Press, 2009

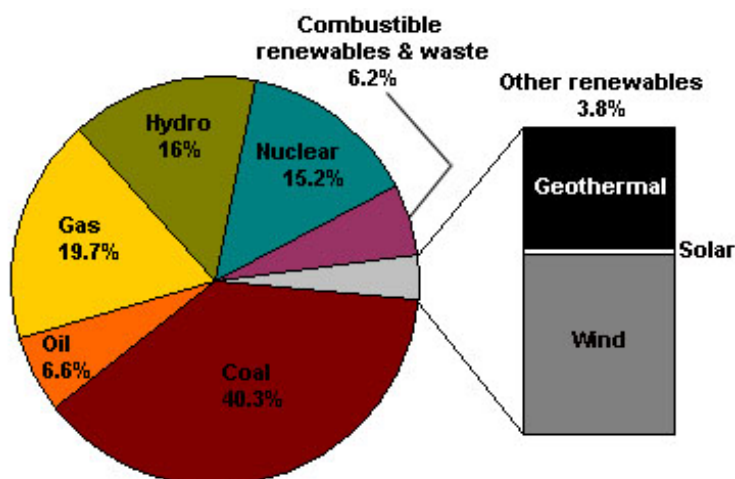
Exhibit 3: Electricity Generation by Fuel Type, US and Global

U.S. Electric Power Industry Net Generation by Fuel, 2008



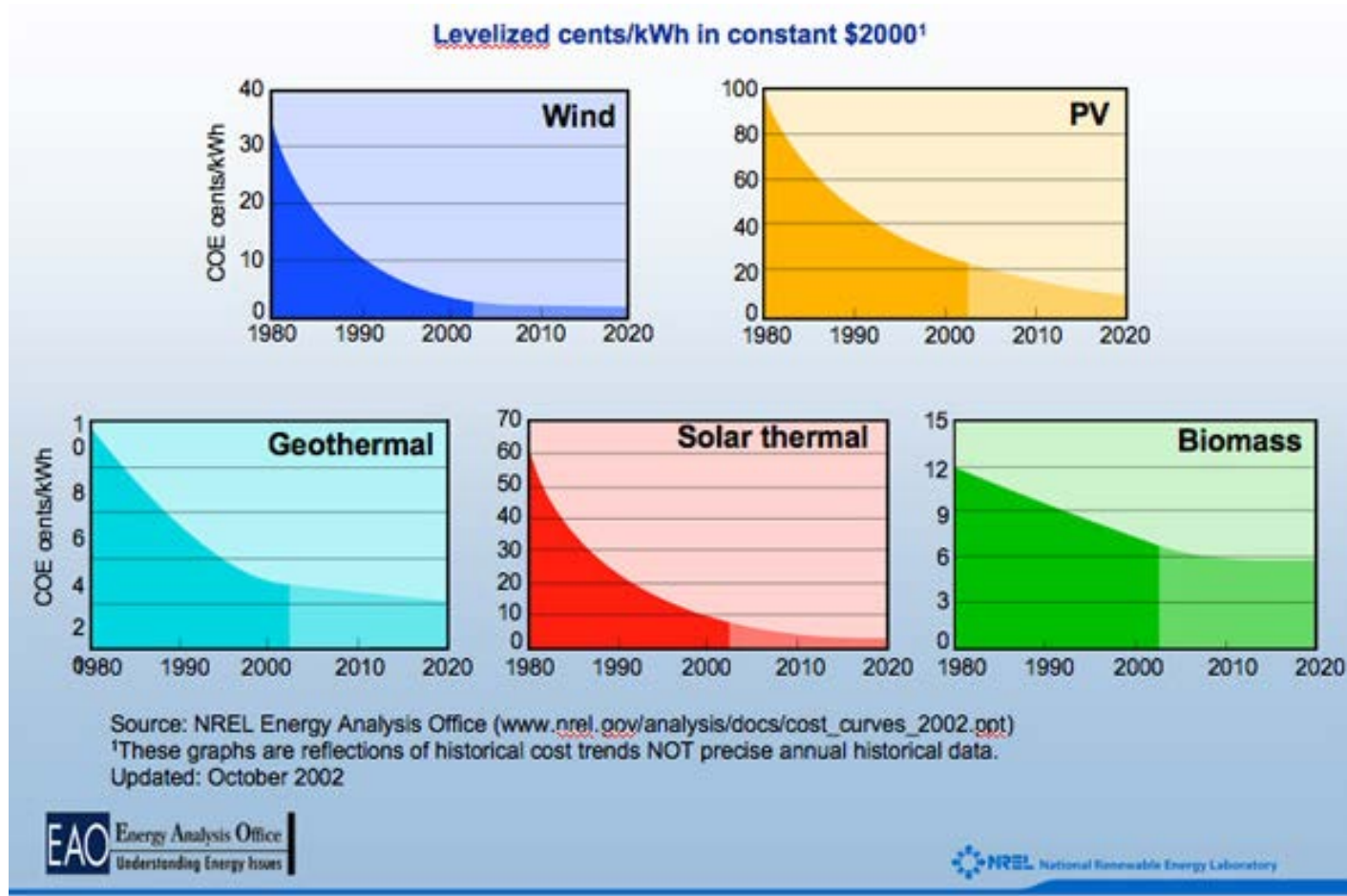
Source: U.S. Energy Information Administration, *Electric Power Annual* (2010).

World Electricity Generation by Fuel Type



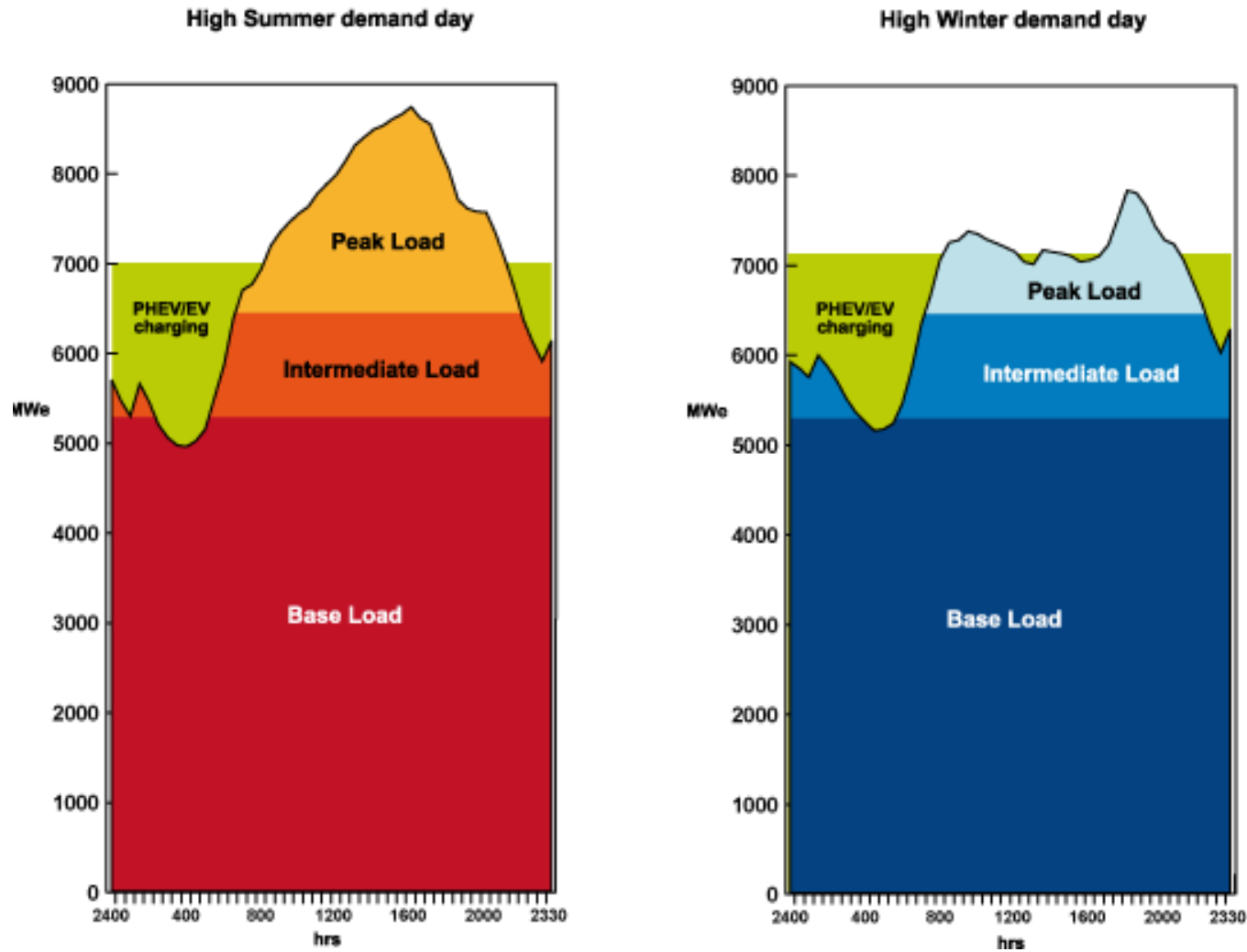
Sources: <http://www.eia.doe.gov/steo> and Earth Trends, using data from EIA 2007

Exhibit 4: Renewable Energy Cost Trends



Source: Greentech History

Exhibit 5: Load Curve for a Typical Electric Grid



Source: http://www.world-nuclear.org/uploadedImages/org/info/summer_winter_Charging.png

Exhibit 6: Gasoline and Electric Car Cost Comparisons

THE GASOLINE VS. ELECTRIC CAR COST PER MILE COMPARISON	
1	unit = one gallon of gas
\$3.00	price - one gallon gas (US)
30	miles per gallon - gasoline car
\$0.10	cost per mile - gas car
25%	efficiency - gas to mechanical energy
120	miles per gallon - 100% efficiency
80%	efficiency - grid to battery to electric motor
96	miles per gallon - electric car
33	kilowatt-hours energy stored in one gallon gas
2.9	miles per kilowatt hour - electric car
\$0.10	cost per kilowatt hour
\$0.03	cost per mile - electric car

Source: Ecoworld – Electric Car Costs per Mile

Exhibit 7: Costs for Fuel and Electricity

Country	Cost of Gas (USD/Gal)	Cost of Electricity (Cents/kwH)	Primary Source of Electricity
Israel	6.76-7.00	12-54 ⁸⁰	Coal, natural gas, diesel oil, fuel oil
Denmark	7-8 ⁸¹	10-11 ⁸²	Coal, wind
Australia	6.40 ⁸³	2.8-3.9 ⁸⁴	Coal, natural gas, hydro
Toronto, Canada	3.86	4.4-9.3 ⁸⁵	Hydro
Hawaii, USA	4.39-4.65 ⁸⁶	26.05-32.50 ⁸⁷	Coal
Japan	4.24 ⁸⁸	19-27 ⁸⁹	Nuclear, coal, gas, oil, hydro ⁹⁰

⁸⁰ Israel Electric Corporation, 2008

⁸¹ <http://www.aaireland.ie/petrolprices/>

⁸² <http://www.cbs.nl/en-GB/menu/themas/prijzen/publicaties/artikelen/archief/2006/2006-1945-wm.htm>

⁸³ <http://www.homebiznotes.com/rising-gas-prices-in-australia-affect-business-owners-where-will-it-stop/>

⁸⁴ <http://www.world-nuclear.org/info/inf64.html>

⁸⁵ <http://www.torontohydro.com/sites/electricsystem/residential/smartmeters/Pages/TOURates.aspx>

⁸⁶ <http://www.findingdulcinea.com/news/Americas/2008/December/Hawaii-Plans-Switch-to-Electric-Cars.html>

⁸⁷ http://www.eia.doe.gov/cneaf/electricity/epm/table5_3.html

⁸⁸ http://money.cnn.com/pf/features/lists/global_gasprices/

⁸⁹

http://www.etaiwannews.com/etn/news_content.php?id=908024&lang=eng_news&cate_img=35.jpg&cate_rss=news_Business

⁹⁰ <http://www.world-nuclear.org/info/inf79.html>

Exhibit 8: A Graphical Representation of the Better Place Concept

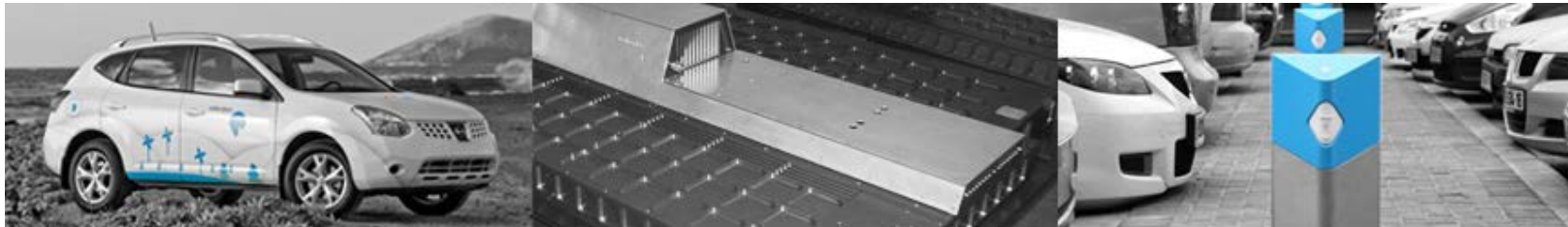


Source: Roth, 2008

Exhibit 9: Components of the Better Place Business Model



The Solution



cars

batteries

charging



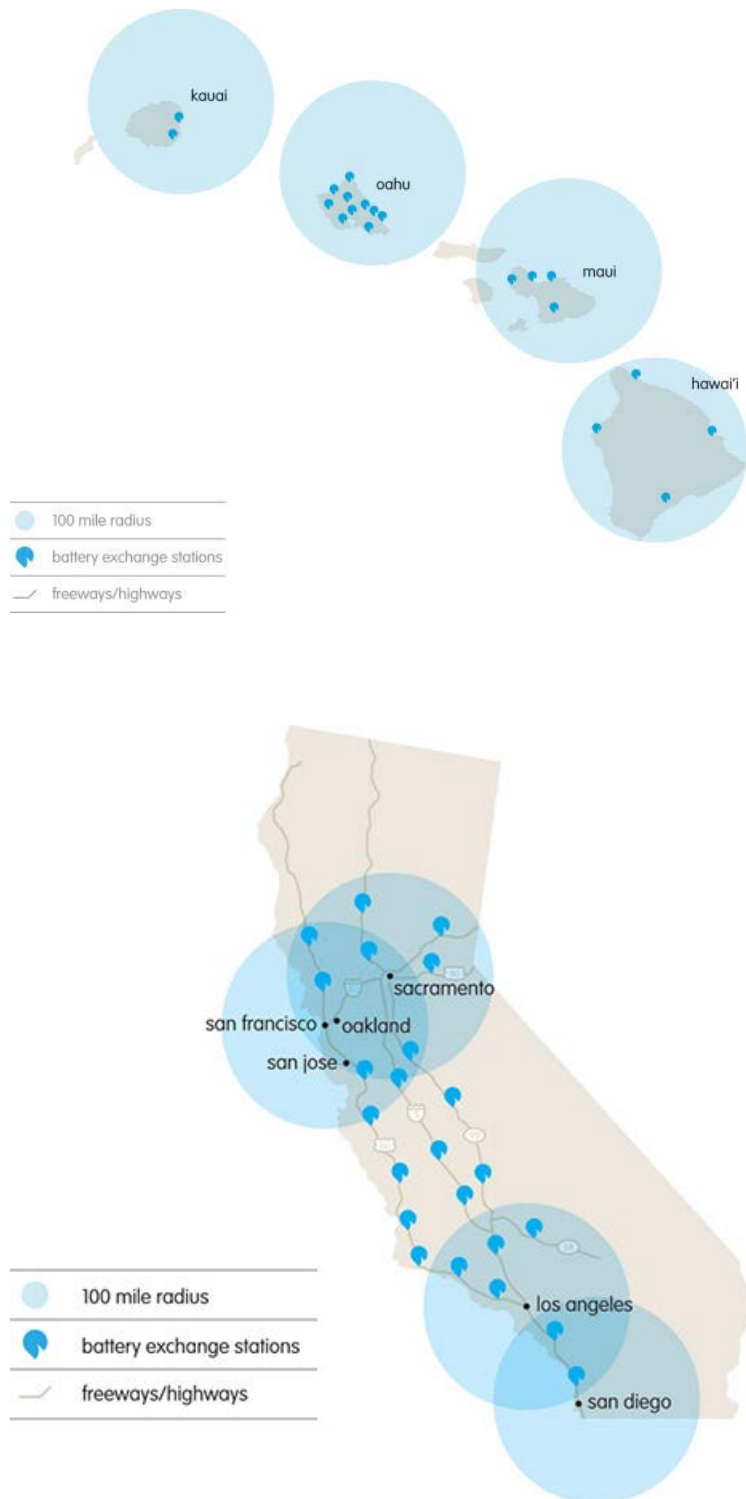
ev driver services

ev network software

standards

Source: <http://www.betterplace.com/solution/>

Exhibit 10: Better Place Battery Swapping Stations



Source: www.betterplace.com

Exhibit 11 : Photographs



Charge spot.



Demo electric vehicle in position.



Battery moving into position.



Renault Fluence concept.

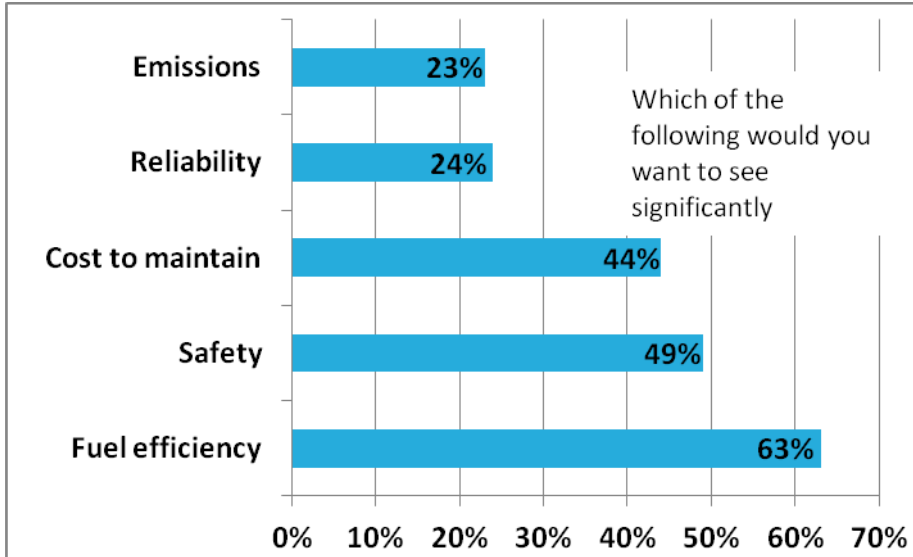
Exhibit 12: Better Place Partners and Investors

Governments	Battery Manufacturers	Utility Companies	Investors	Automobile Manufacturers	Other Private Companies
-Israel -Denmark -Hawaii -Toronto -Japan -Australia	-A123 Systems -Automotive Energy Supply Corporation	-Israel Electric Corporation -Dong Energy (Denmark) -Hawaiian Electric -Bullfrog Power (Toronto) -Australia Gas Light Company -Tokyo Electric Power Company	- Acorns to Oaks II - Esarbee Investments Canada -GC Investments LLC -HSBC Group Israel Cleantech Ventures -Israel Corp -Lazard Asset Management -Macquarie Capital -Maniv Energy Capital -Morgan Stanley Investment Management -Musea Ventures -Ofer Group -VantagePoint Venture Partners -Vayikra Partners - Wolfensohn & Co.	-Renault-Nissan Alliance	- Ahuzat Hof's Parking Lots, Israel -Dor Alon Gas Station, Israel -92 Corporate Fleet Partners, Israel - Nihon Kotsu, Taxi Operator Japan -Microsoft -Intel

Source: www.betterplace.com

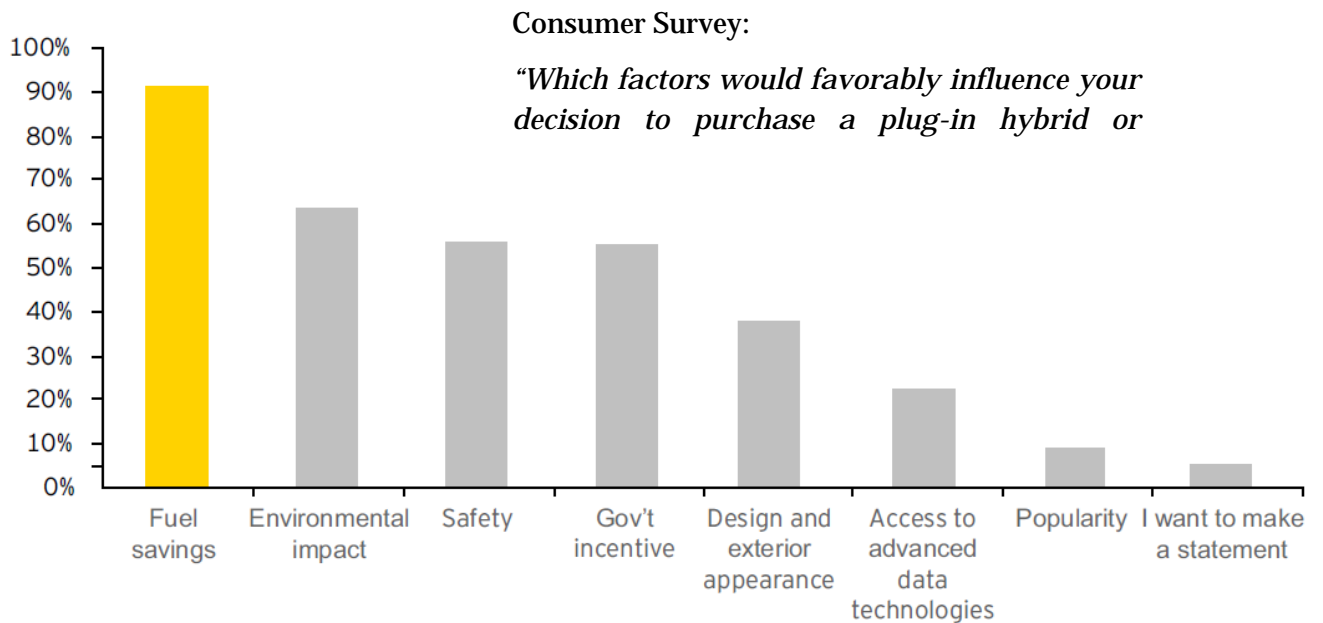
Exhibit 13: Consumer Surveys of Automobile Preferences

better place  Consumer Survey



Source: www.betterplace.com

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Source: Ernst & Young Automotive Survey January 2010

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