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Electrification of Taxi Cabs in Major Chinese Cities with Range Extended Electric Vehicles

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Electrification of Taxi Cabs in Major Chinese Cities with Range Extended Electric Vehicles

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Taxis wait for passengers in China.

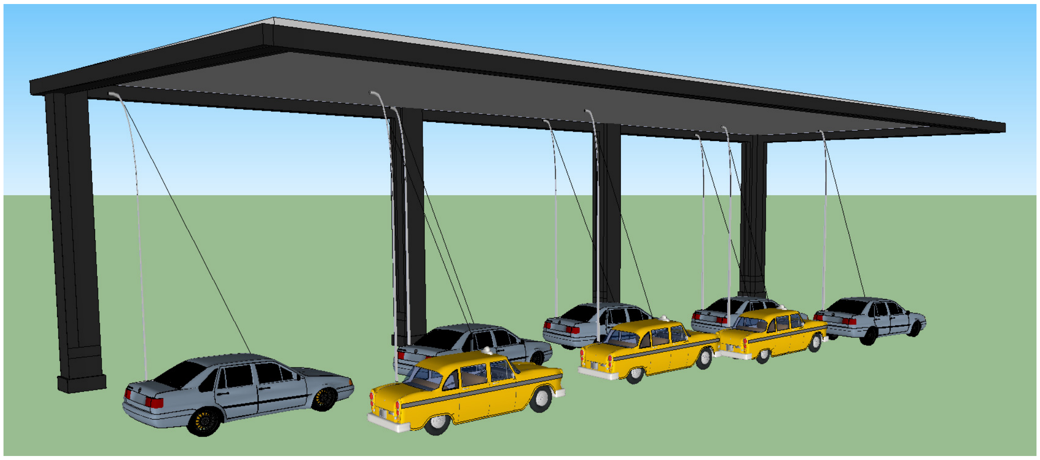
China today faces major environmental and related economic threats. Petroleum prices have been on a constant rise, and air, water, and land quality have all suffered due to overuse of fossil fuels. According to the New York Times, in 2010 alone, China injected close to 2.2 billion tons of carbon into the atmosphere. The effects need not be explained. Global climate change and its effects spell environmental disaster on the horizon. Change must occur.

The best bet for a sustainable future lies in the electrification of vehicles. However, the difficulty in this lies in the public sector's transition to this new technology. The most effective solution to move people over to using cleaner vehicles is to initiate change in public transportation systems; namely by beginning with taxi cabs and buses; in China's major cities. If this is achieved, there will be a solid technological infrastructure upon which to expand into private markets once the public taxi vehicles have shown their success. This major leap will pave a solid path for cleaner energy options for China. This paper will focus on the taxi cab as its central theme because pure electric buses operated by city or other government agencies have both local and central government support to electrify their business, thus implying that the economic factor is not as much a deterrent as more entrepreneurial type of operation like a taxi cab. In addition, the general public can identify with the taxi since it is like a car they could personally own.

Another major reason for starting a clean automotive program with taxis is easier mass-conversion. There is no private car infrastructure on which to base a conversion plan due to individuality; however, with taxis, standardization across a fleet is much more likely and will be more collectively profitable. Finally, if there is large demand, which will come from taxi cab companies, prices will be lowered as production rises. This demand will make this new technology one that could help China achieve and expand the scope of its clean-energy goals, especially the Ten Cities, One Thousand Electric Vehicles program.

Taxis queue at the airport. Charging screens could be placed over the cabs, reducing wasted fuel and time while conventional taxi cabs would normally be idling.

What is proposed for a clean-energy initiative is a taxi cab that can be rapidly charged within a short amount of time. Using a retractable antenna to collect current from high-use charging posts (see following illustration) or other secure, low cost charging concepts, these plug-in hybrid automobiles would be able to fill batteries supplying adequate range to satisfy average trip distances. However, pure-electric vehicles are not sufficient to meet the requirement of constantly fluctuating trip distances traveled by taxi drivers. Due to this, these proposed taxis will be equipped with plug-in hybrid powertrains so that a ~~conventional~~ small internal combustion engine can take over when trip distances exceed battery limitations. The batteries, conversely, will be sufficiently sized to satisfy the vast majority of trip distances solely by their own power.

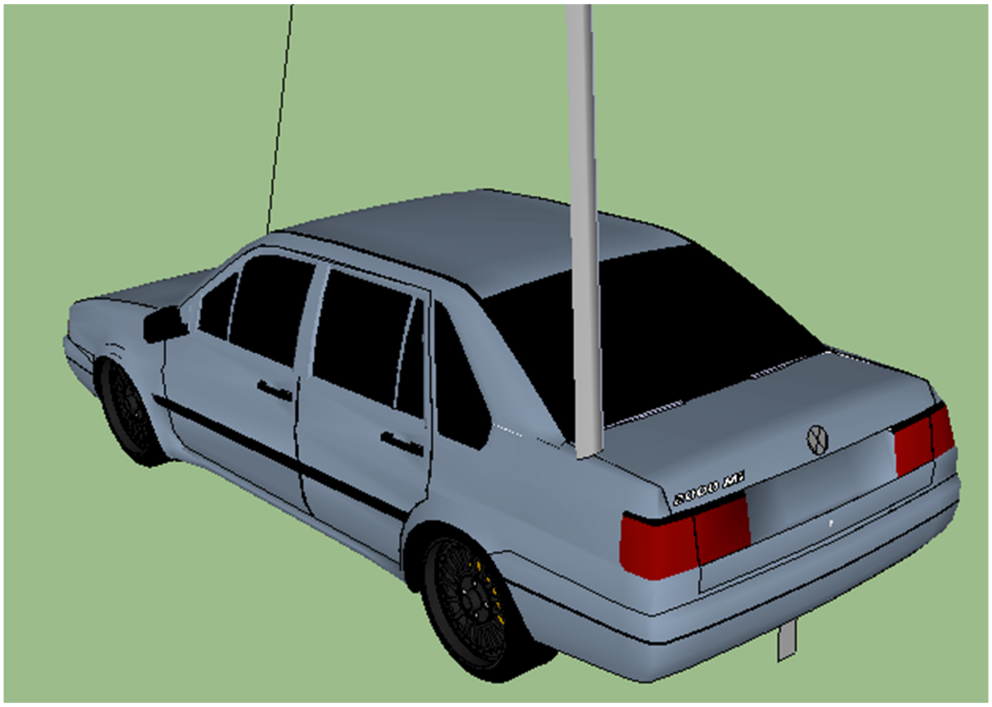


A proposed design for the overhead charging stations for Santana (base car) plug-in hybrid taxis. This diagram shows the cabs picking up charge from an overhang using extendable charging rods.

Overhead charging designs are already in use in China. One is shown above charging an ultra-capacitor

These autos also require a charging infrastructure to allow them to charge on the go. A viable solution is a large 5 to 7 meter overhang, structured like a bus stop, suspending a high-voltage mesh net over the road or charging area with which the car's charging paddle could accept electric current. These charging stations would be placed in areas in which many taxis congregate, such as airports, railway stations, and other major passenger-customer areas. Thus, when taxi drivers wait for customers, their cars can be charging for upcoming trips. Another design involves a charged mesh screen placed over certain road lanes. The screen would be suspended by cables between buildings or other structures in the downtown areas. Using this, a plug-in hybrid taxi could charge its battery while driving passengers to their destinations or while slowly cruising for passengers in the area, not just while waiting at taxi stand overhangs.

Although there are other infrastructure possibilities, these charging options both show great promise for low-cost charging infrastructure.



The taxi cabs would also need to have another way to provide electric current besides that supplied from the overhead screen. Again, there are multiple options for this aspect of the plug-in hybrid electric taxi. One possibility is a retractable tongue, somewhat like the retractable antenna accepting charge, which would make contact with both terminals to accept current (see illustration.)

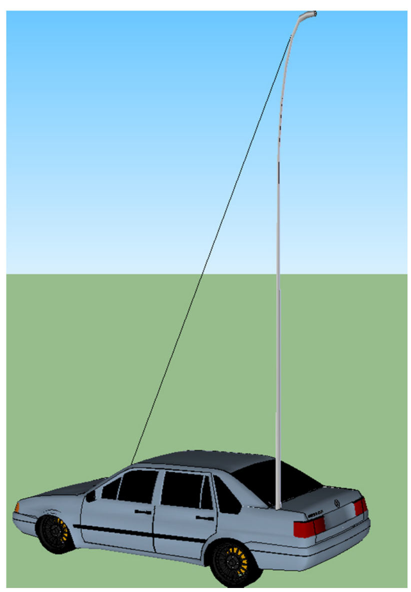
If the overhead system is used, a conductive surface must be placed on the ground in order to accept charge being dispelled to the cab. This surface could be a metal plate, which is cheap and effective, yet inherently safe. A conductive, 0 potential, carbon enhanced asphalt also could be investigated, but it has yet to be designed; nonetheless, start-up concepts ~~would~~ could be manageable. One final option is to use inductive charging by placing magnetic coils in the ground to induce a current into the batteries. This appears to be a safe and effective way to charge the batteries; however, it is still under development, and would likely be very costly. All of these choices have pros and cons, and all will soon be viable options. However, the likely preference will be in favor of ones that are of the lowest upfront and maintenance costs.

A survey done showed that 89% of the nearly 50,000 taxis in Shanghai are Volkswagen Santana sedans. Thus, all further calculations presented will be based on a Volkswagen Santana 2000 sedan. The following table is a list of this car's specifications.

Conventional Santana ($11,000)	
Number of Cylinders	4
Gearbox	5 Speed Manual
Cooling Substance	Water / Glycol
Curb Weight	1081 Kg
Engine Size	1.8 *l*
Power	72 Kw
Torque	143 N•m
Efficiency (At Best)	10 *l*/100 Km*
Top Speed	168 kph

A Volkswagen Santana Taxi waits in Shanghai

* Average taxi driver efficiency ~ 12 *l*/100 km – Future data is based off of this data. This value is higher than the table shows because the average taxi engine is running continuously for 18 hours a day and, at times, under maximum load.



The Santana plug-in hybrid taxi prototype

The best, most easily standardized plug-in hybrid cab for China's major cities could use a Volkswagen Santana as a base automobile, as the car's design allows for modifications. The Santana plug-in will use a smaller, more fuel-efficient gasoline engine as a supplement for its reasonable electric motor when its lithium-ion battery's charge reaches a minimum level. The following is a chart outlining the specifications of the Santana range-extended electric vehicle.

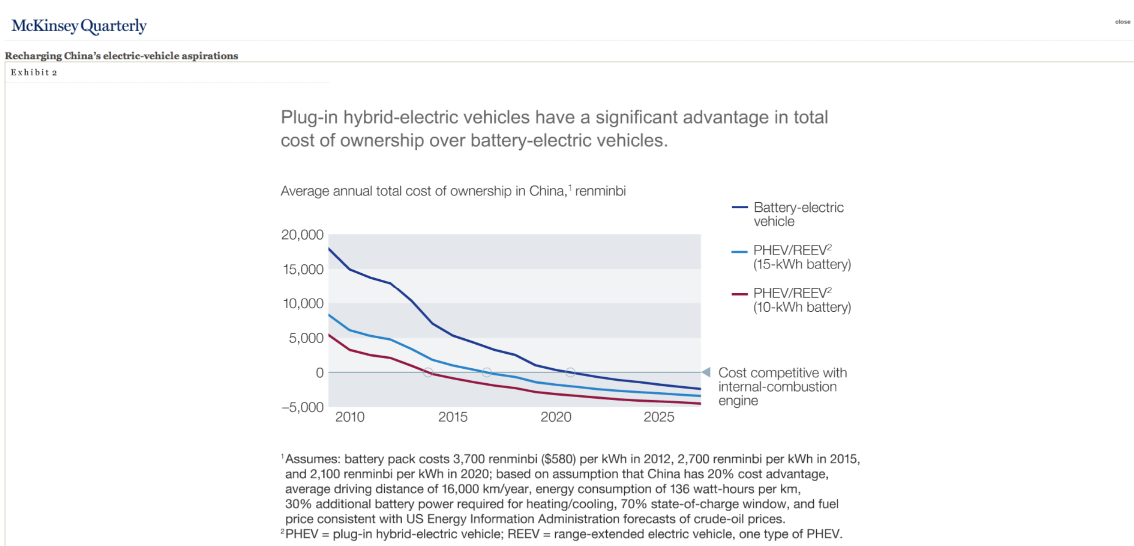
Santana Plug-In Hybrid (Cost Approx. $13000-$14000)

Gas Engine (Alone)

Number of Cylinders	2 or 3
Engine Size	1.0 *l*
Power	50 Kw
Gearbox	5 Speed Manual
Cooling Substance	Water
Curb Weight	Est. 1200 Kg
Torque	70 N•m
Efficiency	5.2 *l*/100 Km
Top Speed	100 kph

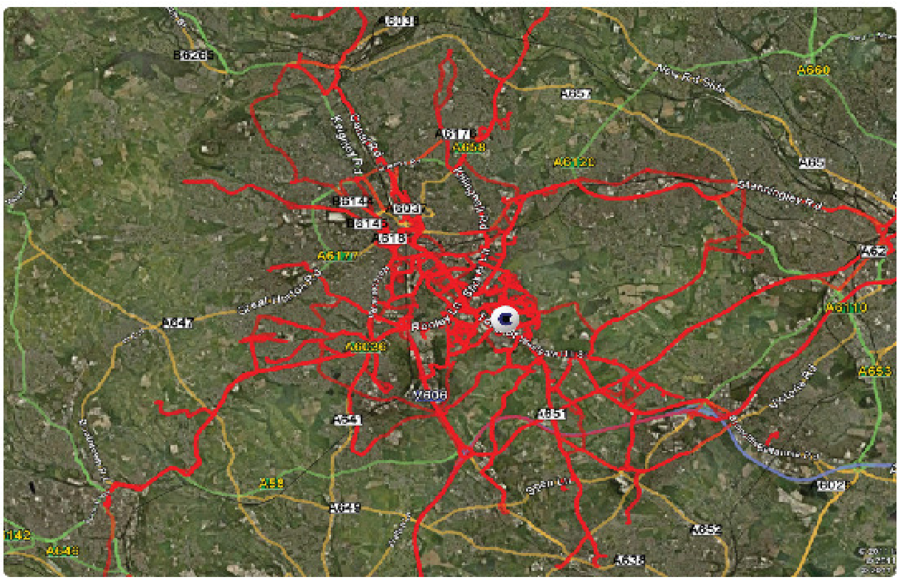
Battery and Electric Motor

Battery	207.2 V
Battery Capacity	4.4 KwHr
Battery Supply to Motor	3.4 KwHr
Battery Power Output	60 Kw
Battery Range	16-24 Km
Motor Power Output	60 Kw
Charge Time for 1 Avg. Trip	5 Min.
Battery Distance on 5 Min. Chg.	9.0 Km
Vehicle Electric Efficiency	186 wh/Km. (.19 Kwh/Km)
Motor Torque	200 N•m



A graph from McKinsey Quarterly illustrating the falling prices of batteries for plug-in vehicles

At the current moment, battery prices for hybrid vehicles are one of the greatest costs in the manufacturing of the car. However, a 2012 report from McKinsey and Company reports that in the near future, lithium-ion battery prices will fall dramatically along a steep price curve as time goes on. In 2012, the battery cost for a Santana PHEV's 4.4 KwH pack lies around $2,545 (16,280 ¥), which is nearly twenty percent of the plug-in's cost. However, McKinsey predicts in the above chart, that as China begins to manufacture batteries on a larger scale, and as ongoing research persists, battery prices will fall to around $425 (2,700 ¥)/KwH in 2015, and even as low as $330 (2,100 ¥)/KwH by 2020. As battery prices fall and taxi manufacturing rises, the cost of a new Plug-in Santana could, in the near future, be as low as $11,500, a mere $500 more than a conventional ICE Volkswagen taxi cab.



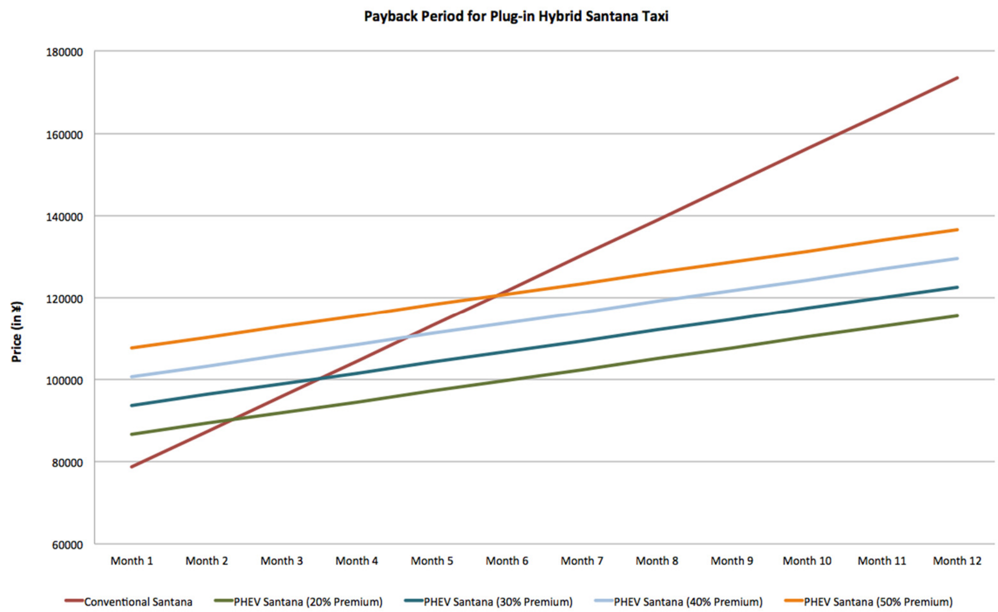
A map of Bradford, UK, showing how taxis spend 90% of their time in city centers

The average New York City taxi trip, according to Schaller Consulting, is between six and nine kilometers (3.75 and 5.5 miles), with an average 5-minute trip time. The average wait time for passengers is also 5 minutes. These 5 minutes spent waiting waste both fuel and time. Since the traffic situation in Chinese cities is similar to that in New York city, the Santana PHEV has the ability to take advantage of these wasted opportunities. As a cab drives through a city, cruising for passengers to pick up, it can extend its charge receivers and accept energy to charge its battery for the upcoming trip. This charging system is especially effective, as 35% of a taxi's time spent driving is used to cruise for passengers, while a mere 65% is spent with the customer, reports the New York Times. Once a passenger is picked up, the electric energy receivers can either be stored or kept extended as the customer rides to his or her destination. An alternative solution is to have the driver extend his receivers when parked at a major passenger waiting point, i.e. an airport or railway station. His receivers can be used to charge the car from a stationary overhead charging terminal while waiting and can be collecting electric energy as the car moves along the waiting lines. Five minutes is enough to supply the automobile with 1.67 KwHr from a 1,000 volt, 20 amp, 20 Kw charging source, namely an overhead screen. The battery's garnered energy is enough to transport the vehicle, solely running on electric power, 9 kilometers, which is far enough to satisfy the upper end of the average of all taxi trips in the city. However, if a longer trip is necessary, such as one to the airport or any other extreme distance, the driver will not be stranded with an immoveable, unusable car; the conventional gasoline engine will simply take control of the automobile and power it until the battery can be recharged in the city center. The gasoline engine will be lightly used, though, as the normal cab driver spends a massive 90% of his work hours in a city center, where he could quite easily charge his battery by one of the many charging ports that will be placed at strategic points throughout the metropolis.

China's renewable energy will, in the future, become the more common method of powering the car, making for a cheaper, more sustainable way of ferrying passengers. Currently, electricity is generated mostly by coal. China has already instigated a conversion of many taxis to natural gas due to its increased cleanliness. To make the proposed plug-in taxi even cleaner, electricity must be generated renewably by solar, wind, or water. By installing wind and solar augmenting systems on buildings in the general areas where the taxis are operating, these renewable energy goals can be achieved. Solar and wind generators would offset the amount of electricity needed from present-day coal plants. As time goes on, these renewable facilities can be increased in volume to finally displace as much as 80 to 90 percent of the electricity that would be used by the PHEV taxi. Of course, natural gas is a viable alternative in the transition to cleaner fuels, but it is still a hydrocarbon and a valuable resource for material manufacturing, as well as industrial and domestic heat. The proposed plug-in hybrid could easily run on natural gas as well; however, it will require only about a quarter of the amount of natural gas for a typical day, greatly reducing the volume required for the natural gas fuel storage tank and drastically increasing interior space.

Long-term benefits of the conversion of China's taxis to range extended electric vehicles (REEVs) are not merely environmental. There also are great cost benefits to mass conversion. A new conventional Volkswagen Santana costs around $11,000 (accounting for company discounts, subsidies, etc.) Assuming that the average taxi driver in any major Chinese city drives approximately 100,000 kilometers a year, averaging 12 *l*/100 Km fuel efficiency with aggressive city driving habits, and using the March 2012 statistic of 8.19 ¥ per liter of gasoline, it is estimated that the average taxi driver consumes 12,000 liters of petrol in a single year. Taking into account fluctuating fuel prices, the price of gasoline for a single taxi in one year is between 94,240 ¥ and 98,280 ¥. With a new Santana costing approximately 70,000 ¥, first-year operating costs could reach 168,280 ¥. Furthermore, one year of gas for this taxi is 140% of the entire cost of the car. Thus, it is no longer cost effective to run an automobile used as frequently as a Chinese cab solely on expensive gasoline.

While the asking price of a new, conventional Santana is less than the predicted $13,000 to $14,000 price of this car's plug-in electric cousin, the ROI, or Return on Investment, period for the range-extended electric vehicle is surprisingly short. The Santana PHEV taxi's smaller gasoline engine can achieve efficiency, by itself, of 5.2 *l*/100 Km. Combining both the car's electric battery and motor efficiencies, the plug-in hybrid will be able to achieve 2.8 *l*/100 Km. Thus, the vehicle will use only 2,800 *l* of gasoline in a year, which stands in stark contrast to the 12,000 *l* of gasoline used by a conventional Santana. The liquid fuel consumed by the PHEV is only 23.3% of that used by the ICE engine in the conventional taxi. Thus, the cost of gasoline used by the plug-in taxi in one year is only 22,932 ¥, contrasted with up to 98,280 ¥ for the conventional counterpart. This means that a taxi operator, running an extended range Santana vehicle, could save over 75,000 ¥ in only one year if electricity was provided at no cost by a city or power plant. However, if the local power company decided to charge for electricity, the cost of energy to operate the car would still be far lower than just running the vehicle on gasoline. In July of 2012, in Shanghai, electricity averaged 0.76 ¥/KwHr. It is calculable that an average PHEV taxi would use 11,340 KwHrs of electricity each year. At a consumption rate of 0.3 Kwh/mile, electricity costs would be 8,618 ¥ per year. Thus, total running prices for the taxi in one year would be 31,550 ¥. This is still less than one third the cost of just gasoline in a conventional taxi cab. Any way it is viewed, the plug-in taxi makes far more sense for China's future than today's cab vehicles.



In a first year buying circumstance, the initial one year cost of both an internal combustion engine Santana taxi and its fuel is 168,280 ¥. For a PHEV Santana using free electricity, the first year cost is 108,932 ¥. For the same car using electricity priced at .76 ¥/KwHr, the 1st year cost is 117,550 ¥. Both of these initial plug-in expenses reflect a $13,500 initial asking price. The above data shows that the Range extended REEV taxi cab returns its investment within the first year of use, even though the up-front costs are higher. Specifically, the plug-in taxi not being charged for electricity returns its total **yearlong** investment within the first 65% of the year. Thus, if the cab were bought at the beginning of January, its full-year premium would be paid off just past halfway through July. Further calculations can be performed to show the profitability of the new car. If the new PHEV taxi cab were to cost a 20% premium over the $11,000 ICE alternative ($13,200), it's first month costs would be ¥ 86,629, assuming one-month costs of gasoline being ¥ 1,911 and ¥ 718.2 for electricity. The first month costs for the conventional cab would be ¥ 78,618, seeing as gas would cost ¥ 8,618 in one month. The returns, however, start as early as just into month three, as the cumulative second-month costs of the conventional car would be ¥ 87,236, while the price of the plug-in would be ¥ 89,258. By the third month, the plug-in takes the lead in cost savings. The chart on the previous page shows how initial prices of the REEV affect the ROI period very little. This means that the incremental cost of the REEV taxi could be as much as 50% more than the conventional vehicle, but, after 6 months of operation, the REEV taxi starts to make more money due to the savings in fuel. Clearly, the Santana, or a similar plug-in hybrid alternative, is a better choice financially for both taxi companies and drivers.

If electricity companies decide to charge for electricity, there needs to be a way for them to collect money from the cab company drawing the current. A proposed way to achieve this is to use an intelligent charge system. When an overhead power screen is out of use, it can be shut off to reduce danger and prevent waste. However, the screen can be re-activated when a vehicle comes in contact. Bluetooth, Wi-Fi, or special types of contact can inform the intelligent power screen which cab company is using the device and thusly charge the correct users. This would be a simple new, high-tech solution to a power company's problem.

Alternatively, in the debut of this system, power companies may wish not to charge for electricity. As the program starts, the structures should be subsidized by either or both the city in which they are being built and the local power company. If this is done, and free electricity is provided, it will pose an additional incentive for taxi companies to shift their cars over to the plug-in hybrid technology. Then, once a large amount of old taxis have shifted over, energy companies can begin charging for power, and taxi corporations will have no choice but to pay. However, even when paying for electricity, the cost of operating the PHEV is still far less than running a conventional ICE. This free energy approach is a way to jump-start the program into life and accelerate adoption and sales which would be beneficial to all parties involved.

Cities such as Shanghai also have reason to subsidize the creation of these power structures. Current Shanghai gasoline subsidies for taxis exist as gasoline prices continue to rise. This costs the city money. Instead, this money could be put towards creation of charging stations and subsidies of the manufacturing of these taxis which could, in the long run, keep the city from spending more money. Eventually, it could even bring in revenue. Gas prices will undoubtedly continue to rise, and if the gas subsidy sticks, Shanghai will have to pay more and more to keep its taxis on the road. As a further example, the American Society of Mechanical Engineering published a report in their August 2012 magazine showing graphs relating to EROI, or Energy Return on Investment. EROI is defined as energy return from system operations divided by the energy needed to extract the fuel and build plants and infrastructure. EROI for gasoline in 1930 was nearly 100%. In 2012, it has fallen to around 80%. The graph, though, showed that EROI will bank sharply downward in the near future until it soon becomes highly unprofitable; energy companies will soon be losing money on extraction, and prices will skyrocket. Thus, Shanghai must keep from subsidizing petroleum, as it will hurt the city increasingly more in the future. On a different note, if clean, renewable energy sources are utilized, creating power structures and systems will help clean cities and make them safer places in which to live, meeting current safety goals. The EROI of renewable energy sources is extremely high and has already matched the

EROI of petroleum at a stable level. Clean energy will very soon be highly more sustainably profitable than gasoline. McKinsey Journal reports that if clean energy is used in PHEVs, CO_2 levels could fall by up to 40%. These arguments show that cities have a lot to gain from the electrification of taxi fleets. Overall, placing this money in this taxi program is a far better bet for the future than staying completely dependent on gasoline.

Taxis line up waiting for fuel in Chongqing. If these taxis were plug-ins, they could spend this time charging their batteries.

Another incentive for the taxi program is to allow for less international dependency (article taken from McKinsey.) If more domestic energy, such as electricity, is used in cars, as will happen in this taxi program, it will leave China less prone to market fluctuations in gas prices, energy prices, and the like. It will also increase domestic supply and lower demand. Furthermore, if China takes advantage of the birth of a new technology in automobiles, as will happen, it could emerge as a global leader in the manufacturing of these new automobiles, especially if the taxis show their success and the private sector begins to adopt these hybrids. It also gives China an advantage over other countries' manufacturing of traditional ICEs. Evidence of this is shown in McKinsey's discovery that the creation of PHEV buses and other public transport grew ten times more in their respective markets than private cars. This gives China a golden opportunity to take advantage of the moment and begin manufacturing these taxis.

Using these plug-in hybrid taxis will also help China satisfy its 5 year plan (reference McKinsey.) The goal outlines that by 2020, there should be 5 million PHEVs and BEVs. This taxi program could help satisfy that goal.

Incentives for drivers also stem from this program. The money saved by driving a PHEV taxi could translate into more money in their pockets. Their salary could be dependent upon how much electricity they use. The less gas they use, the more their income could rise. This incentivizes using as many charging stations along their routes as possible. It is an all-around win for everyone.

CONCLUSIONS:

A plug-in hybrid electric taxi with a 4.4 KwHr or smaller battery makes a cost-effective taxi system. This battery size is similar to the Toyota Prius PHEV battery pack, so it can be readily available for a Chinese Taxi. It caters to all passenger needs and distances while being both drastically cheaper and cleaner than a normal, conventional taxi over a one year period. If the Volkswagen Santana or similar plug-in hybrid prototype proves successful, a high-volume test program could follow. This program has a strong future because of its economic sensibility.

The proposed REEV taxi system has advantages to the every stakeholder, as has been discussed. These stakeholders are drivers, taxi owners, the city, and the power companies; in the near future, solar and wind companies could also benefit from the program.

We have shown that the needed infrastructure can be very simple. This will make the start-up costs affordable with a short payback period. All the concepts discussed can be improved as technology advances, but they provide a way to start. The road map to the future is unknown, but it must start with small, simple, incremental changes; then, it can improve ~~occasionally~~ gradually as new technology is developed. Trying to make big jumps into new technology without a smooth economic transition has always failed in the past, even though the technology can be shown to work in costly, restricted samples. The transportation sector's electrification process is no exception.

It is imperative that China adopts this taxi program to illustrate to its citizens that electrification can be made practical without sacrifice to performance or utility. The benefits to the country, its citizens, and the environment are staggering. If China is to meet its goals of electrifying the cars on its roads and cleaning the air, it must take note of this important technological development. Armed with cleaner technology and cheaper prices, these will help China advance past other countries in clean energy technology and will pave the path towards a better future for China and the world.

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EFFICIENT DRIVETRAINS Inc.,
Transforming Hybridized and Electrified Drivetrain Possibilities
Electrification of Taxi Cabs with
Range Extended Electric Vehicles
Presented by:
Grant C. Watson and Prof Andrew Frank, CTO of EDI
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Chinese Taxi cabs duty cycle and converting to using electricity with PHEV's

- Most of the time (80%) city travel of less than 10km
- Occasional (19%) travel to the airport at 25 to 30km each way
- May be used for long trips (1%)
- Currently no place to connect to electricity automatically on city streets
- Average charging distance can be less than 9km
- Average time for charge: 5-8 minutes in city and ½+ hour at airports and train stations

It is possible to Electrify taxis and still be able to satisfy wide driving requirements

- Need a PHEV-REEV taxi cab at a low price that is compatible with existing taxis and costs
- Current taxis in China are low cost conventional vehicles using gasoline or N/G
- A low cost charging infrastructure for the city and electric companies needs to be constructed to distribute electricity to the taxis due to the physics of energy

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Taxi Cabs queue up in China for passengers at public transit stations

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Taxi cabs queued at the airport

- Time can be used for charging batteries
- A new ***low cost*** electric energy infrastructure is needed

Existing charging infrastructure system for buses

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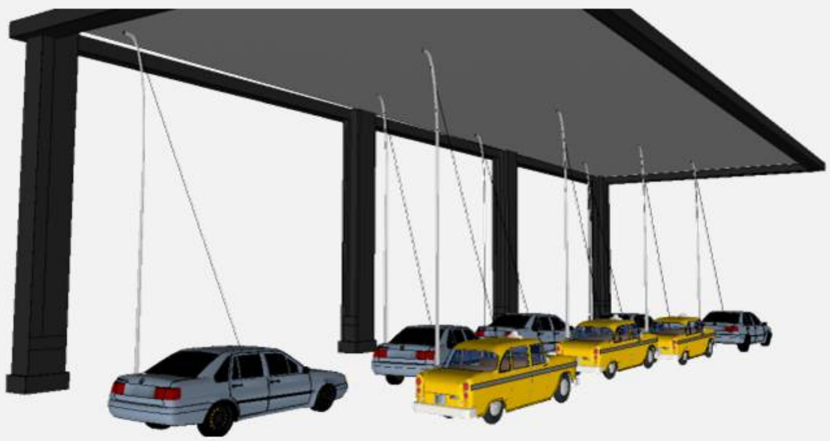
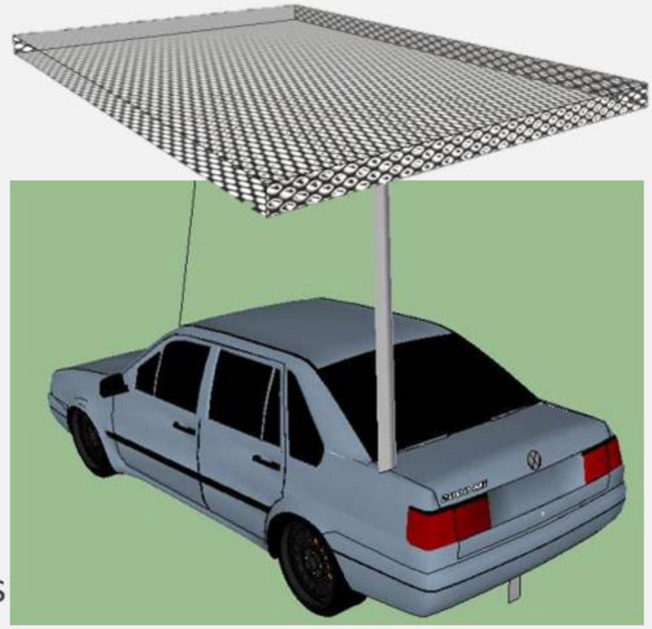
Solution to charge moving taxi cabs

- A proposed solution that allows collecting charge "on the move" to fit the Taxi Cab **moving queue** scenario
- A simple and low cost mechanical solution



Water proof Taxi energy collector in special lanes

- 1000V @ 20amps with ground strap
- 105km range/hour of charge
- Automatic billing and activation by wireless communication
- Located in special lanes where PHEV taxis are allowed.



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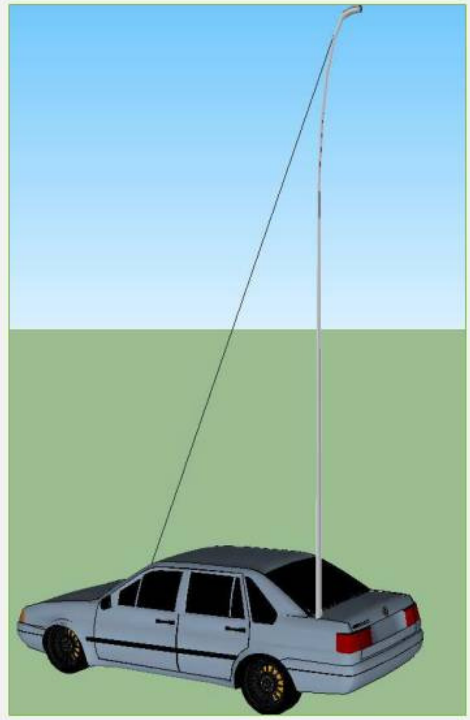
Proposed PHEV taxi charging system

- **Objective:** displace 75% of liquid fuel used
- Charging system must be distributed where taxi is waiting for passengers such as: train and airport stations
- Low speeds looking for passengers
- Average distance per passenger is 6km to 9km requiring about 2.7 kWhrs or 8 min for 9 km.
- Electric pick up can be retracted for highway driving



Current VW taxis cost in Shanghai approximately $11000 - new

- Number of cylinders: 4
- Gearbox: 5 speed, manual
- Cooling system: water
- Curb weight: 1081 Kg
- Engine size: 1.8L
- Power: 72 Kw
- Torque: 143 N•m
- Efficient (at best): 10 *liters*/ 100 Km
- Top Speed 168 kph

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Proposed PHEV Santana Taxi specs

Santana Plug-in Hybrid (Cost approx. $13000 - $14000)

Gas Engine (Alone)

Cylinders:	2 or 3
Engine size:	1.0L
Power:	50 Kw
Gearbox:	5 speed, manual
Cooling system:	Water
Curb weight:	Est. 1200 Kg
Torque:	70 N•m
Efficiency	5.2 / 100 Km
Top Speed	100 kph

Battery and Electric Motor

Battery:	207.2 V
Battery capacity:	4.4 KwHr
Battery supply to motor:	3.4 KwHr
Battery power output:	60 Kw
Battery range:	16-24 Km
Motor power output	60 Kw
Charge time for 1 avg. trip:	5 Min.
Battery Distance on 5 min charge:	9.0 Km
Vehicle electric efficiency:	186 wh/Km (.19 Kwh/Km)
Motor torque:	200 N•m

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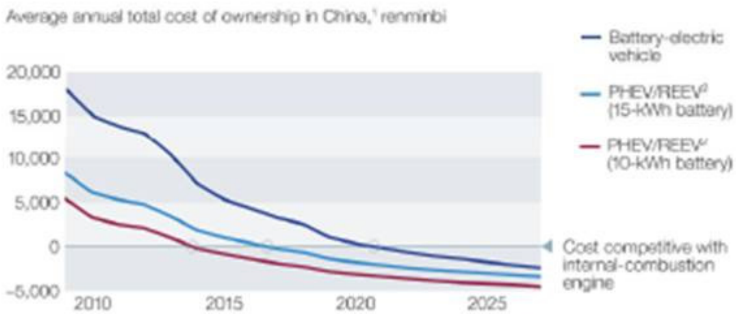
Battery prices will fall in the near future making PHEV's affordable

Plug-in hybrid-electric vehicles have a significant advantage in total cost of ownership over battery-electric vehicles.



[1]Assumes: battery pack costs 3,700 renminbi ($580) per kWh in 2012, 2,700 renminbi per kWh in 2015, and 2,100 renminbi per kWh in 2020; based on assumption that China has 20% cost advantage, average driving distance of 16,000 km/year, energy consumption of 136 watt-hours per km, 30% additional battery power required for heating/cooling, 70% state-of-charge window, and fuel price consistent with US Energy Information Administration forecasts of crude-oil prices.
[2]PHEV = plug-in hybrid-electric vehicle; REEV = range-extended electric vehicle, one type of PHEV.

Ref: McKinsey Quarterly

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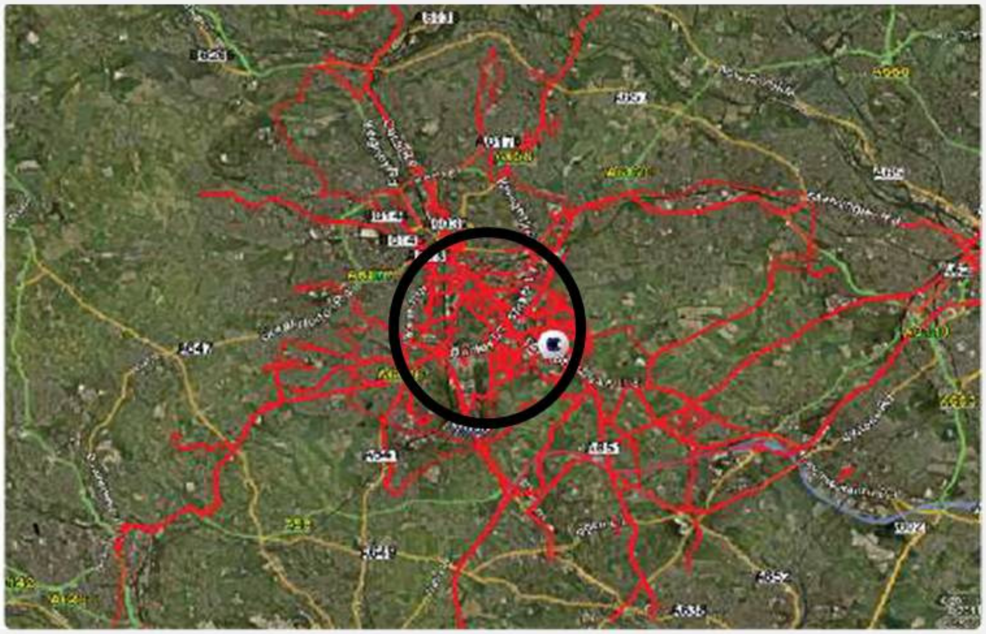
City centers: most Taxi traffic

- Install in-street low speed overhead charging units between buildings



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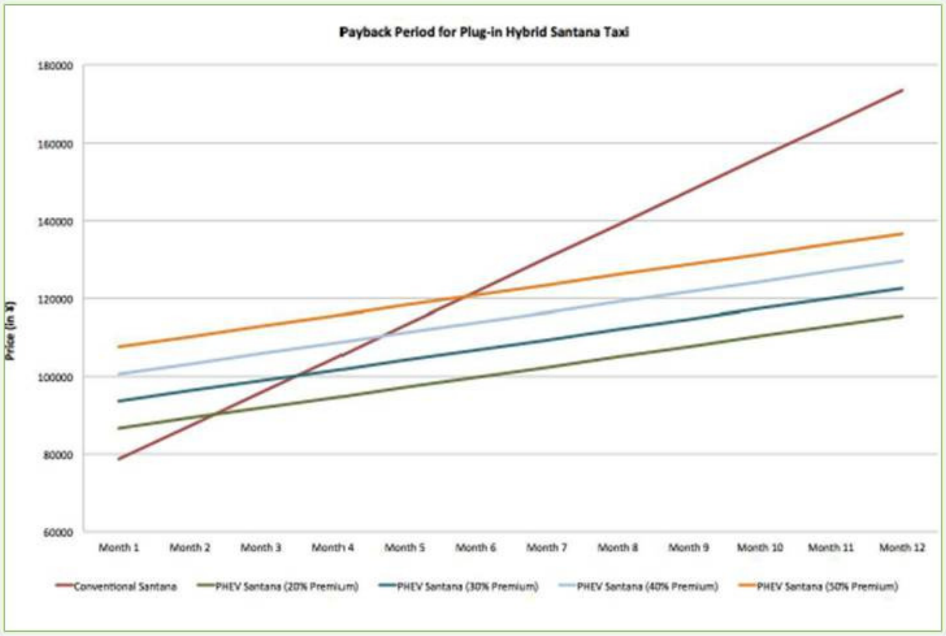
Cost of current new Taxi cab and first year fuel use, compared with PHEV Taxi. --- Crossover in less than 6 months



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Chongqing Taxis waiting for NG– time spent could be charging batteries and cost of fuel could be greatly reduced

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Frequent and diverse charging opportunities

- Charge at transit stations wait time: ½ hour
- Charge while cruising pick ups time: 5-10 minutes
- Charge at hotels and city taxi stations 5-10 minutes
- Use liquid or N/G for airport trips or when charge is low automatically
- Overall use up to 90% electricity and 10% liquid or N/G
- If **no** charge then vehicle uses ½ -¾ fuel of a conventional taxi

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Proposed PHEV taxi charging system

- **Objective:** displace more than 80% of liquid fuel used with electricity
- Charging system must be distributed where taxis are unoccupied; ie: train and airport stations at low speeds looking for passengers
- Average distance per passenger is 5km requiring about 1.5 kWhrs or about 4.5 mins of charge.
- Electric pick up can be retracted for highway driving

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Who will pay for the one time cost and maintaining the Charging Infrastructure?

- **The City:** 30% because it provides zero emission transportation and clean air
- **The Province and Central Government:** 30% because the taxi's displace more fossil fuel with domestic energy
- **The Electric Company:** 30% since they will increase their customer base and earn more money
- **The Taxi Companies:** 10% because their costs will be lower than conventional taxis and they will make more money
- **Overall cost** of infrastructure and maintenance can be less than current fuel subsidy for taxis by the Cities and Provinces
- **Everyone who pays wins!**

Conclusions

- Simple low cost charging infrastructure will allow PHEV taxi cabs to displace more than 75% of the fuel used by conventional taxis
- No loss of performance and can easily use ¼ or less gasoline or N/G
- Electricity can eventually be **Renewable**; Solar/Wind and liquid fuel can be biofuel for zero CO_2 emissions!
- Payback period for incremental cost for a small battery pack and downsized engine and electric motor is less than 6 months

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Conclusions continued

- Should begin taxi and infrastructure design as soon as possible to displace fossil fuels and increase profits
- Charging infrastructure could be used by private compatible EV's or PHEV's since charging costs and controls will be wireless and with coded requests in each vehicle-the taxi system then provides incentives and examples to the general public due to the demonstrated lower costs to create demand for PHEV/REEV using electricity displacing gasoline or fossil fuels and moving ground transportation toward zero CO2