A proposal for an IT-mediated urban electric vehicle system

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Electric vehicle technology has − in spite of limitations primarily on range and price − for a decade or more been able to satisfy the need for personal urban transport on a large scale. But this has not happened. The paper discusses why, and then presents a comprehensive proposal to enable and stimulate a fast and significant transfer to electric transport in congested cities. The proposal exploits advanced but available technologies such as the Web, mobile wireless communication, GPS navigation, computerised data logging − and combines this with political-economic and organisational measures to stimulate transfer to electric vehicles.

1. Introduction

This paper is based on the authors' Norwegian experiences working with electric and hybrid vehicles. Electric vehicles (EVs) have a special attraction in Norway since the country's electric power system is emission-free, being exclusively hydropower and (lately) a little wind power. In Norway and other countries there was a wave of interest in electric and hybrid vehicles starting in the middle eighties. During the nineties, an innovative electric two-seater was developed and put in production in Norway (in addition to being an EV, it had a body of thermoplastic around a crash-resistant cage of welded aluminium profiles and high-tensile strength steel). The latest versions of the car are called "Think", see photo. It made some impact on the world auto scene when Ford bought the concept and the Norwegian plant in 1999, and announced that this car would be distributed worldwide under their brand as Ford's urban EV. Ford decided to do this because of the so-called California mandate, more on this below.

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To facilitate the reading of this paper, which is meant mainly as a political-organisational contribution, it is structured such that many of the technical points are not in the main text but contained in endnotes.

2. EV history, technological and political background

On a global scale, developments in the USA have been decisive for EVs, both recently and in its early days. Electric vehicles have a long history (Schallenberg, 1980; Electric Auto Association, 2004). Around 1900 the U.S. sales of EVs were on a level with ICEV's. In 1913 however, only 10 percent of commercial vehicles were electric, and the share of private EVs was much smaller. The introduction of the electrical self-starter in 1912-13 eliminated the need for manually cranking up the internal combustion engine. Ford had introduced the sturdy, low-priced ICEV Model T in 1908. By 1914, the moving assembly line enabled them to produce far more cars than any other company. By 1925, the share of commercial EV's in traffic in the U.S. had dropped to only 3-4 percent. There, and worldwide, the EV continued its decline as a street vehicle. Except for special applications like the British milk floats, it lay dormant until the early 1980s when it was resuscitated mostly due to urban environment concerns. In the late eighties there were also optimistic reports of breakthroughs in battery technology, for instance the sodium-sulphur battery developed by ABB, which gave a nearly-acceptable range for an EV compared to an ICEV.

The sole serious and decisive obstacle to large scale transit to electric vehicles has since the first EVs were produced been the lack of range due to inferior energy storage in available battery types. Except for that, EVs are very superior to ICEVs:

- No tailpipe emissions.
- Markedly lower noise.
- The motor has one moving part and is completely vibration-free due to rotational symmetry. This means simplicity, robustness and very low maintenance costs.
- No idling, no clutch. An urban EV is usually made without gear shifts.
- Advanced EV motors are more compact and lighter than ICEV engines with corresponding power.
- An EV has superior traction properties, torque is at its highest at low r.p.m. This means that an EV accelerates very fast the first stretch from standstill.
- Two to three times higher motor efficiency.
- Superior motor control through solid state power electronics. This is a fairly recent additional advantage of EV's over ICEV's.
- Except in situations where hard braking is needed and the regular brakes must be engaged, an EV brakes by letting the wheels drive the motor as a generator, charging the battery − instead of the braking energy being dissipated as heat and lost as in an ICEV. Some energy is thus recouped ("regenerative braking"), and wear on brakes is lower.

California passed the Clean Air Act in 1990 (Fogelberg, 2000; Southern California Edison 2004; EV World, 2004). The crucial part of this legislation was the requirement that by 1998, 2% of the vehicles sold by any car manufacturer in California had to be zero-emission vehicles ("ZEV"), which in practice can only be satisfied by EVs . By 2003 the share should be 10%. With 1.7 million cars sold in the state per year (2004 figure), no auto maker can ignore such legislation.This was the decisive reason for a marked turnaround of major manufacturers, from earlier dismissal of EV's as a realistic option, to something resembling enthusiasm. In the early nineties they pledged their support for developing EV's, and they initiated programs with test models. Their main marketing strategy versus consumers was to convince them of the usefulness of having an EV as an additional car for shorter trips in urban areas.

But several setbacks for the EV cause occured later on:

Technologically, some seemingly promising battery technologies turned out to be either disappointing, or at best commercially available some years into the future. One of the most exciting inventions launched at the time, the ABB sodium-sulphur battery, was later shelved due to safety considerations and very low reliability[3], at a great loss to the company. Nickel Cadium-batteries, a safe and tried technology that was commercially available around 1990, is still the workhorse of most EV's. At best they give a two-seater EV a range of around 100 km. There are, however, better battery solutions[4] that are commercially available today at a competitive price to NiCd, but they seem to have arrived on the scene in a worse political climate for EVs, somewhat too late to attract the necessary attention.

Politically, the auto manufacturers in the U.S. used their lobbying power during the nineties, and they have succeeded in watering down the California clean air act. The "10% must be EVs from any manufacturer by 2003" rule was weakened through stages (New York Times 2001, 2002) and finally revoked in 2003, responding to legal pressure from automakers and the Bush administration (New York Times 2003), and substituted with rules that didn't put the same strict demands on manufacturers (Southern California Edison, 2004; Electric Auto Association, 2004). (There is a saying among environmentalists that "when a government passes strict environmental legislation, the Japanese reaction is to hire engineers, while the American is to hire lawyers..."). Auto manufacturers worldwide were through this "victory" able to shelve their EV projects. In the case of Ford, they decided to get rid of the Think EV, and sold the Norwegian plant in 2002. In France, the PSA auto corporation has discontinued its production of their electric versions of ICEV models. In 2003 Toyota stopped production of the RAV4-EV, Honda stopped lease renewals on their EV-Plus, GM did the same for their electric sports car EV-1 (Electric Auto Association, 2004) and Ford is reclaiming their leased Ranger EVs (New York Times, 2004).[5]

Auto manufacturers have by now turned away from battery-powered EV's, and are directing their research towards fuel-cell-powered vehicles, with hydrogen as fuel. Hydrogen is very difficult to carry around, because it must be compressed to extremely high pressures (aproximately 700 bar) to give acceptable range for a (barely) acceptable tank volume and weight. Hydrogen may be made through electrolysis of water, using electrical energy from the grid. But the energy efficiency through the chain electric power grid to compressed or liquid hydrogen to fuel cell to electricy in the car, is inferior to the other option of power grid to battery to electricity in the car. One needs approximately triple the amount of electricity from the grid to get the same usable electric energy in the car via the hydrogen route (Bossel, 2004; a more comprehensive and technical paper is Bossel et. al., 2003). Furthermore, the infrastructure for moving and storing hydrogen does not exist today and will be very expensive to build, while the battery-charged EV already has a supply infrastructure through the existing power grid[6]. An alternative hydrogen-related research activity is based on methanol, since it may be carried in reasonably-sized and non-pressurised tanks. For use in a vehicle fuel cell however, methanol must first be converted to hydrogen, and this requires a miniature chemical process plant in the vehicle − a complex and expensive option. Like hydrogen, methanol is an energy carrier, not an energy source. It has to be made either by chemically combining hydrogen generated by electricity from the grid with carbon, or from petrochemical or biomass sources (the last is the environmentally best option).

Based on the above, skeptics (the authors among them) hold that the feasibility of mass implementation of hydrogen-fed fuel cell EVs is at least a couple of decades into the future, and is therefore something the auto manufacturers today use mostly politically, so that they may continue with business as usual − selling ICEV's.

We have illustrated the negative change in climate from the EV-friendly early nineties to today. But it should be noted that the Japanese auto manufacturers have chosen a more positive strategy than the U.S. companies ("hiring engineers, not lawyers") and developed *hybrid* vehicles − the most advanced example is the Toyota Prius . It is an impressive piece of complex engineering, which is neccesary in a so-called parallel hybrid car which has two motors working together − one electric and one an internal combustion engine. Toyota's strategy seems by now to have succeeded, their Prius is mostly accepted by consumers and motor pundits as a full substitute for a medium-sized ICEV. But the big Japanese brands do not offer pure EVs tailored for urban environments. And it should be noted that a hybrid has some emissions and exhaust noise, even if both are lower than for conventional cars. The relatively small battery is charged by running the vehicle's internal combustion engine, not from the grid. So such a hybrid should be considered on a par with a low-emission ICEV, not an EV[7].

Worldwide, the production of EVs is currently at an all-time low compared to the best period in the nineties. We may sum up the situation as follows: Auto manufacturers have suceeded in watering down environmental legislation favourable to EVs to a degree that allows them to largely ignore EVs as an alternative. The setback in the U.S. has influenced the European and Japanese manufacturers. A factor for the withdrawal from EVs is probably also that the manufacturers had arrived at a stage where they had to decide whether to ramp up from relatively small series EV production to large scale production, a decision that implies very large investment costs. And even if satisfactory battery solutions for urban EVs are now commercially available, they have arrived somewhat too late to turn this powerful trend around.

It is with this recent history in mind and on this background that a proposal for an IT-mediated urban electric vehicle system wil be presented.

3. A feasible short-term-scenario

In this section we will present a scenario that may be implemented today, based on commercially available technology. The next section will discuss development of this scenario to a more advanced level, employing technology that is feasible but is not all of it commercially available, and which needs research and development.

We will assume a two-seater resembling the Think EV as the preferred type of car in the fleet. All technologies involved are commercially available today at an acceptable price: it is a question of assembling available components to build a system. We will use some Norwegian statistics as a basis for our arguments. A Norwegian passenger car drives 37 km per day on the average (Lian, 2002). The average number of passengers is below 1.8 per trip for distances below 50 km and not above two even for the longest stretches (ibid.). In urban areas the speed is seldom above 80 km/h. A Think EV has a top speed of 90 km/h and a range of at least 80 km. This is extended to respectively 100 km/h and 120 km in the latest model (which has not been put into production[8]). There has thus for several years been a good case in Norway for large-scale transit from ICEV to EV transportation in urban areas.

For an EV (and many other new products) the pull from the market in itself is too weak to ensure sufficient sales growth for manufacturer survival in the first critical years. Economies of scale are very decisive in the auto industry. Therefore different government measures to make EVs more attractive are necessary. This has to some degree been accepted by the Norwegian authorities, and the following measures are in place:

- EVs are exempted from VAT and the special Norwegian personal car purchase tax which is quite high, depending on weight, engine power and some other parameters. These taxes taken together constitute approximately half the sales price of an ICEV in Norway.
- EVs are exempted from the yearly road tax which for 2004/2005 is 2755 NOK [9].
- They drive without paying a fee on toll roads, and through toll gates around cities.
- They can park for free in urban public parking areas.
- They are as a trial project from July 2003, allowed to drive in the lanes reserved for buses and

taxis.

Some of these incentives have been implemented just recently, after intense lobbying from environmental and EV interests in Norway. These measures contributed to an increase in the population of EVs with a relative high growth rate, starting at 178 vehicles in 1998 to 1140 today. But the number of EVs is still less than 0.1% of a total fleet of 1.9 million private cars. The small amount of EVs and the limited period the above incentives have been in place, makes it difficult to draw conclusions about which of the incentives are the most effective.

Additonal measures are needed to create a steeper growth in EV sales. We believe that the *single most efficient incentive* would be to pass a "California 1990" type law in Norway (and other industrialised countries for that case): an obligation on all auto manufacturers that a certain percentage of cars sold by each of them in the country would have to be EVs. This would mean that any manufacturer, if they did not have an EV model to offer under their own brand, would have to buy "green certificates" from companies that had sold more EVs than needed to meet their own obligations[10]. An auto maker would not need to start EV production themselves, as long as they could buy such certificates from another maker or a dedicated EV producer. To ensure sufficient demand, EV sales prices would have to be subsidised through transfers enabled by a slight increase in the sales prices on ICEV's. This should not be an intolerable burden on auto suppliers, since the percentage of EV's sold in the initial years would be small compared to the corresponding number of ICEVs[11]. Furthermore, competition would not be distorted between suppliers, since all brands would have to comply with such a law. We emphasise that this type of reform presupposes only the necessary political will from the authorities in a given country (or a supranational region like the EU) − there is no technological barrier that makes it infeasible.
Another important and feasible incentive would be to define no-go zones for private ICEVs in strongly congested and emission-plagued parts of cities, so that only EVs and public transport vehicles would have access.

This paper, however, is mainly about two other measures:

- Sharing cars in a rental system, as opposed to private ownership.
- Extensive use of available information- and communication technology ("IT") to mediate and facilitate the use of the cars in such a fleet.

Consumers are reasonably skeptical against investing 180.000 NOK (around 27.000 USD) in a two-seater with limited range, and a (battery) technology that is not very well known. Experience with car sharing systems ("CSS") − as opposed to individual ownership − indicate that this is a much better way to get a larger share of the population to use EVs[12]. In a car sharing system, one becomes a member, either by paying a refundable deposit (in the order of a couple of 1000 NOK), or paying a smaller enrolment fee followed by monthly membership fees. Then one may use any car in the fleet, through paying per km and hour of use. Since many users share few cars (a representative factor is 10 - 25 members per car, and this factor increases when the car sharing organisation has many members), total expenses are much lower per person than when owning one. The members also don't have to worry about maintenance and cleaning. Such services are purchased by the CSS from appropriate providers.
But car sharing also has obvious drawbacks. The main ones are that a car is very seldom parked in the immediate vicinity of the place where you live, and the other is that there may not be any car available when you need it (but both problems become less severe the larger the CSS is). [13]

There is also the need for some sort of manned "central" to find out if cars are available and where they are, and then book one. A further disincentive is that many will not want to use a vehicle that has been used by other people, possibly leaving their trash or the residuals of cigarette smoking.

All these drawbacks may be alleviated by extensive use of information and communications technology. We propose that every EV shall be equipped with an embedded computer system, which is connected to a GSM mobile connection for wireless digital communication and a GPS navigation unit which keeps track of the car's location. The car sharing system has a server which communicates with all cars in the fleet, and which hosts the system's website. This server also does the accounting of car use, and billing.

In the city there are dedicated parking bays for the cars in the CSS. These bays are equipped with power points for charging. An EV is routinely connected for charging by the user when it is parked. A parked EV will unlock for a user if it is not reserved by someone else. Information about possible reservation is shown through the window on a display, which also shows battery charge level. In the system server there is updated information about available cars, where they are parked and their battery status. Users may check this via the CSS web page, and reserve a car which is parked acceptably close. If the user is on the move, similar operations may be executed via a mobile phone. One receives a message about available cars in the vicinity, and sends an SMS reserving one of them.

The user has a smart card that is read by a scanner in the car through the front window. The car unlocks if it is free or reserved by the person requesting it. When finished with the car, the card is used in a similar way to lock it. The car (and the central server) also registers whether the user connected the car for charging before leaving it (and the car may give the user a reminder in the form of a honk or blinking lights). If this is overlooked, a small penalty is deducted from the user's deposit (more on this below). The car computer sends information about the user's identity to the central computer, and about driving length and duration. This (inclusive possible reservation time before starting to drive) is converted to an amount which is added to the user's monthly bill. This information may also be sent by the server in the form of an e-mail to the user, for control purposes.

As mentioned, a crucial factor for success of a car sharing system is that a car is usually available within an acceptable walking distance. Small car sharing systems (few users and cars) have the drawback that the cars are usually parked in a few locations, so that the average walking distance for a user is fairly long. Therefore it is vital that a CSS is large from the outset, so that the probabilty of a negative declining membership spiral is low. The dynamics of membership are unstable both ways. One must ensure that the starting population of cars and members is above a critical point, so that the instability works positively: more members join up, more cars may be bought, the system becomes more attractive, still more members join up, and so on. This can probably only be ensured by some sort of public funding of a CSS, for instance by defining the CSS to be an extension of an existing urban transportation system. Or one may invite private investors to submit tenders for a CSS which shall be strongly subsidised in the pioneer period.
For a given CSS size, there is a measure that may enhance the growth of the system: Define two categories of CSS members, let us call them "A" and "B" members. The "A" as opposed to "B" members place a parking bay outside their own home at the disposal of the CSS. This gives "A" members the advantage that there will often be an available car right outside their door. But any member may use such a car, as long as it is not reserved by someone else. With many "A" members, the CSS will become more attractive for everyone, because cars will be more finely distributed across the urban area. Average walking distance to the nearest car will be shorter. The installation of a charging point at an "A" member parking space is financed by the CSS, and the

"A" member is paid a small rent by the CSS.

Any member may rent a car in the CSS for as long as (s)he wants. This means that a permanent lease of a specific car is one possibility, if that is the preference. At the other end one has the user that very sporadically needs a car for a city trip. If the balance between types of uses of cars in a CSS is considered to be skewed in some way, this may be remedied by adjusting the parameters: enrolment feet, monthly fee, kilometer price, driving duration price and reservation time price.

A successful CSS is dependent upon responsible behaviour from its members. This is the main reason for the proposed deposit (and/or monthly fees). A breach of the rules of the CSS results in a penalty deducted from the member's deposit. One does not smoke in the car, one does not leave rubbish there, one drives in a responsible way. A car may be equipped with for instance a smoke detector and accelerometers, and events will be logged and sent to the central server. The point of accelerometers is to register unreasonably frequent and sharp braking or acceleration, or even impacts and blows, indicating reckless driving. Combining a mandatory deposit that may be (partly) forfeited, real-time logging of driving (and other) behaviour with the central server's knowledge of which member is currently (or has just been) using a car, gives the CSS a credible threat against irresponsible member behaviour. The point is the threat, not extensive use of penalties. It should ensure good behaviour and make the CSS more attractive, increasing membership and contributing to a positive spiral as mentioned above.

The GPS units in the cars and the wireless digital connection ensure that the central server knows where any parked car is at any time, and can inform users of its location. This means that a car − as long as the battery charge is reasonably high − may be left in an available space *anywhere* in the city, not only in the dedicated parking bays with charging stations (we assume that many public parking places are free for EVs in a CSS system, or that cars may be parked outside the home of some CSS members). This means a more finely spread network of available cars. The drawback is the risk of a low battery, but this can be countered by the driver being automatically warned that the battery is now so low that the car has to be parked in a bay with charging facilities. If a driver ignores such a warning and leaves the car without connecting it for charging, there is penalty deducted from his/her deposit. See also endnote [4]. An option to facilitate information about available cars in the vicinity is to equip all vehicles with a light on the roof like on a taxi. This light will then be on whenever a car is not reserved and the battery is sufficiently charged.

4. A more advanced scenario

A weakness of the short-term proposal is that members cannot "summon" a car that is available but not within reasonable walking distance − something that will probably be a fairly frequent situation. Ideally, such summoning should be possible. But computer-controlled steering of unmanned cars in city traffic is not an option for the foreseeable future. We therefore propose that another solution is evaluated: Using cars that are currently in use by CSS members as "locomotives" in electronically but not physically connected "trains" of EVs through the city. This idea is perhaps best explained through an example: Alice enters a car at location A, and keys in her destination F on the car's control panel. The car informs her on the display that there is a car waiting at B destined for a customer at location C and one at D which is destined for location E. Is she willing to let these cars be electronically slaved to her own for part of the stretch? If Alice confirms this with a keystroke, she will get a rebate on her bill for the trip, but she is then obliged to drive a route that passes the locations B, C, D and E on her way to F. The CSS server would however, not have proposed this at the outset if B, C, D and E were not conveniently located along the route from A to F. When Alice approaches location B, the car goes into "pick-up mode", which means that there is an automated ceiling on speed. An instruction about how (close) to drive past the waiting car (which − unmanned − has backed out of a 90 degree parking bay and positioned itself parallel to the lane) is given to Alice by the car computer, perhaps verbally to avoid distraction. The waiting car senses Alice's car passing by, locks on, and then we have a "train" of two closely-positioned EVs continuing through the city. When they pass point C, the slaved car is released. If the user is waiting there, it just stops parallel to the lane and is immediately taken. The user has informed the system by SMS that (s)he is waiting, or users may be furnished with a handy remote control for signalling the car directly that a CSS member is present and waiting to pick it up. If no one is waiting at C, the car noses unmanned into a free dedicated EV parking bay. The system will only allow a car to be relased at a given location if such a bay is available or a CSS member is waiting.

This "slaving" of one car (or more) to a manned one may also occur even if no one has requested a car to be brought to his/her location. The CSS server may decide, based on statistics of where and when vehicles usually will be in demand, to pre-emptively exploit manned cars to re-locate cars that are currently not in use.

This scenario obviously poses some problems. The first one is safety. If we assume that when a car is slaved it is fairly safely accounted for, it still remains to ensure that the unmanned stopping by the roadside, and the car's exiting and entering from/into a parking bay is done with acceptable risk levels. First, the car may be equipped with sensors that halts it if there is some close obstacle to its movement. Such technology is available today. Secondly, a few meters' stretch from the road and into a parking bay there may be an electronic track embedded in the tarmac, which guides the car in and out. Thirdly, and in a large CSS which is what we assume here, one may with negligible relative costs have a central where a few operators, through rear and forward-looking cameras in the cars connected by wireless via the CSS server to the operator, steer any unmanned car slowly and carefully in or out of a parking bay[14].

A smaller obstacle is unmanned connecting and disconnecting for battery charging. This may be achieved by exploiting the phenomenon of high-frequency induction coupling, a technology that is available today. It means that there is no need of physically inserting a plug into a power point. It suffices with a simple robotic arm for instance emerging from the surface of the parking bay and touching the underside of the car. Inductive coupling between the transmitter coil on the end of the arm and a pick-up coil embedded in the car ensures that electrical energy is transferred to the battery. Such a coupling is also completely safe against electrical shocks if touched.

5. Final words

We have first presented a straightforward scenario which is short-term feasible, so it is "only" a question of political will among those in power to implement it. Then we have presented a more "science-fiction"-like long-term scenario. The first step in making any change possible is to propose and describe it. Proposals that hardly get a chance to be aired can easily be disparaged as unrealistic by their detractors. Conversely, the more frequently a new idea or solution is presented to the public, the more realistic it will seem. The mechanism of the self-fulfilling prophecy is at work in both cases. We hope that this paper will be a small contribution to the positive version of this mechanism.

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Notes

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[3] Andreas Goubeau of BMW: "During the 80ies and the beginning of the 90ies, when we were busy with Sodium-Sulphur batteries from ABB, we burned down one of our workshops. We learned enough from this to at least let the next fire take place outside the building. Even if the Sodium-Sulphur battery was a rather deeply developed system, it proved to be very dangerous and difficult to control.

After the withdrawal of ABB, nobody has continued with the Sodium-Sulphur batteries." (Wormnes, 1998).

4 Perhaps the best commercially available technology with a proven safety record and battery life, is the maintenance-free, high-temperature, hermetically enclosed "Zebra" battery (Dustmann, 2003; Rolls Royce, 2004). It will give a Think-like two-seater 200 km range on a single charge.

5 A recent incident that provoked an international outrage in the EV community, was Ford's decision to destroy 358 Think EVs that until then had been leased out on three-year contracts in the U.S. Ford refused to sell these EVs to users there that wanted to buy when the program was terminated. 180 of the EVs were scrapped. Later the conflict reached a climax when Ford insisted on also scrapping the remaining vehicles, even after receiving an offer from a Norwegian EV producer of paying 2800 USD per vehicle and also freight costs, to get them back to Norway on behalf of buyers there. At the time of writing, Ford says they accept the proposal following a plea from the Norwegian transport minister. But the deal is not concluded.

6 Since battery EVs will mostly be charged at night when other energy consumption is low, the peak power requirements on the grid will seldom be a problem. And the energy consumption, even for a large fleet of EVs, is surprisingly low. Assume that all 1.9 million Norwegian personal vehicles were electric. The average distance driven each year by a Norwegian car is 15.000 km. A conservative estimate for energy consumption from the grid per car and km is 0.25 kWh (A two-seater Think consumes 0.19 kWh). The total energy needed for this ultra-large EV fleet is then $1.9 \cdot 10^6 \cdot 15 \cdot 10^3 \cdot 0.25 \cdot 10^3 = 7.13 \cdot 10^{12}$ Wh = 7.13 TWh. This is only 5.9 % of the Norwegian power grid's yearly output of around 120 TWh (which admittedly is higher per capita than in most other countries).

7 One may argue that a vehicle that consumes only 0.45 liters per 10 kilometers like the Prius gives smaller emissions than the contribution of an EV that draws 2+ KWh per 10 kilometer from a grid that in a worst-case scenario is supplied only by coal-fired plants. Such calculations are difficult, depending on the assumed mix of plants and their emissions-cleaning systems. Calculations are further complicated by a possible share of nuclear, hydro- or wind power plants. What remains however, is the fact that in the EV case *all emissions and most of the noise are moved out of the congested urban area* − even if a Prius-like hybrid may be said to be closer to an EV than a mainstream ICEV with respect to emissions.

8 The production of Thinks is currently discontinued. *(Remark October 2006: Production has been resumed, and there are now waiting lists of purchasers for the car.)* The second generation model, designed for the Californian market and shown in the photo earlier, was almost ready for production when the original and strong version of the California clean air act was dropped. Ford decided to shut down the Think plant in Norway, but they had to try to sell the company first to comply with Norwegian laws. They found a buyer, and the new owner has redesigned the vehicle to match their own drive line. The model is however, still not put in production due to limited financial resources. The new Think is equipped with a battery that gives a range of 120 km, but is designed to carry a maximum battery size that allows for a 200 km+ range.

9 One Norwegian crown (NOK) is (October 2004) approximately 0.15 USD or 0.20 AUD.

10 The Green Certificate system is currently in use in another area: to implement renewable power production in several countries (the Netherlands, Sweden, United Kingdom among others). The utilities are obliged to supply a certain percentage of their total energy through renewables. The mandatory percentage of renewable power is increased year by year. Each kWh produced by qualified renewable power installations is getting a green certificate. Such certificates are tradable. Companies may then choose to buy certificates instead of building their own renewable energy plants.

11 About 100 000 new cars are sold in Norway annually. A 2% quota would then imply 2000 EVs sold per year. If we assume that an EV is subsidized with maximum 50% of the price of an ICEV, then the ICEVs would be 1% more expensive due to such a regulation.

[12] A report on experiences with a representative-sized car sharing system with ICEVs may be found here: http://www.scotland.gov.uk/cru/kd01/blue/carclub-08.asp .
The world's largest CSS (Switzerland) is hosted here: http://www.mobility.ch/ .
Car sharing run by locals but in cooperation with a railway company (Deutsche Bundesbahn) is on this website: http://www.dbrent.de/ .

[13] An intermediate solution between individual EV ownership and a car sharing system for EVs, is individual car ownership, but leasing the battery. This, all other things being equal, would reduce the purchasing price of the EV significantly, typically with one third. And the energy costs are so low (corresponding to a consumption of typically 0.2+ kWh/km measured from the grid) that the rental costs of the battery could be considered to be an acceptable component of "fuel costs". Leasing the battery also relieves the EV owner of worries about battery lifetime, which at the current stage is a legitimate concern with most battery types.

[14] If this seems exotic, it could be compared to the concept of robot-assisted surgery through human operator via an Internet connection, which currently is an object for research and has already been tried with success (Marescaux, J. et al, 2001)