Knowledge base for the market in electric vehicles and plug-in hybrids

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Preface

In February 2009 the Energy Agency was commissioned by the Ministry of Enterprise, Energy and Communications with providing an integrated knowledge base for the market in electric vehicles and plug-in hybrids. The work was to be carried out in collaboration with the Energy Market Inspectorate, the Swedish Transport Agency and the National Road Administration, as well as in consultation with representatives of the automotive industry, electricity distributors, electricity producers, consumers, the Swedish Association of Local Authorities and Regions and the relevant authorities. The final report on the commission was to be made on May 29, 2009.

The work has been carried out by an internal reference group at the authority and an external reference group between the authorities. Furthermore a public hearing was held on May 4 with the aim of consulting with the players by means of a report on the enquiry’s preliminary findings. The hearing was held with about 70 participants.

In the internal working party at the authority the following have participated: Anders Lewald, Magnus Henke, Gregor Bunge, Tobias Persson, Mikael Fjällström and Kenneth Asp. In the external reference group from the Energy Market Inspectorate Rebecka Thuresson and Johan Carlsson participated, from the Swedish Transport Agency Per Öhlund and from the National Road Administration Olle Hådell and Håkan Johansson.

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1 Summary

The Swedish Energy Authority was commissioned by the Swedish government on February 12, 2009 with producing an integrated knowledge base for the market in electric vehicles and plug-in hybrids. The work was to be undertaken in collaboration with the Energy Market Inspectorate, the Swedish Transport Agency and the National Road Administration and a report was to be made on May 29, 2009. The commission was to be carried out in consultation with representatives of the automotive industry, electricity distributors, electricity producers, consumers, the Swedish Association of Local Authorities and Regions and the relevant authorities.

With the short time allowed the commission has primarily been carried out on the basis of existing material or material that was under development. The collaboration with the authorities has been carried out by means of a reference group which met on three occasions. Collaboration with the players has been carried out primarily through an open hearing on May 4, but also through direct contacts.

Electric vehicles and plug-in hybrids have in recent years received increasing attention in the press. A number of car manufacturers have published plans to produce and sell electric vehicles or plug-in hybrids. A number of new players have also received attention for their plans to become electric car manufacturers or to rebuild cars as electric vehicles. The Swedish car industry is today developing both the technology for electric vehicles and plug-in hybrids, but has not released any production plans.

The heavy vehicle industry is working on the development of hybrid vehicles, vehicles which also contain batteries. Today there are no electric cars or plug-in hybrids for sale through the usual sales channels in Sweden, but the players have taken the initiative in importing a number of vehicles directly.

Of the established car manufacturers, some intend to begin small-scale production of electric cars and plug-in hybrids as early as this year. In future years most manufacturers report plans for the production of both kinds of vehicle. For this reason factories are now also being built to supply batteries for these vehicles.

On what scale electric vehicles and plug-in hybrids will actually be manufactured is difficult to assess, but presumably it will take many years before the market is large in relation to ordinary cars. The Energy Agency states in its latest long-term forecast that the number of electric cars and plug-in hybrids in Sweden with current control measures is assumed to be 85,000 by the year 2020.

The Energy Agency makes the further assessment that the cost of batteries, and in this way the cost of vehicles for electric cars and plug-in hybrids, today comprises the most important obstacle to the introduction of these types of vehicle.

The charging infrastructure for electric cars and plug-in hybrids is even today considered by the Agency to be sufficient for the introduction of both types of vehicle. How much the market for these vehicles can grow through the expansion of the charging infrastructure is not possible to assess precisely in the current situation. Trials of such an expansion are already ongoing in Sweden, but there are not as yet so many vehicles to charge either in the existing or the expanded infrastructure.

Trials are also ongoing with various types of more rapid charging in Sweden, but primarily internationally. Trials are also being conducted into battery exchanges. Common to all charging is that there are as yet no standards, but proposals exist. Evaluations and trials of efficient charging platforms are planned in many places. For Swedish conditions, against the background of the development of the electrical system but also through our cold climate, it is important to take part in international development of charging systems. The Swedish electrical power system is assessed as being capable of managing the introduction of electric cars and plug-in hybrids without any problems.

Locally the electricity system may need to be supplemented using simple measures such as earth fault breakers and stronger fuses. In the trials of electric cars in the 1990s existing power outlets were primarily used for charging. Electricity use was very seldom metered separately and electricity use therefore appeared as a cost to the individual who was a subscriber of the power point. Debiting electricity usage requires some form of metering. Electricity use is relatively modest for electric cars and plug-in hybrids.

When there are few vehicles and the cost of metering and debiting therefore may be expensive, then maybe one needs to evaluate how charging systems and payment solutions can be introduced in a cost-effective way. The electricity industry can boost incentives in order to participate in this development.

Based on metering in the 1990s of electricity use per kilometre driven, and on the basis of data provided for new cars, the Energy Agency assesses that both electric cars and plug-in hybrids will be very energy-efficient. In the long-term forecast the Agency expects an electricity use of 0.24 kWh/km including losses.

Electricity use per kilometre will presumably be even lower than this. The Agency shares the electricity industry’s assessment that, if the majority of passenger transport movements today were made by electricity, then the electricity used would be in the order of 10-15 TWh. The 85,000 vehicles in the Agency’s long-term forecast for the year 2020 are then expected to use 0.17 TWh. The electricity industry and the Royal Swedish Academy of Sciences (IVA) have formulated an ambitious vision of 600,000 electric vehicles by the year 2020, which if it is realised is assessed as using approximately 1.5 TWh, or approximately 1% of Sweden’s current electricity use.

The current regulations for network concessions, metering and readings are assessed by the Energy Market Inspectorate as not providing any obstacle to the introduction of electric cars and plug-in hybrids.

Society’s support for electric cars and plug-in hybrids is carried out primarily by the opportunity, through the green car definition, of help in buying a car and later in a reduction in vehicle excise duty or through a reduction in the value of fringe benefits tax assessment. The total support to ethanol and biogas cars through the green car definition or the fringe benefit tax assessment and tax reduction on fuel is today higher than it is to electric vehicles and plug-in hybrids. With the performance of electric cars and plug-in hybrids it is reasonable to increase the support for electric cars and plug-in hybrids. Support is presumably best provided in connection with the purchase of the car. The extra costs of an electric car or a plug-in hybrid is assessed at between SEK 50,000 and 150,000.

The Agency’s assessment is that the additional cost in a few years time will fall. In cars under development, those that may result from Swedish technological development, the additional cost will be considerably greater than that. The same applies to heavy vehicles. The type of infrastructure development which provides the best possible situation for a market launch of electric cars and plug-in hybrids cannot today be assessed. It is therefore difficult to propose a general control measure for the development of infrastructure.

The Energy Agency, against the background of the above, is proposing the establishment of a national trial for electric cars and plug-in hybrids and the development of a charging infrastructure. Furthermore, that the support to electric cars and plug-in hybrids is reviewed and increased in relation to other so-called green vehicles. It is also proposed that a trial is used as a form of support, because the extra cost of electric cars and plug-in hybrids in the immediate future will be considerable, but in its scope uncertain, that cost reductions may be anticipated, that the development of the charging infrastructure is the subject of strong development and standardisation, and that the Swedish vehicle industry is provided with the opportunity of taking part in the development of important components such as, for example, battery technology.

The trial is described in greater detail in the report, but is proposed to be a four-year project with state contribution of at least SEK 500 million.

Overview of the general support to electric vehicles and the support through a trial comprises an integrated strategy to overcome the initially very high extra cost of these vehicles.

2 Description of the commission

2.1 Background

In its commission the government states that both traditional manufacturers and recently established companies have announced their intention of introducing plug-in hybrids or electric cars in the next few years. Improved battery technology makes these solutions interesting. In order better to understand this development, a special stimulus is required and in that case an integrated knowledge base for electric cars and plug-in hybrids.

2.2 Aim

The government further states that energy efficiency in the transport system must improve in order for Sweden to be able to meet the number of national and international commitments in the climate field. The government has identified an opportunity for Swedish industry to become world leaders in the field through the transition to greater electrification in the field. Sweden has as its target a fossil fuel-independent vehicle fleet by the year 2030.

2.3 Delimitations

The report is limited by the commission the Energy Agency received on February16, 2009 from the Ministry of Enterprise, Energy and Communications. This commission primarily refers to an analysis of the current technological situation and an analysis of possible market development on two different preconditions, whereof the first applies to an infrastructure of current size and the second an expanded infrastructure.

The commission also contains an analysis of regulations and laws surrounding the development of infrastructure, the introduction of vehicles and the state of play as regards standardisation, control measures and the need for further research and development.

By its nature the commission has been under time pressure, and there has therefore not been an opportunity to carry out investigations on its own initiative but it has instead collated the existing knowledge base in a condensed form.

Within the research and development section and to a certain extent in control measures there has been for some time a large amount of accumulated knowledge within the Agency, which is why this section has to a lesser extent had to be dependent on external reports and investigations.

3 Present situation

Today a development is taking place in which a number of manufacturers are seriously aiming to produce electric cars to be able to fill niches in the market for e.g. commuting and small distribution vehicles, but also more luxurious vehicles, where the environmental values with which this type of vehicle is associated are greatly appreciated. This last is a major shift in attitude to the category compared with earlier attempts made to introduce these vehicles.

What is new at the present time is also the category of vehicle called plug-in electric hybrids which may come to form a link with and transitional solution to an increasingly electrified vehicle park which, with a developed battery technology, may in time become a reality.

A hybrid car is a car with both an internal combustion engine and an electric motor providing the propulsion for the car. The hybrid car contains either a battery or other energy storage system to take advantage of, e.g. braking energy. The plug-in hybrid is a hybrid car in which the battery can be charged from the electricity supply.

The development of more energy-efficient vehicles and vehicles that are possible to run on renewable power sources is today, on the grounds of climate and of securing the energy supply, of very high priority both for the automotive industry, its customers and policymakers.

Despite the economic recession the entire automotive industry, irrespective of its geographical location, and all manufacturers, are faced with major changes. One of the areas that has been identified as most important for being able to meet the challenges of the future is the transition to completely or partly electrical power trains combined with making conventional vehicle solutions more efficient.

New strategic alliances are being formed at a rapid pace in order to ensure supplies of knowledge, raw materials and logistics chains.

At the same time as this is occurring there is a greater demand for transport, primarily in the populous countries of Asia. A number of new and existing manufacturers in these countries are meeting this need with plans to build electric vehicles on a vast scale, primarily in China and India. In China there is already a major industry constructing two-wheel electric vehicles.

The recession has also given rise to a large number of measures on the part of individual states to ensure employment within their own state. These often take the form of measures aimed at their own vehicle production in, for example the form of support programs, innovation support, control measures influencing the consumer etc. Even in this context attention has been given to electric vehicles and plug-in hybrids.

4 The state of the technology

4.1 Vehicles

Electric vehicles and vehicles propelled by internal combustion engines have now existed side-by-side for approximately a century, and have developed considerably over this period. The internal combustion engine has been allocated most resources, in that the cheap energy resource of oil was discovered in large quantities at the beginning of the twentieth century. Electric vehicles are not being allocated nearly as many resources, but have nevertheless found a niche where they have been able to survive as a competitive technology.

The development of electric vehicles which occurred during the 1990s with a large number of manufacturers involved stalled at the beginning of the 2000s, but without ceasing completely. A number of manufacturers and interested parties maintained both knowledge and a certain basic structure in being. The interest then grew gradually over the intervening years. This was thanks to the interest in energy-efficient solutions.

In recent years new opportunities have appeared for combining two propulsion systems to increase system efficiency, at the same time as flexibility and opportunities for long runs have been maintained. Developments in controlling powerful electrical currents through electronics and computer support have in many ways assisted in this process. In the immediate future we will in all probability see a powerful development in precisely the control aspects of combinations of internal combustion engines and electric motors.

Electric vehicles which previously were intended for applications in very small vehicles such as golf caddies and the like may grow into vehicles which are more like normal passenger cars.

Plug-in hybrids which need the extra cost of double technologies will presumably, among the European, Japanese and American manufacturers, make their appearance in the more exclusive segments of the market, where owners will not lower their demands on performance, but where demands for efficient vehicles nevertheless provide an advantage from an image viewpoint.

A number of established manufacturers as well as completely new, primarily Asian, manufacturers today have programmes that are already well advanced for the production of electric cars and plug-in hybrids. In Europe Renault/Nissan are collaborating and will within a year be marketing electric vehicles to selected customers and hope also to be able to establish systems for battery exchange technology at a number of places within and outside the EU.

BMW, through its electric elMini has plans for trials which will also work together with charging systems trials. Of the Asian manufacturers Toyota, with its earlier trials of hybrid drives now in their third generation, is a very strong player who, within a year or so, will be demonstrating the first plug-in hybrid models which may presumably reach large volumes in Europe.

The interaction of the vehicles with the power transmission network will also, with the introduction of plug-in hybrids and electric cars, be the subject of a major development as regards communications between vehicles and the network. Where rapid charging is the aim, it will be necessary to make preparations to be able to introduce efficient payment routines for public charging points and trials may play an important role here in producing working and in the best case uniform models for this.

4.2 Battery technology

The development of the electric car and plug-in hybrid is closely linked to developments in the battery field. The main challenges in this field lie in capacity, cost and safety.

Even if possible alternatives to energy storage do exist, such as fuels cells and supercapacitors, the discussion will focus on the development in the battery field. This is because batteries are the centre of attention in the electrification of vehicle power trains both in the USA, Europe and Asia.

4.2.1 Demands on batteries for EV and PHEV applications

The different applications in electric cars and plug-in hybrids respectively require a different optimisation of battery technology. Electric cars (EV) primarily need access to an amount of energy to manage the task as an electric vehicle for the entire intended run. This means a very large battery which is not supplemented by an internal combustion engine.

The hybrid electric vehicles (HEV) which exist today primarily use batteries for a very short distance on electricity, and instead use battery capacity for increasing range and for fuel saving. This means that a relatively small battery capacity has to be optimised towards being able to provide high power for a short period of time and without the battery’s charge level dropping too much.

The demands on batteries for plug-in hybrid electric vehicles (PHEV) ends up somewhere between these two in the table of categories below, depending on the configuration chosen.

Table 1 The table shows the desired properties of batteries as a function of the vehicle category (according to a report from BERR1[1])

	Max weight (kg)	Max power (kW)	Field intensistyt (W/kg)	Starting capacity (kWh)	Energy density (Wh/kg)	Cost ($/kWh)
HEV	50	40-60	800-1200	1,5-3,0	30-60	
PHEV	120	65	500	10	60	300
EV	250	75	300	30	130	150

The description in the table coincides with those targets identified by United States Advanced Battery Consortium for vehicle batteries (USABC) according to the BERR report. US ABC was established during the 1990s to develop vehicle batteries in cooperation with the automotive industry and the state in the USA.

4.2.2 Available battery technologies

A large number of battery technologies/chemistries are possible for the application in electric vehicles, but none of these is without disadvantages in one or other way. Optimisation from the point of view of performance, cost, access to the basic component elements etc is a challenge in each individual operating case and customer segment.

Below is a list of possible candidate technologies which does not claim to be exhaustive, but nevertheless hopefully illustrates something of the demands and limitations that need to be met in order for the vehicle categories of electric cars and plug-in hybrids to be able to replace the current fossil fuel-based technology. By way of comparison data for a so-called supercapacitor has also been included.

Table 2 Performance for different battery technologies, BERR[1]

	Li Jon	Li-M-Polymer	Ni-MH	$Na\text{-}NiCl_2$	Lead-Acid	SC (supercap)
Energy denisty (Wh/kg)	75-120	100-120	50-70	100-120	20-30	3-4
Field intensity (W/kg)	1000-3000	200-250	1000-1500	180	200-500	1000-3000
Life (cycles, 100% DoD)	1000-3000	?	2000	1000	300-800	500k-1M
Cost ($/kWh)	300-2000	?	1000	600	100-200	15000
Question marks	Safety, cost	Not commercial	Temp. limitations	Only one supplier	Weight	Life cycle issues

[1] BEER – Department of Business Enterprise and Regulation Reform, ”Investigation into the scope for the Transport Sector to Exchange to Electric Vehicles and Plug-in hybrid Vehicles”

Prioritisation will differ depending on the application considered, electric or plug-in hybrid, when ranking the different technologies. Electric cars have a greater focus on energy density in order to travel a long way, whilst plug-in hybrids focus somewhat more on field density. It is also possible to combine different types of energy storage in one vehicle in order to achieve the best total efficiency and cost.

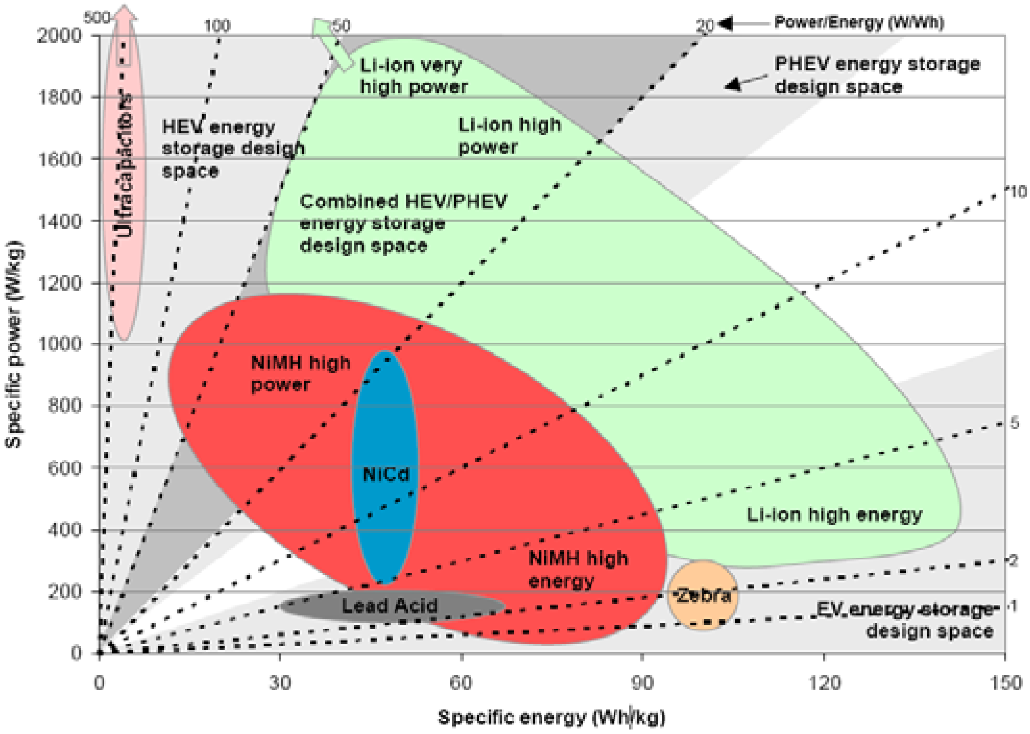

Figure 1 – Battery preferences for different vehicles, Ricardo.

Today nickel-metal-hydride batteries (Ni-MH) are used predominantly for vehicle applications, with the Toyota Prius as the absolutely largest category by volume. The next model of the Toyota Prius will also in the main use this technology.

Within future applications and to a lesser degree already today lithium-ion batteries have begun to make inroads in this segment. In the field of portable computers this type has also made a breakthrough and is now the major variant. The advantages of the lithium-ion battery are its weight and its ability quickly to produce large amounts of power and to absorb these.

In the even longer term, one may possibly imagine vehicle types in which the internal combustion engine has been replaced by fuel-cell technology in order to maintain battery capacity over longer distances. Combinations of these two technologies may possibly in the situation of that kind eliminate the need for the internal combustion engine and will have become a new kind of hybrid.

Lithium –ion betteries

This variety of battery has been identified by many automotive and battery manufacturers as most interesting for future vehicle application. The technology already exists in several applications where the requirements are not as strict as, for example, in hand drills and similar equipment. For vehicle applications however, completely different concentrations of cells are needed, resulting in high voltage levels and a great deal of stored energy. Something that makes great demands on handling, sealing, systems for battery regulation, etc. The fire risk is, what is more, something that has to be dealt with in this type of battery.

Lithium is to be found at the extreme left of the periodic table and, what is more, near the top (which means that it is a light element), and this makes it attractive as a cathode material in batteries as a result of its high electropositivity.

The world's supply of lithium is often adduced as a limiting factor on the manufacture of efficient batteries for electric vehicles and plug-in hybrids.

Studies of this made by Björn Sanden at Chalmers University of Technology[2] show that, admittedly there is a need for development as regards extraction and refinement technology of lithium, but that the supply, even in the longer term perspective is scarcely a limiting factor. What is more, the lithium-ion battery is not the only battery chemistry, which may be possible for energy storage in electric vehicles.

4.2.3 Cost of batteries

The cost of batteries is currently the greatest barrier to a rapid introduction of electric cars and plug-in hybrids. And this is at a time when these vehicles within the immediate future will reach such a capacity that they will be usable by a large number of those people who currently use vehicles based on fossil fuel combustion technology.

Estimates made by both the automotive and electricity industries show that the additional costs relative to a corresponding medium-sized passenger car is between SEK 50,000 and 150,000 depending on the technology chosen (EV or PHEV).

Those price ranges which are given today for different types of batteries and those forecasts regarding price developments at present have a much greater range both as regards levels and time perspectives. What they have in common is that in principle the price is expected to drop despite the very rapidly increasing demand, and that this to a great extent is linked to hopes of a radically more efficient manufacturing technology. There are at various places worldwide major plans to develop this type of manufacture, and one can expect results from these investments within 2 to 4 years.

The technology required for manufacturing the type of battery needed for electric vehicles is different compared with the technology required for manufacturing, for example, batteries for computer applications as the requirement specifications differ. A computer needs continuous low power over a prolonged period, whilst

[2] Verbal communication with Björn Sanden, Environmental Systems Analysis – Chalmers University of Technology

the vehicle application on its part needs very high power for a relatively short interval.

The requirement of being able to recharge the battery with high amperage for a short interval is something that characterises electric vehicle application.

In the same way as happened in the computer world it will be necessary to learn this new application and which type(s) of battery design and combinations with other technology which are advantageous and work best.With the size of batteries required for electric vehicles and plug-in hybrid applications a comprehensive automatic control and monitoring technology is also required.

Lithium batteries are often classed as dangerous goods for transport purposes, which means that local manufacturers of batteries in a number of markets may be needed. This would possibly open up certain opportunities for establishing strategic cooperation at a regional level dependent on how the pricing structure for the shipping of dangerous goods such as batteries develops. The Swedish automotive industry has, starting with the need for heavy industry of batteries in hybrid vehicles such as buses and trucks, therefore been able to create the basis for the establishment of a battery industry in this country.

Despite the fact that the lithium-ion battery is being discussed most in the press and scientific articles, one should not forget other battery chemistry/technology, for example the technology involving lead-acid which has been successfully used for more than 100 years, which is being constantly refined and has a very attractive price/performance relationship for many applications. The most favoured technology today, nickel-metal-hydride (NiMH), which has been found in hybrid cars and a number of other applications for a good 10 years, is still being developed as regards both price and performance.

4.2.4 Safety

The safety of batteries and power systems and safety in connection with charging are three special aspects to be taken into account in electric cars and plug-in hybrids.

Safety aspects have not been mentioned explicitly and are therefore touched on here only in a general way.

Safety risks in the form of fire risk exist for certain types of lithium-ion batteries, and these aspects have presumably delayed introduction of these batteries for vehicles somewhat. In order to reduce the safety risks a monitoring system is required in the batteries, something that increases the cost. Both battery developers and the automotive industry are working on these issues.

Vehicles with high voltages are another safety issue which may become relevant in accidents and also in servicing vehicles. It may be necessary to invest in training here.

Safety at the charging point is another important issue.

The Swedish Energy Agency considers that all these aspects of safety are a suitable area for evaluation and elucidation in a trial in order to find solutions to the problems that are as cost-efficient as possible.

4.3 Infrastructure

4.3.1 General

Sweden has good preconditions for becoming a successful country as regards the introduction of electric vehicles. Sweden's electrical system is strong and can cope with a greater use of electricity and vehicles or can be adapted in time. There is also good access to power outlets at car parks. What is more, Swedish consumers and companies are accustomed to using electricity for vehicles in the form of engine heaters. Swedish electricity is produced to very high degree without adding carbon dioxide to the atmosphere.

4.3.2 Previous experiences

Those trials made of electric cars in Sweden during the 1990s showed that the predominant form of charging was a normal 230 V power outlet at parking bays in garages or in other car parks. Trials were also conducted with more rapid charging and with battery exchangeing. The trials are described in detail in the report "Clean vehicles with electric power, the Swedish Transport and Communications Research Board's final report on electric vehicles and hybrids" (Rena fordon med eldrift, KFBs slutrapport om elfordon och hybrider).

4.3.3 Charging at car parks

Charging at home, at work and in certain car parks is a system which will indubitably for a long period ahead from the introduction of electric vehicles be the commonest method of charging. Both national and international experience and the vast majority of new trials planned involve this form of charging.

In Sweden there are 230 V systems with both 10 or 16 A fuses available to a great extent for the potential charging of electric vehicles, even seen from an international perspective. The possibilities of charging exists in many cases everywhere from private houses to public car parks and housing co-operatives and the like as well as the opportunities of charging on business premises where vehicles may be expected to spend long periods.

Altogether this is a question of several million power outlets which directly or with small adjustments can be used to charge electric vehicles. In addition to this there are approximately 600,000 engine heater power outlets in Sweden which can also, with minor adjustments, be used to charge electric vehicles.

4.3.4 Public charging points

For applications where electric vehicles need access to charging in the urban environment there is a certain need for public charging facilities.

Even this is primarily in connection with housing and often in this case where apartment buildings or housing cooperatives do not have access to their own parking facilities.

Apart from this, to further develop the use of electric vehicles there will presumably be a need for public charging points which are not associated with housing. This is, however, an issue that needs to be analysed further, as it is a question of identifying in what situations it is motivated for an electric car driver to use charging facilities. This premise implies that charging occurs so slowly that it will presumably not be motivated to recharge unless the parking period is rather long, at a rough estimate more than an hour.

As we in Sweden often have access to 400 V three-phase current with a relatively high fuse protection, one can imagine situations where charging with this type of connection may be attractive in public contexts. In order for this type of high-voltage to be usable in the public contexts the standard would, however, presumably need to be upgraded considerably in terms of physical protection and training measures.

4.3.5 Rapid charging

Several concepts for rapid charging that are relatively far advanced have already been presented today but harmonisation worldwide has as yet not caught up. On the European stage there has, since the end of April 2009, been an agreement about a rapid charging standard of 400 V and a maximum of 63 A.

Rapid charging systems have their specific problems, in that each type of battery has its own individual characteristics as regards the opportunities of rapidly receiving large amounts of energy. Communication between vehicle and charger may prove necessary, or one might imagine a system in which the vehicle owner indicates the battery type involved in the same way as they today choose the octane rating when filling up with fuel.

Rapid charging of batteries has further problems in the form of fire risk and the like in choosing the “wrong” type of battery. A clear need for standardisation exists therefore. Standardisation is dealt with in more detail in Chapter 9.

For charging heavy vehicles, given the amperage, the concept of rapid charging is the only solution at hand. It is not possible to transfer those amounts of energy required to charge a battery on a heavy vehicle with a normal single-phase cable. For these amounts of energy it is also probable that an upgrading of the local network will be needed to be able to charge safely.

Even in cases of rapid charging initiatives in the form of information and a high level of safety awareness are necessary so that unnecessary accidents do not occur.

4.3.6 Battery exchange systems

Battery exchange systems are an attractive concept as they provide the opportunities for an energy replenishment speed which can compete with that achieved in filling up with fossil fuels. Unfortunately the system is also associated with a number of question marks involving obstacles to the introduction of this technology.

One of these is that installations of this kind are expensive and require a large amount of monitoring and maintenance as well as initial training of those people who are to use them (a battery pack would weigh around 300 kg for a normal car). This fact makes it rather less attractive to use the systems even in a trial, as the capital investment to acquire the necessary frequency of charging points is very high.

A relatively large area would also be needed for the trial, as one of the advantages of a system of this type is that the mobility of electric vehicles would increase markedly, if it were possible to charge the energy storage system at regular intervals in a simple way, for example at precise intervals along motorways, in approximately the same way as the location of current petrol stations.

A further obstacle which might possibly in time be overcome with a high degree of standardisation and cooperation between automotive manufacturers, battery manufacturers and power distributors is the necessarily uniform design of the battery pack. This is because it is not realistic to believe that each manufacturer would be prepared to install special charging points for their specific battery pack.

Despite these obstacles there are today initiatives aimed at precisely this type of solution. In Israel there is a large-scale project being planned with support from the vehicle manufacturers Nissan/Renault. They hope presumably (and according to verbal information) to set a de facto standard which will be difficult for other players to deviate from on the same market once it is established.

4.3.7 Payment systems

Both public charging points and in particular rapid charging points and battery exchange systems will need a payment systems for debiting the cost of electrical energy or a battery exchange. Payment systems are dealt with in greater detail in Chapter 8. Certain public charging points will however offer free charging in connection, for example, with purchases; see Chapter 5.3

4.3.8 Effects on the power network

The Swedish power network is very well equipped for an introduction of electric vehicles and can accommodate large numbers of electric vehicles without the effects of this normally becoming noticeable from the viewpoint of stability.

The vision of 600,000 vehicles presented by the electricity industry and the Academy of Engineering Sciences will not generate the need for more than approximately 1.5 TWh out of today's total production of approximately 150 TWh.

If the power generation capacity does not prove to be sufficient under certain circumstances when demand reaches a peak, greater differentiation within the tariff system with tougher incentives for using electricity during “cheap” times of day may to a certain extent even out demand without capacity needing to be expanded.

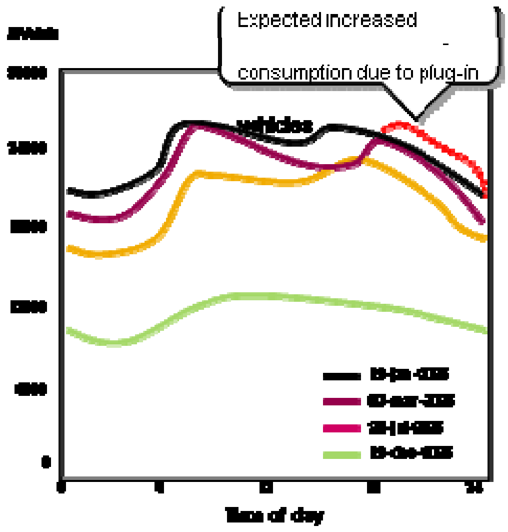

Figure 2 Increased need for electricity as a result of charging electric vehiclas (Source: Fortum)

Introduction of renewable sources of power, such as for example wind and solar energy may mean that a greater proportion of the power has to be allocated to control power. A possibility in the future which is being discussed is also the use of electric vehicles as charge equalizers through the storage capacity to be found in the battery.

4.4 Performance figures for electric vehicles and plug-in hybrids

When electric cars are discussed today one often sees performance figures in terms of range given without these being moderated by information about what preconditions are involved. In the same way as fuel consumption figures for petrol and diesel vehicles the published ranges are produced under the most favourable conditions. Uniform test methods for presenting range are still not available.

Factors which either raise the performance the electric motor has to produce for the vehicle to achieve the desired result, or factors which reduce the performance of the battery or tasks that are added to the battery which were not included in calculations at time of testing are such as, with the already short range of the electric car, may result in a considerably shorter range than the figures for range state.

Sweden has a fairly unfavourable climate in the context of electric vehicles, which produces roads with very high rolling friction for a large part of the year. Slush and sub-zero temperatures produce all the factors mentioned here. Slush in itself multiplies the rolling friction, which with the same factor produces a reduction in the range at a constant speed. Weather conditions with low temperatures produce a need for heating the passenger compartment, which may require a number of kilowatts just for this. In really hot conditions the reverse applies, when drivers and passengers are used to the opportunity of using air conditioning in the car. Most cars today are, for example, equipped with stereo. Lights are a requirement in Sweden. The above are examples of factors which are not obviously included in the figures for range.

5 The market

5.1 General on the introduction of new technology

When new technology is introduced into a market, there is what is often called an S bend. This bend can in its turn be divided into a number of phases, of which there are 5 main phases. It is possible that the introduction of electric vehicles on the Swedish market will also follow this type of development. The phases are as follows:

The preparation phase

The Energy Agency assesses that the market is already in this phase of development as regards the introduction of electric vehicles into Sweden. It is characterised by the market players gathering together to form groups and interested parties who together initiate trials and build up knowledge of the market and technology. There are as yet no vehicles on general sale on the market. A few test fleets are used for this and no large volumes are being produced.

Introduction

This phase is also to a large extent about development and preparation before market growth. Individual vehicles are available for sale and not all of the technical problems have been solved. The cost per vehicle is still high and there is no standardisation on the market. There are also often obstacles to growth.

Growth

The technical performance of the new technology is approaching that of the old technology, and the major obstacles have been eliminated. Rules and regulations are beginning to be harmonised so as not to prevent an obstacle to a broad introduction of the new technology. An increasing number of suppliers of the new technology are selling their products on the market. The cost of new technology is still higher.

Breakthrough

Strongly positive sales figures appear and many varieties of the new technology as well as a good understanding generally of the new market.

Commercialisation

This phase is only reached when the market for the new technology is independent of external support in the form of control measures, and can continue on its own merits.

5.2 Potential strategy for initiating the development of at charging infrastructure

The City of Stockholm's Environmental Department has in a report to the Environmental and Public Health Committee[3] put into words ideas on how the introduction of electric vehicles might be achieved and has also considered the effects this might have on the rate of introduction. Initially only limited intervention may be needed in the form of investments in charging infrastructure, but those measures that are carried out should be such that they achieve the maximum possible effect from the point of view information and advertising. They also feel that there is a need to identify places and situations where primarily owners of electric vehicles can obtain real benefits from the possibility of charging, i.e. in those situations where they are planning to stop for any longer period at the same place before a return or onward journey. A quotation from the official statement is given below.

"DEVELOPMENT OF THE INFRASTRUCTURE

There is much talk today about establishing an infrastructure of charging electric cars, and this is an important precondition for a successful market launch. The reasoning must however be taken a stage further in order really to identify how extensive this infrastructure has to be, and in what situations it is suitable to establish charging points.

Previous experience shows that users preferred to charge their cars in their own garage or at visitor parking spaces where they are staying for longer periods.

Public charging points were used rather little during the trials in the 1990s. One reason for this may be the users' need for security in their travel arrangements. They want to know they will be certain to arrive at their destination, and electric cars cannot be equipped with a "spare tank" when the battery has discharged. The result is that drivers plan their journeys such that they know with certainty that the battery is fully charged when they set off, and the journey they are making is short and predictable. In order to be able to trust the battery charge, the charging process has to be quick, taking not much longer than filling up with petrol, and the network of charging points has to be fully developed. Rapid charging is complicated and requires different charging cycles for different vehicles/battery types. This will be an extensive and costly investment, which presumably lies many years in the future.

But there is also a considerable uncertainty here, as an intensive technological development is ongoing with, for example, induction charging and other rapid charging technologies at the same time as trials are ongoing with exchanging the entire battery package, where the discharged batteries are exchanged for a fully charged battery special exchange stations. Today's users of conventional cars fill

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[3] Official statement by Eva Sunnerstedt and Björn Hugosson, The City of Stockholm's Environmental Department, Reg no.: 2009-004321-211 26

up their cars at a normal filling station, and it seems natural to imagine that chargeable cars might be used in the same way.

But, considering that rapid charging points are more expensive than points for slow charging, it is reasonable to believe that chargeable cars will primarily be charged up slowly where they are stationary over long periods, i.e. at home and in visitor parking spaces in town and at companies.

Rapid charging points can become profitable only in the long term when the market is large. For plug-in hybrids the situation is a little different, as they do not necessarily require charging in order to work. The charging will instead be a way of reducing the environmental impact and costs. Together with the experiences outlined above this leads to the conclusion that an extensive public charging infrastructure is not needed at all in order to get plug-in hybrids to work. One can get a long way by those people buying plug-in hybrids also installing charging points in their own garage or their own outdoor parking space. Then electrical power is used for all short journeys, whilst the longer journeys are undertaken with the usual propellant, and this may be enough.

A certain development of public points is necessary, on the one hand to create publicity and on the other to make it possible to drive battery cars in a more flexible way.

The need arises primarily at visitor car parks where the users are stationary for a long period, for example that at company car parks with company visits, in public multi-storey car parks and in shopping centres. The development of charging points should begin where there is a clear need, where it is simple and inexpensive and without the necessity of altering laws and regulations.

An initial list of possible developments is given below:

1 A limited number of public bays in multi-storey car parks and ground level parking in order to attract attention and make it easy for existing electric vehicles and the first new users. Primarily this is a question of central locations and to a certain extent inner suburbs and park-and-ride facilities. For the city this means a commitment on the part of Stockholm Parkering. This first phase has already begun in that Stockholm Parkering in collaboration with Fortum is planning 100 charging points in Stockholm during 2009.

2 Company car parks where the company or organisation has bought in its own charging cars. The cheapest bays are those in multi-storey car parks, as ground-level parking often needs excavation and the running of cables.

3 Private parking bays for benefit car drivers with houses. The city has no financial role here, and there are already to a great extent engine heater power outlet that can be used.

4 Company-owned visitor parking where the customers use charging cars, e.g. large service companies, restaurants and shopping centres. Here the city has no financial role.

5 More public bays in multi-storey car parks and ground level car parks in the inner-city to facilitate the purchase of charging cars by inner-city residents and overnight charging. This applies to private parking bay owners and housing cooperatives, but also to a greater involvement on the part of Stockholm Parkering.

6 Street parking in the inner city if it proves possible and necessary to make parking easier for residents and visitors. It seems clear that the diagonal parking bays along quieter residential streets in the inner city may be the most suitable.

7 Rapid charging at petrol stations along motorways."

The Energy Agency in general terms shares the views held by the Environmental Administration in Stockholm about the introduction of a charging infrastructure. To achieve the greatest possible benefit from the infrastructure it is, however, necessary to come up with standardised solutions. These do not exist today but are under development – see Chapter 9.

In order to find good standard solutions it is, however, important to gain experience of those solutions presented by different players before a standard is proposed. It is, therefore, important to conduct trials with different forms of development.

5.3 Market development

Global markets are more than ever linked together, and this applies naturally to electric vehicles to at least as great an extent as other vehicles. In order for manufacturers to have any chance of reaching the volumes at which vehicles become profitable to develop, a global market is required.

In the same way as the work on standardisation of fuels used to be important to be able to rationalise production and optimise engines, this time standardisation of electrical units for charging and physical connection equipment are very important for development.

We see a new strategy for automotive manufacturers where that part of the development which previously comprised preparatory trials in secrecy is now being transformed into part of a global positioning strategy. In order not to lose contact with possible customers most manufacturers have, with some exceptions, a number of years to go before they reach the stage when they can expect a major launch of an electric vehicle. They then choose to carry out their final development openly, in collaboration with, for example, power companies.

The gain in the form of goodwill and the opportunities of showing that one is a player to be taken into account outweighs the advantages of secrecy.

The market for any product to be introduced is strongly linked to the demands that might be expected and the control measures which can facilitate its introduction if, initially, it is an expensive technology but one which has desirable properties for society. This may apply to everything from subsidies to laws about recycling levels or vehicle excise duty rates. In the case of new vehicle technology there are examples in the form of the tax imposed on fringe benefits which helped the ethanol car market to open up in Sweden. At the same time one should be clear that it was not just this factor which caused the technology to reach a broad commercialisation stage.

The British BERR report from October 2005[4] (before any insight into the seriousness and scope of the financial crises, author's note) has analysed a number of different possible development scenarios, where it is stated clearly that state control measures have a very strong influence on development. Four cases have been described which envisage the future as far ahead as 2030. These have been adapted to Swedish circumstances by Elforsk in a rough estimate, as circumstances in countries are not directly translatable.

Table 3 Market development in relation to time and control measures

Number of electric vehicles (EV and PHEV) in the Swedish passenger car fleet			
Scenario	**2010**	**2020**	**2030**
Current control measures Current incentives remain but no further measures are taken	600	42 000	480 000
Mid-Range Incentives continue to develop at the same rate as today The life cycle cost of electric vehicles is at parity with conventional vehicles in 2015 .	800	125 000	650 000
High-Range The charging infrastructure is broadly accessible in cities, suburbs and some smaller towns. The life cycle cost of an electric vehicle is at parity with a conventional vehicle in 2015 and battery leasing is a realistic alternative.	800	240 000	1 780 000
Extreme Range The demand for electric vehicles becomes extremely high and is limited in the short term only by the availability of vehicles.	800	480 000	3 270 000

Current control measures

Also assumes that the battery cost does not fall more rapidly and that the entire life-cycle cost is comparable with conventional vehicles earlier than around 2020.

Mid range

Environmental incentives continue to increase at the current rate which means that electric vehicles become competitive from a price viewpoint around 2050. Electric vehicles are sold mostly around large cities because of their limited

[4] *Department for Business Enterprise and Regulation Reform* 29

capacity, and plug-in hybrids continue to be disadvantageous because of the double technology design.

High range

Strong control measures to encourage the sale of electric vehicles. The charging infrastructure is accessible in towns and suburbs and at certain selected places in the countryside. The life cycle cost of electric vehicles is comparable with vehicles using fossil fuels by 2050. Battery leasing is a viable financial model.

Extreme range

Presupposes a great demand for battery vehicles and sales limited only by the availability of vehicles. Towards the end of the period almost all the vehicles sold are electrically driven.

When these scenarios are outlined it is important to bear in mind that today we see no range of electric vehicles, with the exception of hybrids, in greater volumes at all in Sweden. Chinese manufacturers have begun the launch of their vehicles, but we will presumably have to wait some time before they are available on the European or American markets. Considering that the average life of vehicle in Sweden is something around 15 to 20 years, it is not difficult to realise that it will take a very long time to replace this fleet. Nor is it socio-economically efficient to change one's car too soon on the current basis of calculation, but if an environmental economic calculation is included in the reasoning then, of course, the life span is shortened.

The analysis of the scenarios above is based on the establishment of the electric vehicle in the inner-city areas in the metropolis. This is a reasoning which has traditional support in the idea that it was the environmental targets in the form of a pollution which comprised the threat which had to be removed. This has in part been changed with the shift in focus towards climate and the CO2 problem which has occurred since then.

If local environmental problems in inner-city areas no longer comprise such a great problem, then the major potential is possibly to be found among the large majority of commuters who travel limited and well-defined routes every day to and from work. In inner-city areas there are, what is more, more problems associated with electric car ownership which would seem to impede its development than, for example, access to simple and cheap charging opportunities initially.

The problems of parking exist also for ordinary cars, but electric vehicles should also be compared with efficient public transport. For the suburbs or the like there are often problems with public transport in the form of frequency of service, direction, reliability and flexibility.

5.4 The current market for electric vehicles and planned trials

The following description comprises merely some examples of planned projects or vehicles that are on sale. Almost every day new initiatives are presented worldwide.

5.4.1 Europe

Sweden

In Sweden the electricity supply industry, with for example Power Circle and Elforsk and a number of other players such as Vattenfall, Fortum and, for example, the City of Goteborg, has initiated different forms of activities regarding electric vehicles. Most have been cases to do with trial sites for electric vehicles and charging infrastructure. So far today only a small number of Think cars from Norway are operating at a few places in Sweden. Volvo Cars in collaboration with Vattenfall and with support from the Energy Agency is running trials with plug-in hybrids. Volvo also has a research project ongoing with pure electric vehicles. Initiatives are also being taken to convert both Saab cars and Fiat cars in Sweden to electric operation.

France

Electricité de France (EDF) is a very active player within electrification of the vehicle fleet. In October 2008 the French state put forward a plan with finance of MEUR 400 for the development primarily of battery cars.

The French automotive manufacturers have in connection with this signed a collaborative agreement with EDF for battery development and the development of charging points. EDF has previously collaborated with Toyota as regards, for example, a three-year plug-in hybrid trial based on the Prius model, which is equipped with a charging socket and extra battery capacity.

Renault/Nissan are collaborating with the organisation A Better Place on the introduction of electric vehicles but also trials of battery exchange systems.

Germany

BMW, Vattenfall and Eon have plans to demonstrate 50 “Mini” electric cars in Berlin with renewable electricity. Users in Berlin will pay EUR 650 per month to use the cars, but will receive a subsidy of EUR 250 as a compensation for taking part in a scientific program. The total cost will, therefore, be lower than for corresponding conventional vehicles.

Denmark

The Danish government is today providing incentives to electric car buyers by not taxing low emission (CO2) vehicles up to 2012.

In Denmark programs are planned both through A Better Place for vehicles, infrastructure and battery exchange systems, as well as collaboration between Siemens and IBM (on the island of Bornholm). On Bornholm issues of the stability of wind power driven networks will be investigated. A great deal of the work is done by simulations, but a number of electric vehicles will be stationed on the island.

Norway

In Norway the company Think has been given a great deal of attention for its trials in launching an electric car. The company has financial problems, and has therefore not succeeded in supplying as many vehicles in Sweden as previously announced by Swedish players such as, for example, Power Circle. Apart from this company, several electric vehicle companies have been established in Norway for some years, and new initiatives are being taken. The reason is that the benefits for electric vehicles there are very great, and the interest in electric vehicles there has “survived” the first part of the 21st century.

5.4.2 Japan

Most vehicle manufacturers in Japan are planing to launch electric cars or plug-in hybrids, or are at least planning trials of these vehicles. Toyota will build a number of plug-in hybrids based on the new Prius model. Mitsubishi has already launched a small electric car in June on the Japanese market. The model is planned to arrive in Sweden at the end of 2010.

Nissan/Renault has, as mentioned previously, plans to launch several electric car models and also to conduct trials with battery exchange systems.

5.4.3 USA

There is a great interest in plug-in hybrids in the USA , and a market has appeared for the rebuilding of the Toyota Prius into a plug-in hybrid. General Motors is planning to launch a new model called the Volt in 2011, which is a charging hybrid. Major federal investments are now being made in the development of electric cars and charging hybrids, for example battery development.

5.4.4 China

In China an intensive development of both vehicles and battery technology is ongoing. The company which has received a great deal of attention is BYD (Build Your Dream).

6 Control measures

In the commission the agencies are asked to “investigate whether there is a need for control measures to stimulate the development of charging infrastructure and the introduction of vehicles, and if this is the case, also to propose what control measures may be suitable”. It also says that “in this context it should also be stated what existing regulations need to be changed in order to stimulate the development of the charging infrastructure”.

The description in previous chapters of the high costs of vehicles and uncertainty about strategy, choice of technology and costs for developing charging infrastructure means that the assessment is that further control measures need to be added if the interest exists to stimulate development beyond what is being done today. In particular it is a question of additional costs for batteries and in this way for vehicles which the Agency assesses as most critical.

The primary motives for supporting electric vehicles and plug-in hybrids are their opportunities for reducing emissions which will impact the climate, more efficient energy use, reduced emissions generally including noise, and industrial development within the vehicle sector but also the power industry.

The question of control measures for electric vehicles and plug-in hybrids is, therefore, treated in broad outline in both Climate Checkpoint 2008 (Kontrollstation 2008) and The Swedish Strategy for more Efficient Energy Use and Transport, EET (Strategin för effektivare energianvändning och transporter) which is one of three strategies within the framework of environmental quality objective work.

In the so-called green car definition there is a class for electric vehicles and another for electric hybrids and in this way there is already support for these two types of vehicle and scope in the regulations to stimulate these types of vehicle further.

Without carrying out a careful analysis of the support through the green car definition one might nevertheless say that the scope of this support in relation to the additional cost of the vehicle is relatively small, and presumably does not influence the choice of purchasing a electric vehicle or plug-in hybrid to any great extent. Biogas and ethanol cars have clear support both for purchasing and operating costs, whilst the electric car has no corresponding support for operating costs.

Biogas and ethanol cars are therefore today more favoured in total than electric cars. The operating cost of a biogas or ethanol car is supported by a tax reduction worth approximately SEK 2-5 per 10 km, dependent on the valuation put on depreciation and the size of the car. Electric cars and plug-in hybrids have therefore less support today from society than other so-called environmental cars, despite the fact that they have the potential to produce a very good environmental performance.

The additional cost of electric cars and plug-in hybrids is, compared with those other cars given support through the green car definition, in most cases considerable. The additional cost of an electric car or a plug-in hybrid is assessed in this report as being at least SEK 50,000-150,000 for vehicles manufactured in small production runs and considerably more for preproduction models.

Support for electric vehicles or particularly energy-efficient vehicles, of which electric vehicles may be one, is considerably greater in countries such as, for example, the USA, France, Norway and Denmark than it is at present in Sweden.

The Swedish automotive industry is today investing considerable resources in the electrification of vehicles. This is both a question of hybridisation and of electric vehicles and plug-in hybrids. Some of this investment is being made in collaboration with the state within, for example, the framework of the programme “Strategic vehicle research and innovation” (Strategisk fordonsforskning och innovation), which is described in greater detail in Chapter 11.2. Investment in the electrification of vehicles is being carried on to as great an extent for heavy vehicles as for passenger cars, and therefore the question of battery costs, battery systems etc is at least as important for truck and bus manufacturers as it is for the passenger car industry.

When support for electric vehicles and plug-in hybrids is being considered, it should therefore also be possible to discuss support for heavy vehicles, and for these the additional costs are considerably greater than for passenger cars.

The uncertainty about how great the additional cost for electric vehicles and plug-in hybrids is for different kinds of vehicles means that the Energy Agency in this report is not proposing a suitable level of support through the green car definition or other possibilities, but the Energy Agency nevertheless wishes to point out that the support is lower than in several other countries, and not least against the background of the opportunity for industrial development in Sweden, it may be suitable to adapt levels of support more closely to the levels applying in other countries.

As regards the expansion of the charging infrastructure, the report indicates that there is a well-developed infrastructure already, and that this constitutes a basis for being able to introduce electric vehicles and plug-in hybrids even today. What type of infrastructure it is best to develop further is difficult to determine. For further expansion of the type of infrastructure that already exists the costs are relatively modest in many cases and incentives already exists for both private individuals and companies to use and supplement the charging infrastructure for charging vehicles.

The difference in variable costs per kilometre for operating with electricity and operating with fossil fuels provide sufficient stimulus to use and even make simple additions to the infrastructure even today. If the market in electric vehicles and plug-in hybrids is to grow, more rapid charging may be needed. What is more, an on-street charging infrastructure may be needed. These types of intrastructure are today lacking standardisation, and here the costs are greater, which is why sufficient incentives do not exist for a comprehensive expansion. The City of Stockholm's Environmental Department has conducted a relatively comprehensive study of the possibility of expanding the charging infrastructure in Stockholm, and here describes the opportunities and obstacles.

All in all, the Energy Authority makes the assessment that further control measures need to be put in place to stimulate this development. This should happen with both general control measures, such as for example the opportunities of using the green car definition to provide extra support, but also in the form of a larger scale trial involving electric cars and plug-in hybrids. A trial is described therefore in greater detail in Chapter 12.

The IEA has surveyed the control measures in 18 countries and compiled inclusions in a document from 2002 in which they draw a number of conclusions which have been summarised by Elforsk[5].

The strategy for control measures should be based on a stage-by-stage introduction

Major investments in, for example, trials should not be made until a really sound technology has seen the light of day and the risk of setbacks in the form of bad publicity and little confidence on the part of potential buyers is less of a risk. This is possibly what we have seen earlier in the history of the electric car.

It applies particularly in relation to the expectations of the buyer has of the product. A small number are presumably prepared to buy lower performance at a higher price without any form of compensation.

Direct investment to the correct market segment

It is not likely that private individuals will be buyers of any large numbers of electric cars or plug-in hybrids initially (plug-in hybrids have a somewhat higher probability) but instead in this case the first measures should be aimed at bigger players. Such bigger players often have the opportunity of relying on the image advantage which is involved in buying in vehicles as a goodwill item in the accounts. As regards those types of vehicle fleets which might come into question, they are of types with very specific tasks/routes and sets of requirements. Private individuals normally have in comparison very varied requirements of passenger vehicles.

For certain categories of electric vehicle such as, for example, the Tesla, an electric sports car, there may be a reason to direct sales-related expenditure towards financially strong private individuals or otherwise people in the public

[5] Control measures for the introduction of electric vehicles and the expansion of the charging infrastructure,, Elforsk report 09:48 35

eye who are able to provide major help to this category of vehicle, from a marketing viewpoint

Focus on technological applications which can be adjusted to the market and become generally accepted by the users

The technology supplied should be of a nature that it provides either unique advantages to the segment or is so constituted that it does not require great behavioural changes on the part of the customer.

Involve everyone concerned at an early stage

Cordination of interests is important in order to achieve great market potential. In the case of electric vehicles and plug-in hybrids this means automotive manufacturers, electrical power producers and distributors.

7 Social effects of the introduction of electric cars and plug-in hybrids

7.1 Energy use in the road transport sector

The Energy Agency assesses on the basis of metering carried out in the 1990s of electrical use per kilometre driven and on the basis of those figures given for new cars that both electric cars and plug-in hybrids will be very energy-efficient. In the long-term forecast the Agency estimates an electricity use of 0.24 kWh/km including losses. Electricity use per kilometre may probably be even lower than this. The Agency shares the assessment of the electricity industry that, if the majority of passenger car movements today were made with electricity, use would be of the order of 10-15 TWh.

The Agency's long-term forecast from 2009[6] makes the assessment that electric vehicles and plug-in hybrids will have a certain market penetration by 2020. The report details the assessment that 85,000 vehicles will reach the market by 2020 and will be then expected to use approximately 0.2 TWh. This may be compared with the electricity industry and IVA who have formulated an ambitious vision of 600,000 electric vehicles by 2020 which, if this is realised, is assessed as using approximately 1.5TWh, or approximately 1% of today's electricity use in Sweden. In the report 0.2 TWh of electrical use is assessed as replacing approximately 0.5 TWh of fossil fuels in the form of petrol or diesel.

In the EU's sustainability directives there is a target of 10% renewable energy within the transport sector. In this target renewable electrical use in the transport sector can be included. What is more, from an accounting viewpoint electrical use in the transport sector can be adjusted upwards by a factor of 2.5.

7.2 Emissions

Estimating emissions from electric vehicles relative, for example to diesel vehicles or ethanol vehicles is a complex procedure. An important starting point is the energy efficiency of a particular service that is provided by an energy carrier. Electricity in vehicles has the possibility of being a particularly energy-efficient way of using energy for propulsion.

In the report "Carbon dioxide estimation of energy use" (Koldioxidvärdering av energianvändningen)[7] the Energy Agency states that it is not possible to estimate in advance the change in energy supply and its effects on the climate of the measure. But it is always good to make energy use more efficient and choose

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[6] Long-term forecast 2008, Swedish Energy Agency 2009:14
[7] "Carbon dioxide estimation of energy use – what you can do for the climate", (Koldioxidvärdering av energianvändningen, vad kan du göra för klimatet), Background report, Swedish Energy Agency, 2008

production-specific energy with a low climate impact, as this makes possible a change in energy supply.

If a marginal evaluation of electricity is made, one should at the same time make a marginal evaluation of what one is comparing with. The report gives a value for carbon emissions electricity of 1,000 kg CO2/MWh and for marginal oil from coal as 850CO2/MWh. Driving a diesel car with a fuel consumption of 0.4 litres per 10 km (70.6 mpg - UK), i.e. a very fuel-efficient diesel car, emits on the margin approx. 3.4 kg of CO2, and the electric car emits approx. 2.4 kg of CO2.

Figure 3 shows columns which with different vehicle occupancy clearly illustrate the argument above. The highest emission values in the column with one passenger correspond to the marginal argument. The lowest figures are, for electricity, a good environmental choice, and for the diesel car conventional oil emissions.

It is ultimately the buyer of electricity who, through their choice of electricity supply, influences the outcome. The choice of diesel is more difficult to make.

The choice of electricity which has low carbon dioxide emissions is easy to make in Sweden and also in the rest of Europe, which is why electric vehicles provide an opportunity for a substantial reduction in emissions.

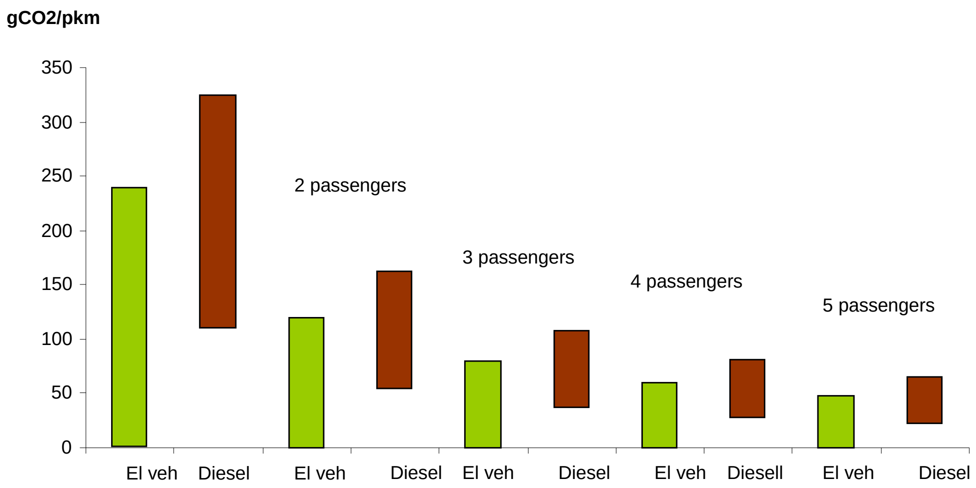


Figure 3 Carbon dioxide emissions as a function of vehicle occupancy. Comparison of an electric car and a very fuel.efficient diesel car from diffrent perspectives on the basis of emissions.

7.3 Economy

Without exception general control measures such as taxes and different market-based systems have a high socio-economic effect, especially for internalising short-term external effects. Carefully considered projects for information and marketing can be a good complement to these control measures. Beside these control measures there should be projects for research and development and also for market introduction included in strategies within the energy and environmental fields.

Different forms of contribution to investments in specific products should, however, be used sparingly, as they are often not socio-economically effective.

Certain measures, primarily investments in new technology, may need time-limited support for introducing help to the markets. The assessment is that electric vehicles are a new technology which needs some form of support.

Measures supporting green cars and many other measures within the transport sector are today not climate efficient in the sense that they cost more per reduced carbon dioxide equivalent other measures. Measures such as, for example, support for electric vehicles must, therefore, be regarded as long-term and evaluated gradually to assess whether they lead in a positive direction, i.e. a reduction in the cost of the measures.

8 The power network and the vehicles

8.1 Concession, metering and connection (the Energy Market Inspectorate – Basic data for the Swedish Energy Agency regarding the survey of the market for electric vehicles and plug-in hybrids)

On February 12, 2009 the Swedish Energy Agency was given a commission in collaboration with the Energy Market Inspectorate, the Swedish Transport Agency and the National Road Administration to provide an integrated knowledge base for the market in electric vehicles and plug-in hybrids. The commission is to report to the Ministry of Enterprise, Energy and Communications by no later than May 29, 2009. Against this background the Energy Agency has asked the Energy Market Inspectorate to "analyse the current regulations for network concessions, metering and monitoring of electrical use and consider the need for any changes. If a need is found to exist, suggestions or changes should be submitted."

The Energy Market Inspectorate's assessment is that the current regulations allow for an expansion in the infrastructure for charging electric vehicles and hybrids. There may, however, be reason to review certain areas in which the regulations can be improved with the aim of facilitating this expansion. A review of some of these areas is given below.

The Energy Market Inspectorate therefore supports the Energy Agency's proposal for a trial programme in support of the launch of electric vehicles and plug-in hybrids. The Energy Market Inspectorate should also have a role in this work.

8.1.1 Concession issues

According to the Electricity Act the power grid is to make high tension powerlines available for transmission of electricity.

Part of this power transmission work involves planning, construction and maintenance of lines, distribution plant and substations, the connection of electrical plant, metering and estimation of power and energy transmitted and other work required to transmit power over the electricity grid (Chapter 1, Paragraph 4 of the Electricity Act (1997:857)).

Electric high tension power lines may not be constructed or used without permission (power transmission concession). A transmission concession must refer to a transmission line with a largely predetermined route (power transmission concession for the line) or a transmission network within a certain area (power transmission concession area) (Chapter 2, Paragraph 2 of the Electricity Act).

8.1.2 Power transmission not requiring a concession

An ordinance (2007:215) concerning exemptions from the requirement to obtain a power transmission concession according to the Electricity Act states when a transmission line may be constructed without a power transmission concession. The motivation for the regulation

(Fm 2007:1), which clarifies the aims and background to the regulations, states that three basic preconditions have to be fulfilled: the line has to be an internal network, i.e. the owner has to transmit electricity at their own expense; an internal network must not be too extensive; and the area should be carefully delimited.

With the development of electric cars and plug-in hybrids a need may arise to expand the possibility of building networks for charging points without the necessary of obtaining a concession, for example at service areas, park-and-ride sites. There is, therefore, reason to analyse the need for expanding the regulation on exemptions from the demand for a power transmission concession.

8.1.3 Connection issues

The owner of a power transmission concession for an area is, if there are no compelling reasons otherwise, responsible for connecting an electric plan within the area to the power transmission network on reasonable terms. Disputes about the duties of the concession holder are decided by the network authority (Chapter 3, Paragraph s 6-7 of the Electricity Act). According to the electricity regulations the Energy Market Inspectorate is the network authority.

A customer can therefore apply for the EI to adjudicate whether a connection fee and other terms for a connection are justified. The network companies themselves determine their connection charges and adjudication occurs only subsequently.

The connection charge must be distance-dependent, i.e. it must be calculated with regard to where the connecting customer’s plant is located. EI’s adjudications can be appealed in an administrative tribunal.

A comprehensive expansion of charging points will involve a large number of applications for adjudication on connections. There is reason to consider whether the connection charges can be regulated in the legislation in order for these cases to be determined quickly, simply and predictably.

8.1.4 Metering

The regulations of the Electricity Act state that anyone possessing a network concession is responsible for carrying out metering of the amount of transmitted electricity and its allocation over time. If an electricity user has a power rating contract of a maximum of 63 A the network concession owner must instead on the one hand provide preliminary metering of the amount of electricity transmitted and its allocation over time (preliminary standard estimate), on the other finally meter the amount of transmitted electricity and calculate its allocation over time (final standard estimate).

This does not apply to an electricity user who is asked for the amount of electricity transmitted and its allocation over time to be mentioned. It is incumbent on the network concession holder to report the results of the metering and calculations that have been made (Chapter 3, Paragraph 10 of the Electricity Act). An electricity user who wishes the metering to be conducted in a different way than the above can have such metering, but must as a rule themselves pay for the extra costs involved ((Chapter 3, Paragraph 11 of the Electricity Act).

From July 1, 2009 the requirement is introduced for monthly meter readings. This means that all electricity customers can be charged according to their actual usage (STEMFS 2005:7).

According to current legislation individual metering should be made of each socket. There is a reason to consider whether this requirement is necessary when the infrastructure for electric cars and plug-in hybrids is to be expanded. EI has been tasked with investigating the opportunities of exempting smaller plants from the requirement for individual metering, for example of odd street lamps, advertising hoardings etc.

In this task EI will also consider the issues raised above. EI will report on its commission to the government at the end of September.

8.2 Business models and opportunities

The development of the charging infrastructure for electric cars or plug-in hybrids brings with it a number of opportunities and challenges. A great part of the gain is reckoned in terms of benefit to the climate and a reduction in local and global pollution, but there are also a large number of business opportunities involved in the new structure for energy supply for transport. A large number of players have already identified this as being the case, such as, for example, the electricity supply companies.

Apart from the clearly positive effect on these players there are a number of interesting opportunities which may affect sectors such as finance, insurance, risk capital, construction, electrical installers, electronics suppliers, recycling and many other sectors which can be positively affected by investment in this area.

Apart from the purely physical effects of an infrastructure expansion, agreements between players on the market also require managing, as well as business models, so that those people who provide the charging service are able to do so in a manner attractive to customers.

One of the challenges involves being able to receive payment for the electricity provided at a charging point which is not the vehicle’s normal parking bay. Experience so far shows that charging primarily takes place at “home base”, and public charging points are used relatively little. There may then be a challenge to apportion costs, at least initially, for metering at charging points, to the customer at those charging points of our provided. If a higher rate of payment is taken for electricity charged at “home base”, then the incentive to charge is reduced. It may therefore be difficult in certain cases to repay an investment in charging equipment.

Other business models are, however, quite conceivable, in which charging in a simple way forms part of the parking fee, as a fixed sum when visiting shopping centres, etc.

A number of special solutions where it is not possible to charge your vehicle despite the fact that there is charging capacity will not promote the growth of a vehicle parked with a high proportion of plug-in hybrids and electric vehicles.

Agreements between electricity producers, distributors and others in a way which perhaps is similar to the so-called roaming agreements between telecom operators is, therefore, an important factor.

New entrepreneurial activity or new business models can, therefore, arise in production and expansion of charging equipment and related technologies such as, for example, metering.

As the cost of acquisition of batteries is thought to be considerable during the introductory phase of the electric car and plug-in hybrid market, business models involving the leasing of batteries are ongoing and planned. One may also envisage co-ownership of vehicles through carpools in order, in this way, to increase the use of the car and thereby more quickly recover part or all of the costs of the battery because the car is being used more.

Trials are also ongoing through the telecom system to, for example, provide information about where charging points are to be found with the opportunity of pre-booking these.

A large number of new or old business models may be needed for the launch of electric cars and plug-in hybrids, and these initiatives should also be evaluated and followed up with the aim of evaluating the social economy involved.

9 Standardisation

Elforsk has, in its role as co-ordinating body for the Swedish electric power industry, conducted a study of standardisation in the area of electric vehicles[8]. The Energy Agency has received this report and below quotes the document in its entirety. It should be added that, since the report was written, there has been a consensus arrived at by the main European automotive manufacturers and energy companies that, for charging faster than the normal charge at 230 V and 16 A, a level of 400 V and 63 A has been adopted as rapid charging until further notice. Below we quote from Elforsk's work.

9.1 Who does what in the standardisation process

The standardisation process for electric vehicles and charging infrastructure is continuing internationally within IEC and ISO. Most active in the standardisation process are Europe, Japan and the USA. In Sweden the work is being conducted through SEK Svensk Elstandard (working to IEC) and SIS (working to ISO). The work involves both the revision of existing standards and the production of new ones. The standardisation process is conducted in a close dialogue between automotive manufacturers, electrical companies and equipment suppliers.

Some of the views that have been put forward during the winter of 2008/2009 within this cooperation have concerned:

- The avoidance of "lock-in effects" in the choice of various components and systems
- It should be possible to use simple solutions and existing standard plugs

9.2 Where standardisation is going

9.2.1 What is standardised

Within the IEC safety standards have been produced showing what designs are considered to fulfil the requirements for reasonable public safety.

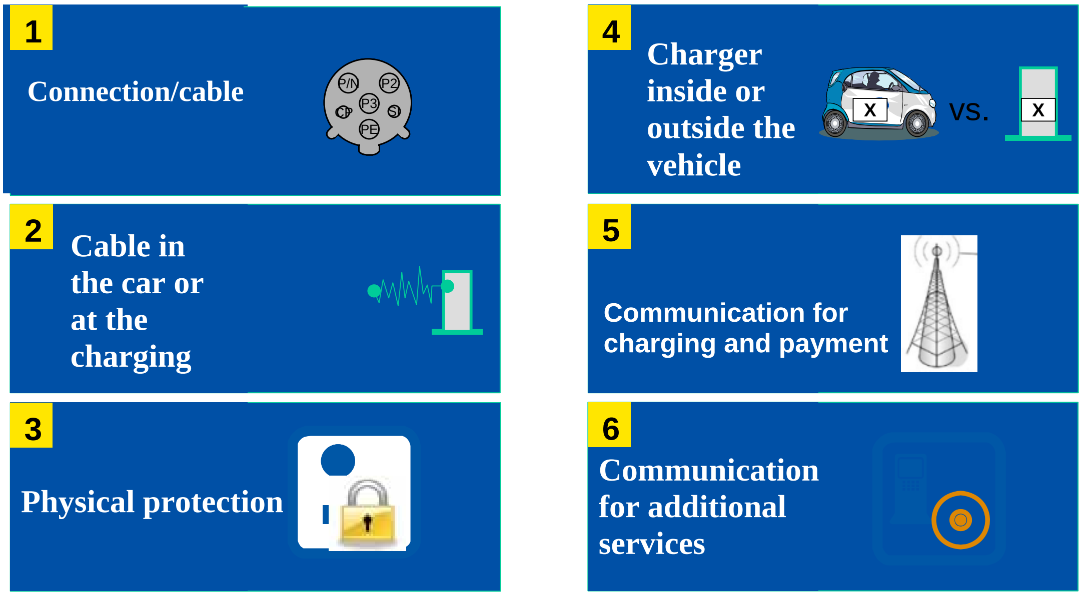
The standards fulfil the low tension directive. The IEC standards show suitable solutions for charging vehicles.

The IEC standards show several suitable solutions. As electric cars have been a local phenomenon, it has so far not been a major problem. As regards cable connections and plugs there has been great freedom of choice for national deviation, as a large number of different national rules and standards exist.

[8] Standardisation of electric vehicles - Progress report, Elforsk report 09:46

In a larger scale introduction of electric cars and plug-in hybrids to be charged the existing standards do not, however, suffice, as one then has to assume that these cars must be chargeable anywhere in Sweden and also in other countries. What is more, requirements will be made for more rapid charging and thereby the introduction of components into the charging systems.

With the aim of achieving compatibility between the charging systems in cars, an industrial initiative has been taken in Europe in which a majority of automotive manufacturers, component suppliers and electrical companies are cooperating in order to develop standards for the details of construction in order to achieve compatibility and desirable functionality and performance by charging systems and their component parts.



Source: RWE

9.2.2 Electrical

Current standard:

- Open to users of 1-phase, 2-phase or 3-phase
- Open to AC or DC
- Possible to choose different solutions for electrical safety (mode 1, mode 2, mode 3)

Need for standardisation:

- To make possible charging with both 1-phase and 3-phase
- To make possible slow or rapid charging

Trend:

- Possibility of 3-phase charging throughout Europe, even in countries without general 3-phase installations. 3-phase is assessed as being of interest here in certain public places where it is necessary to charge more quickly.

9.2.3 Connection, cables etc.

Current standardisation:

- • Provides an opportunity for a large number of different connectors, which means one cannot be certain that charging is possible without using an adapter.

Need for standardisation:

- • Connectors, electrical internets sockets, cables

Trend:

- Charging using 230 V/16 A should be possible at every household socket equipped with an earth fault breaker (or possibly as part of the cable).
- At higher requirements for charging power (3-phase and/or currents above 16 A, alternatively at least 32 A) special equipment is needed with greater safety.
- If high compatibility is to be achieved, it is necessary for 3-phase sockets to be used also for 1-phase charging. No special dedicated 1-phase connector is proposed.
- In order to be able to use weaker cables than for 63 A these weaker cables will have to be coded (mechanically or electrically) in order the car's charger not to overload the cables.
- Apart from 5 pin plugs (3-phase, neutral, earth) the connectors must have at least 2 signal contacts for control (pilot signal and presence of plug)
- Contact dimensioned for 63 A to achieve compatibility with high power 1-phase charging
- For compatibility with existing charging points and with household or industrial sockets it must be possible to use an adapter or additional charging cable

Uncertain:

- Type of earth fault breaker and the effects of the type of charger
- Possible safety equipment for unprotected household sockets
- Positioning of charging points and electrical intakes on cars
- Design of the contact zone on vehicles and electrical outlets
- Test specifications for connection equipment
- Pin configuration for 1-phase outlets

- Type of connection which will become standard
- Cable construction, e.g. colour, spiral or not, coding of high current

9.2.4 Positioning of cables

Current standardisation:

- Leaves question open as to whether loose cable at one end or both.

Need for standardisation:

- To make possible loose cable at the same time as it has to fit in the outlet and possibly in the car

Trend:

- Loose cable at both ends. Standardised contacts at both ends.

9.2.5 Physical safeguards

Existing standardisation:

Need for standardisation:

Trend:

- Future plugs, outlets, charging points and cars will possess physical safeguards against improper disconnection and misuse as well as disconnection whilst charging
- Locking mechanism will have an emergency opening feature

9.2.6 Positioning of the charger

Existing standardisation:

Need for standardisation:

Trend:

- For normal charging (AC, low power) the charger will be placed inside the car.
- The charger can be separate or integral with the alternator in the power train

Uncertain:

- Automotive manufacturers view chargers for rapid charging as part of the charging point outside the car in order to avoid extra weight in the car. The electricity companies are doubtful about the investment in expensive rapid charging points with a low occupancy rate. Further investigation is proposed into the preconditions for profitability.

9.2.7 Rapid charging

Existing standardisation:

- None

Need for standardisation:

- For contact equipment
- For dedicated charging equipment
- For communication

Trend:

- More than 80 A is rapid charging
- Rapid charging is when one has time to stand next to the car and wait for it to finish charging
- Off-board charging

9.2.8 Communication for charging, payment and additional services

Existing standardisation:

- Exists for charging control between off-board chargers and cars (pulse-width modulation)

Need for standardisation:

- For more advanced charging restriction (e.g for 3-phase) to avoid the main fuses and secondary fuses tripping out.
- For exchange of information between the vehicle and the power transmission network, e.g. for charging restrictions, V2G (Vehicle to Grid).

Trend:

- Authentification of the person charging (contract or possibly equipment) through transmission of ID to the charging point. Automatic payment and roaming are future possibilities.
- Bidirectional communication between vehicle and charging point. Information exchange regarding capacity of the electrical installation, power network restrictions, available loading time, forecasts of electricity price, safety functions, metering data. The vehicle obtains the framework but optimises itself.
- Data possible from the car, car driver and electrical provision side.
- Communication assessed as coming perhaps through the charging cable.
- Vehicles without communication possibilities can be expected to be chargeable also where advanced charging and payment solutions are being used.

Uncertain:

- Not clear whether low or high bandwidth is considered necessary

- Power line communication (PLC) or separate conductors unclear, but it is looking like power line communication.
- Description of use-cases and cost analyses can provide a basis for taking a decision on the choice of technology.
- Channel of communication and bandwidth for additional services. Should the same communication be used both for charging/payment and additional services?

9.3 Timetable for standardisation

Development of an international standard usually takes approximately 3 years. If it is quick, it will take two years.

The existing IEC standard for testing plugs and electrical outlets IEC/SC23H:

- May-July 2009 - Draft for comments from national committees
- October 2009 - Publication for voting

Rapid charging has been assessed as being possible within approximately 5 to 10 years. Standardisation of connections for rapid charging forms part of IEC/SC23H.

Proposals for standards for communication between car and charging point might possibly be in existence at the end of 2009 for completing a proposal for voting within the IEC during the spring of 2010.

9.4 Important areas to follow up from a standardisation viewpoint

9.4.1 Safety level

Existing standard IEC 61851-1, "Electric vehicle conductive charging system – Part 1 General requirements" is a safety standard. Safety refers to public safety as well as functional safety on the basis of avoiding the generation of heat and sparks in the contacts. IEC 61851-1 fulfils the requirements according to the low-tension directive. For contacts in general use national regulations apply. It should be noted that standard IEC 61851-1 (and SS-EN 61851-1) provides a description of requisit functionality for charging, but provides scope for national variations in order to suit local preconditions (some examples are the choice of mode and connection).

In normal charging with AC various modes can be selected for charging. These modes describe suitable solutions for safe charging:

- Mode 1 – The simplest variant usually used in existing outlets when no installation is needed if the outlet is equipped with an earth fault breaker. Available up to and including 16A, 1-phase or alternatively 3-phase charging, 230/400V.

- Mode 3 – The safest variant that has been developed for sites where stricter safety requirements are demanded. Requires the installation of special safety equipment at the electrical outlet. The safety equipment continually checks that the earth wire is intact and the contacts are properly connected.

  When the contacts are pulled apart the current is broken before the contact becomes disengaged. Turning the charge on and off can be done in a controlled manner, because the electrical equipment and the vehicle have “given their permission”.

- Mode 2 – A variant of mode 3, which does not require special installation at the outlet. In this case safety equipment is installed on the cable near to the plug, which makes possible the use of ordinary standard outlets without any specially installed equipment.

In Swedish electrical installations outdoors an earth fault breaker is required on installation. This corresponds to the mode -1 charging according to the above. In the community there are today a number of older outdoor installations which do not use earth fault breakers. These are legal to use. Bearing in mind the widespread and well-functioning use of engine and car interior heaters in Sweden whose high-voltage sockets correspond to a normal charge of 10A, 230V, it is reasonable that existing electric outlets could also be used for normal charging vehicles. The electrical industry should, however, recommend the installation of fixed earth fault breakers or alternatively portable earth fault breakers when fixed ones are not suitable.

In special cases where greater safety is desirable there may be cause to apply mode 3 charging, as this prevents the generation of sparks, which may be a problem in certain environments with the risk of explosive gases. Mode 3 also supports for example, ventilation control. One may, however discuss whether it is suitable to use cars in environments of this kind, and whether one should be charging cars there at all. Garage charging has been described as a case where extra safety may be necessary. It may, however, not be the charger itself or its potential generation of sparks which is dangerous, but the results of a potential vehicle fire. The vehicle fire does not need to be ignited by the charge, and it would be other factors, for example smoke and gas formation, that one should be afraid of.

A further case where greater safety may be motivated is at unsupervised charging points if one assumes that fuses and earth fault breakers do not provide sufficient safety, possibly with on-street charging where theoretically one can be injured if the current in a damaged cable is discharged between the phase and the neutral wire through a human body. In this case the earth fault breaker does not trip, as the current takes the “correct conductor” back. The probability of this is, however, small.

Electrical accidents may also occur if the charging outlet/ point becomes damaged. Irrespective of which charging mode is used, there is however the possibility of cutting the current to the outlet/point if no vehicle is connected.

Finally one might ask the question of who is to determine what level of safety is to be applied in an individual case: the car manufacturer, the car owner, the owner of the electricity supply equipment or the authorities/municipality. Bearing in mind that it will probably be the owner of the electricity supply equipment who is affected by a potential accident, it seems reasonable that this individual also takes a decision about suitable safety levels.

Currently there are unconfirmed reports that in most countries in Europe mode 1 is felt to be sufficient.

There may possibly in certain cases be advantages in introducing mode 3 charging, if one then can also have access to communication functionality between the vehicle and the electrical installation. This is, however, not an established standard today, even if technical solutions for it are possible.

9.4.2 Possibility of charging everywhere

Fuses - People in general should not need to worry about whether a fuse blows in the charging point or electrical supply installation. There should, therefore, be a function making it impossible to trip a fuse by connecting a perfect charging cable and vehicle. This should be done through simple coding (mechanical or electrical) or more advanced communications between the vehicle and the charging point. An alternative is that it should be easy quickly to remedy a blown fuse. Occasions where there may be a need for a particular safety function are at engine heater points with 6A fuses and charging at home with 10 A fuses, as this cannot be expected to be common in other countries where the normal household fuse is 16 A.

9.4.3 Possibility of half-speed charging

Unlike many other countries in Europe there is in Sweden among other things the opportunity of 3-phase charging, which makes possible relatively rapid charging.

This is important to monitor, as in Swedish electrical installations it is often not possible to conduct a rapid charge with 1-phase.

9.4.4 Possibility of simple, inexpensive solutions

9.4.5 Interaction between the power network and the vehicle

If possible existing types of outlets should be used for charging, at least during the initial phase of the introduction of electric vehicles. This could be done with normal charge 1-phase (230V, 10A) and mode 1 charging (earth fault breaker). At a later stage this could be supplemented with other solutions for safety and communication.

There is, therefore, reason in some way or another to influence the charging of cars at other points in time or charging on lower power.

Under certain circumstances it would also be interesting for vehicles to charge when there is an excess of electricity production, for example, with surplus wind power or other energy sources that are not possible to control.

Under certain circumstances vehicles in the future may also be able to act as energy storage feeding electricity into the power network.

9.4.6 Interaction between the electricity supply installation and the vehicle

When the vehicle recieves current, or the current that it is set to charge with, there can be problems when the electricity supply installation does not have the capacity to supply the desired load voltage at every point in time. Some type of limitation of loading voltage is needed so as not to trip the installation’s fuses.

10 Laws and regulations

10.1 Vehicle regulations for electric vehicles (Transport Agency)

10.1.1 Type approval of vehicles

Certain categories of vehicle have to be EU type-approved in order to be registered and used within the EU. According to the vehicle regulations (2002:925) passenger cars, motor cycles and tractors should currently be type-approved in the EU. All vehicles should, however, fulfil harmonised requirements as regards condition and equipment, that is to say there are regulations decided within the EU regarding technical requirements on vehicles that all member states must apply.

10.1.2 Registration of vehicles

An EU type-approved vehicle is registered by using a CoC (Certificate of Conformity), which is a document the manufacturer and holder of the EU type approval issues for every vehicle manufactured. The CoC contains technical data and information that is entered in the road traffic registry. It also certifies that the particular vehicle conforms with the type-approved construction.

The possibility also exists of registering a few vehicles without EU type approval and CoC by a registration inspection. The difference is that the vehicle owner has at the registration inspection to attest that applicable requirements have been met.

10.1.3 Regulations for electric and hybrid vehicles

It has not previously been possible to EU type-approve an electric vehicle with the support of the framework directive 70/156/EEG, which only allows vehicles with internal combustion engines to obtain EU type approval. After April 29, when the new framework directive comes into force, new opportunities will open up.

It is formally still not possible to EU type-approve an electric vehicle because certain regulations are missing, electrical safety amongst other things.

The opportunity does exist, however, to approve as a national short run vehicles on the precondition that relevant alternative requirements are made of the vehicle. The vehicle of this type is, however, not free to circulate within the EU.

10.1.4 Exhaust requirements, hybrid vehicles

Hybrid vehicles must meet requirements for exhaust emissions corresponding to vehicles driven only by a combustion engine. Those vehicles that are available today have an exhaustive approval according to EU directive 70/220/EEG or alternatively UNECE R 83 amendment 03. In common parlance up to exhaust level requirement euro 4. The vehicle has been tested as an entirely combustion engine driven vehicle.

All new EU type approval issued as regards exhaust emissions after September 1, 2009 must fulfil requirements in accordance with EU regulation 715/2007 and EU regulation 692/2008, exhausts level requirement euro 5 or better. The EU regulation contains special conditions for how hybrid vehicles should be exhaust-tested.

10.1.5 EMC

All vehicles registered as new after January 1, 1996, and electrical systems on such vehicles, must meet the requirements for electromagnetic compatibility (EMC) according to EU directive 72/245/EEG or alternatively UNECE R 10 amendment 2. This requirement applies both to entirely electrically driven vehicles and vehicles with hybrid drive.

10.1.6 Electrical safety

As regards electrical safety there are conditions in UNECE R 100. These are, however, not updated for existing technology and modern standards, that is to say an updating of the regulation is necessary before it is possible to apply it. The regulation is not included in the framework directive, which means that EU type approval of electric vehicles based on UNECE R 100 cannot formally be issued. Standardisation is ongoing within ISO as regards electrical safety for electric vehicles.

10.1.7 Electrical energy consumption, fuel consumption and CO_2 emissions

All light vehicles must provide data on fuel consumption and CO2 emissions. For vehicles which are exhaust -approved according to EU regulation 715/2007, euro 5 or better, this also applies to hybrid vehicles. Entirely electrically driven vehicles must have data on electrical energy use. Conditions for testing fuel consumption, CO2 emissions and electrical energy use are contained in EU regulation 692/2008.

10.2 Regulations for charging points

The City of Stockholm has, in preparation for a trial with PHEVs in the town, investigated the regulations applying to different types of installations, which are reported here.

What follows is a quotation from an official statement from the City of Stockholm[9].

[9] Official statement by Eva Sunnerstedt and Björn Hugosson, The City of Stockholm’s Environmental Department, Reg no.: 2009-004321-211

10.2.1 On-street

Within the roadway located in the local plan under public law traffic legislation and road traffic regulations always apply. By using the roadway/reclassifying land use for charging points the city's Traffic Office must ensure that account is taken of street cleaning (including snow clearance), the townscape, traffic (all traffic including pedestrian traffic, cycle traffic, traffic for people with disabilities, etc.) and the environment. Police permission may be necessary according to the Public Order Act.

The Traffic Office is today making the general assessment that it will be difficult to fulfil the requirements primarily applying to street cleaning and traffic along pavements in the inner city if charging points are installed. Today the city has completely abandoned individual parking meters at parking bays, and parking bays on the street are not even marked off by boxes any longer – the exception being places reserved for people with disabilities and for motorcycles and diplomatic vehicles.

According to traffic regulations it is possible to reserve a place for certain vehicle types stated in the regulations, e.g. vehicles for people with disabilities. Green cars, electric cars, carpool cars etc. are not included in the traffic regulations, and parking bays cannot be reserved for these vehicles (traffic regulations 1998:1276 Chapter 10, Paragraph 2).

For that reason the road sign regulations have no additional sign for "electric car". There is currently no possibility of free parking for electric cars (or other environmental vehicles) according to the "Law on the right of municipalities to charge for certain concessions in a public place etc." (SFS 1957:259). According to this law the municipality only has the right to excuse people with disabilities from paying a fee.

Charging from a charging point on-street is not possible, as the city, according to the Electricity Act, may not re-supply electricity to external customers. Electricity supply may only be provided by companies with concession rights. The city could apply for concession rights, but this implies that it has to enter into a business in the electricity field in competition with the already existing companies such as Fortum, E-on, Vattenfall etc. Several European cities have introduced reserved parking spaces for electric cars where both parking and charging is free of charge, for example Oslo and London.

10.2.2 On private land

Areas designated as parking spaces according to the local development plan can be provided with charging facilities if the owner of the land gives their consent. When the city owns the land, the parking area is often rented out to, for example, Stockholm Parkering, and then the tenant has to give their consent. On private land it is possible to reserve spaces for particular vehicle types, for example electric cars or green cars. This is already being done on Norr Mälarstrand in Stockholm. Today no building permit is needed, but the City Planning Administration can, if it is a question of multiple points, according to verbal information received, make these subject to a building permit primarily out of aesthetic considerations.

10.2.3 Multi-storey car park

The owner of the car park determines whether a charging point should be installed.

Stockholm Parkering already has a dozen or so multi-storey car parks with a couple of charging points. Three regulations govern safety in installing charging points indoors:

• National Board of Occupational Safety and Health code of statutes AFS 1988:4 “Lead batteries”

• National Board of Building, Planning and Housing building regulations BFS 1993:57 with amendments up to 998:38, requirements for a garage in 6:232

• Swedish standard from SIS: SS-EN 50272-3 “Chargeable batteries and battery plants – safety – Part3: Traction batteries”

None of these mentions lithium-ion batteries or nickel-metal-hydride batteries, which are the modern types that may be expected to be found in electric cars and plug-in hybrids. According to the Civil Contingencies Agency (MSB) the crucial point is whether hydrogen gas is formed during charging. A clarification of safety aspects in charging these new battery types must be made. Before this is done, Stockholm Parkering is finding it difficult to take a decision on further expansion.

The same rules apply to the city’s own indoor car parks such as, for example, Tekniska nämndhuset. The city’s Real Estate Administration currently has certain parking bays with engine heaters, which could be used for charging. On the other hand, the same uncertainty as regards safety regulations applies to charging indoors as is mentioned above. On Kungsholmen, Stockholm there are approx. 280 parking bays altogether in Tekniska Nämndhuset and ground-level parking at Hantverkargatan 2 and 3.

10.2.4 Occupational health and safety-directives

It is the employer who is responsible for the working environment. As regards electric cars/charging points, this implies that the Work Environment Authority is the standards authority from an employer/employee perspective. There are two important regulations to consider:

• AFS 2000:42 on the design of the workplace

• AFS 2001:01 on systematic work environment policy

Requirements are made in these for, for example, the employer having to conduct risk analyses and proceed from safety regulations for his employees. There are also special regulations as regards lead, AFS 92:17, and general advice on the application of these regulations. The regulations to a great extent cover all work in which exposure to lead might arise.

AFS 2005:17 also provides a maximum permitted hygiene level and measures where pollution in the form of dust, smoke, haze, gas or fumes may occur.

To summarise, there are clear work environment requirements as regards lead batteries, but nothing about lithium-ion or nickel-metal-hydride batteries. Whether or not this is a problem is unclear.

11 Research and development

Resources for research and development into electric vehicles have varied internationally over time a great deal, in keeping with the idea that the electric vehicle may be the solution to different social problems. During the 1970s and 1980s it was primarily to replace oil, and during the 1990s – during the so-called zero emission legislation starting in California – it was local emissions. During the 1990s a strategic development of battery technology began however for more advanced users such as, for example vehicles, and that research has been ongoing.

What is more, battery technologies have developed very positively for minor applications such as hand tools over the past 15 years. Hybrid vehicles using batteries have also been commercial since 1997, when Toyota launched its first Prius model in Japan. Since then the number of batteries sold for vehicles has increased every year.

Against the background of the breakthroughs that have occurred in battery technology, primarily in lithium-based technologies, a continued and again extended discussion on the replacement of oil as well as the climate issue, the majority of vehicle manufacturers worldwide have in recent years stated that they are considering starting production of electric vehicles. What is more, the development of hybrid vehicles has led to the idea of the so-called plug-in hybrids. PHEVs are normal hybrids with a somewhat larger battery and the possibility also of charging the batteries from the electric power supply. A number of companies have also presented plans to launch vehicles of this kind.

The demands on local emissions and greater energy-efficiency also for heavy vehicles, such as, for example, buses in London, have also led to demands on the heavy vehicle industry to produce vehicles with different types of electrication solutions for urban traffic.

As this report is being written, projects for electricity and vehicles are gaining pace rapidly worldwide. Through the Agency's business intelligence we can state that resources both for research and development and also investments in battery production are increasing rapidly.

11.1 International

Battery technology is at the top of the agenda as regards the need for research and development globally. It is almost exclusively questions of capacity that are being addressed, and specifically identified areas that are being focused on are:

- Weight – lower weight is intimately connected with the vehicle's capacity, primarily its range.
- Price – the price is still very off-putting to most people.

- Size – opportunities for a built-in battery (linked to capacity to a certain extent).
- Lifespan – the number of charging cycles before capacity diminishes.
- The possibility of rapidly absorbing and dispensing energy, as well as monitoring and control of the batteries so that guarantees about lifespan can be maintained, are important aspects.

Perhaps the most important nation from a research viewpoint as regards battery technology for vehicles and hybrid vehicle technologies is Japan. One measure of this is usually, for example, the statistics for patents within these fields. Other important countries are the USA, China, Korea and Germany.

The EU is refining and planning both within the seventh framework programme a major project within electricity for vehicles as well as infrastructure, and in the wake of the vehicle crisis special projects in innovative technology for more climate-efficient vehicles. This last investment will also presumably include electric vehicles and charging infrastructure in large part.

In the USA too new resources within battery development and projects for electric vehicles have been forthcoming this spring. With finance from the Department of Energy there are, for example, the projects “Freedom Car” and US ABC (US Advanced Battery Consortium).

It is difficult to provide a comprehensive picture of how the resources are allocated, but it is clear that they are considerable.

11.2 Swedish initiatives

In Sweden there have been specific long-term projects for electric cars and hybrid vehicles for more than 15 years. In recent years resources have, however, increased, and the National Energy Administration and industry chose in 2007 to initiate a joint long-term hybrid vehicle centre with Chalmers University of Technology as host, but with units for implementation at both the University of Lund and the Royal Institute of Technology in Stockholm.

The vehicle research programme since its inception in the green car in 1999 has also conducted projects primarily on hybrid vehicles. Within the framework of the last period of the green car, 2007-2010, work on hybrids grew considerably and also came to involve work on PHEVs.

On January 1 this year a new vehicle research programme was initiated, FFI (Strategic vehicle research and innovation), where a considerable amount of resources has been channelled towards the electrification of vehicles. Amongst others there has been a major project in pure electric vehicles set up in collaboration with Volvo Cars.

In its latest research and innovation bill the Swedish government has invested SEK 1.8 billion annually in 24 strategic research areas. One of these areas is

Energy, which is divided into three parts, one of which is electrical drive systems and hybrid vehicles.

In the budget proposals for 2009 the government also set aside SEK 875 million to support trials and commercialisation of second generation biofuels and other energy technology. In the call for outline plans made in the spring of 2009 Volvo Cars has a project proposal for a trial project with electric vehicles. Volvo's outline plan was one of six asked to submit a full application. The application has been submitted and is now being scrutinised in competition with other applications.

11.3 Industrial development as a possibility through a Swedish trial

Swedish vehicle manufacturing industry is today developing technology so as in a few years time to be able to invest heavily in electric vehicles.

On the heavy side they are primarily working on the hybridisation of buses, as there are major customer demands; for example, from London Transport for this. In hybridisation they are working primarily with battery solutions or supercapacitor solutions. There are extensive projects ongoing also into trucks, for example refuse trucks, but also delivery trucks and those used for long-distance transport. There is also considerable development of working machines in the direction of different forms of hybrid solutions.

On the light side Volvo Cars and Saab are both developing a technology for electric vehicles. Both companies previously were given special responsibility by their respective American groups for hybridisation, and have therefore developed the competence not only for the brand, but also the group. The National Board of Occupational Safety and Health's research and development project is financed by both companies within the framework of the state research and development programmes. Volvo also has projects, in collaboration with the Energy Agency and Vattenfall projects in the PHEV field, and with the Energy Agency within pure electric vehicles.

Jointly they are now looking for suppliers for this development, and there are still opportunities for established Swedish companies to come in more decisively on electric vehicles, and also to establish new companies or attract companies to Sweden from abroad.

Technology-wise it is clearly a matter of batteries, and not merely battery cells but also control and monitoring systems for batteries. It is also about, for example, power electronics, electric motor technology and systems for heating and cooling all areas of technology with very strong Swedish competence, but which to only a minor extent is industrially linked to the vehicle industry.

Even today there are a number of applications for support for trials lodged with the Energy Agency and discussions are being conducted with industrial partners on very considerable investments. The level of support for these exceeds the possibilities within the framework of ongoing R&D programmes.

As many of the issues surrounding electric vehicles are common to both the heavy and light vehicle industries, a trial for both Swedish vehicles and other vehicles may provide the answers to many questions about the technology in the vehicles, through evaluations made by, for example, the Swedish Hybrid Vehicle Centre and TSS (Test Site Sweden).

Apart from the opportunities of development, in Chapter 8.2 other business opportunities are described which may arise through a trial.

12 Conclusions and recommendations

The Energy Agency is proposing a four-year trial and development programme to support the launch of electric vehicles and plug-in hybrids (electric vehicle programme). This is against the background of the uncertainties about the launch of vehicles, the cost of importing components such as, for example, batteries, the opportunities of industrial development in Sweden, and the uncertainties regarding how one should supplement the existing charging infrastructure in a socio-economic manner.

Apart from this, the more general support measures for electric cars and plug-in hybrids should be reviewed. Today electric vehicles, hybrids, ethanol vehicles, biogas vehicles and fuel-efficient vehicles receive support through the green car definition and the environmental classification system. What is more, ethanol vehicles and biogas vehicles receive support through a reduction in the tax on biofuels. Taken together society’s support for electric vehicles and plug-in hybrids is lower than for the introduction of ethanol vehicles and biogas vehicles, and does not mirror the environmental advantages of these.

The overall general support to electric vehicles and the support through a trial comprises an integrated strategy to overcome the initially very high additional costs of these vehicles.

The electric vehicle programme should include both support for the additional costs of vehicles and the additional cost of support for trials in the expansion of different forms of charging infrastructure. Apart from this, research and development resources within the framework of the programme should follow up and evaluate the projects in order to absorb the results at an early stage of the programme.

Often the focus is directed at projects within the field of passenger cars. Projects within heavy vehicles are, however, also relevant and important. Major developments are ongoing for hybridisation of buses and trucks, where, among other things, battery issues are often common to the passenger car side. What is more, there may be opportunities of these vehicles also to charge from the electricity power supply.

The overarching motives behind the electric vehicle programme are that electricity in vehicles offers an opportunity for a powerful streamlining of energy use in the transport sector, and thereby an opportunity for reducing the sector’s carbon dioxide emissions. What is more, a programme supplements in a very clear way the now greatly increased efforts of the Swedish vehicle industry within the field of electric vehicles. As regards heavy vehicles, Swedish industry already offers electric hybrid vehicles on the market, and on the passenger car side projects are accelerating in this area.

Apart from this, there is a very considerable involvement from the electricity sector for projects within the field, as well as experiences in involvement on the part of society at large as regards the introduction of new technology for renewable energy in the transport sector, such as E85 fuel and biogas. Internationally major projects are being carried out or being planned. It is, therefore, of vital importance to participate in this development with the aim of contributing positively to it. It is also of importance to create opportunities for Swedish industry to participate actively in developments.

The opportunity exists against the background of the competence of both the Swedish vehicle industry and the Swedish power generation industry for developing this, but also for creating new business with an export potential. In order to do this a “home market” is very important. In order for Sweden to be regarded as a leading nation and be taken into account in an early introduction of vehicles from international electric vehicle producers, the symbolic value of trials and other clear means of control is vital.

In order to achieve a long-term view in a trial a great degree of involvement on the part of private companies is necessary. Achieving this presupposes that financial incentives exist, i.e. that it should be possible to recoup investment in vehicles and charging structure, at least in the long-term. It is therefore important in a project of this type to try out new business models.

It is also important to link business intelligence and the history of technology to the programme in order in this way to acquire, communicate and analyse previous and current projects in other countries as well as in Sweden.

These should be analysed from an interdisciplinary perspective in which the stress should be placed on a business and socio-economic perspective. An analysis of the driving forces and considerations involved in the process towards more sustainable transport systems is a key factor for a successful technological revolution. It may also be valuable to create a think tank with “free thinkers” in connection with the projects that are being carried out.

It is important to place electric cars and plug-in hybrids in a system perspective, which is why a high level of system efficiency is required in a trial. For example, electric cars and plug-in hybrids may be an energy-efficient alternative for commuting to and between cities and towns. The link to renewable energy should be prioritised in order further to reinforce the system perspective in the project.

Sweden has a strong vehicle industry with both automotive manufacturers and suppliers. At the same time Sweden possesses considerable competence within electric power technology and telecommunications. This creates a unique platform on which to build the transition to electric cars and plug-in hybrids. It is therefore important that the preconditions within a trial should be designed to exploit these areas of strength for increased growth and employment.

This can be done by creating various technological clusters, where the aim is to develop experimental vehicles where Swedish suppliers, power development companies, telecom development companies and vehicle manufacturers collaborate. It may be a question of developing a new electric mail van, a goods delivery van, etc. In order to acquire an interest in the market the vehicle customer should also be involved in the process of development. Business development resources are provided for these clusters with the aim of finding opportunities for creating long-term business linked to the work of the cluster.

A large-scale trial close to the market will create interest in the world outside. This creates an opportunity to attract new suppliers to the vehicle industry in order to establish manufacture and development in Sweden. In order further to reinforce this opportunity the programme should have an adequate marketing budget and a marketing strategy which emphasizes Swedish values.

Previous initiatives involving electric vehicles, such as the so-called zero emissions legislation in the USA in the 1990s focused primarily on the local environment. This means that one may need to look at the motives behind various previous initiatives, if one wishes to make comparisons with the current situation. Apart from this, there were no plug-in hybrids in earlier electric vehicle initiatives, and they therefore comprise a new feature of technology and market where knowledge of these vehicles today is very limited.

For this reason a more detailed proposal is given below for how a programme of this type might be constructed. The proposal for an electric vehicle programme contains in principle five different sections:

- Initial extra support for the launch of vehicles
- Support for trials in the expansion of the charging infrastructure
- Innovation, coordination and procurement
- Follow-up and evaluation of the project
- Information and international cooperation

12.1 Proposals for an integrated electric vehicle program

12.1.1 Support for vehicles

Initially both electric vehicles and plug-in hybrids will be considerably more expensive than normal vehicles. It is batteries and other components which initially, because of, for example, production and small series, will be expensive. On the other hand, one can foresee that, if the market for these vehicles takes off internationally, the additional costs will fall relatively quickly. Battery vehicles will, however, very probably also in the longer term be more expensive to buy than normal vehicles, whilst the mileage cost will be lower than for normal vehicles. Initially the lower mileage costs will far from outweigh the additional cost of the batteries either in an electric car or a plug-in hybrid.

Support for electric vehicles and plug-in hybrids has and generally should be found in the environmental classification system for vehicles, if the vehicles are energy-efficient. The environmental classification system for support may, however, need to be adapted for electric vehicles and plug-in hybrids.

In the underlying data for the report however it is stated that the additional cost of electric vehicles and plug-in hybrids initially is between SEK 50,000-150,000 per vehicle, and that this is a higher additional cost than for other vehicles using renewable fuels. For developmental vehicles both on the passenger side and for buses or trucks the additional cost is considerably greater than the sum given above.

What is more, there is considerable uncertainty as to how much vehicles such as plug-in hybrids will be able to "tank up" with electricity instead of normal fuel, and it is therefore difficult to estimate the value of the lower mileage costs. Experience of electric vehicles is that they are driven relatively few kilometres each year, but the same experience does not apply to plug-in hybrids.

If an electric vehicle or a plug-in-hybrid running on electricity covers 5,000 to 10,000 km p a, the value of the lower mileage cost is approximately SEK 2,500 p a to SEK 5,000 p a, which initially does not recoup the additional cost of the battery, but may do so in the longer term.

As the additional cost over several years will, however, presumably fall, the Energy Agency proposes, over and above support of the vehicle through the environmental classification system that an additional cost system through the electric vehicle programme would be a more flexible way of providing support to the launch of these new vehicle types.

12.1.2 Support for expansion of the infrastructure

In the year 2000 there were 600 vehicles running from the electric car launch in the 1990s. Despite this basis it was difficult to draw any conclusion about how an expansion of the charging infrastructure should sensibly be carried out. At the same time it was possible to say that most charging was conducted with existing infrastructure or with only minor alterations. For plug-in hybrids the Energy Agency's hypothesis is that expansion of the charging infrastructure is less critical, as these vehicles work well even if they cannot be charged from time to time. The Swedish Transport and Communications Research Board's final report[10] on the 1990s electric vehicle programme states:

"Conclusions on charging infrastructure.

New innovative types of infrastructure for charging, such as more rapid chargers, have in all cases been associated with technical problems, which presumably would not have been discovered if the equipment had not been used in trial situations. Trials have involved diagnoses and solutions of almost all of the

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[10] Clean cars with electric propulsion, final report from KFB's R&D and trial programme on electric and hybrid vehicles 1993-2000, KFB-report 2000:26, ISBN 91-88371-81-6 63

technical problems. Normal charging has been relatively reliable. However, trial planners have been faced with difficult problems, namely at what level and to what extent should the infrastructure be provided? Public rapid chargers in particular are actually needed rather rarely, apart from providing the user with an important feeling of security that they will not be left with a battery-driven electric vehicle with too short a range. What is more, they can be installed in a preventative capacity so as, in the future, to be able to serve more powerful electric vehicles.

Normal chargers in public places are seldom used, but increase the visibility of electric vehicles, which makes them a practical transport alternative integrated into the community. It seems that customers normally charge at “home base”, as well as at a few centrally accessible public facilities. In a study of trial users of electric vehicles, 60% stated that they would have used rapid chargers if they had been available.

There are today several million power outlets that are suitable, or will be suitable after minor alterations, for normal charging of electric vehicles in Sweden. In addition there are approximately 600,000 outlets for engine heaters, which in many cases can be adapted to charge electric vehicles. The situation is similar in other countries, but the large number of outlets for engine heaters is unique.

The conclusion of the arguments presented above is that electric vehicles and plug-in hybrids can be launched with the existing, or a slightly modified, infrastructure as a basis. How a supplementary expansion should be undertaken needs to be evaluated through practical trials.

Many trials with different forms of infrastructure are ongoing worldwide. Some strategies involve supplementing existing infrastructure with normal charging in city centres, while other strategies involve different forms of more rapid charging as the best way of supplementing what already exists. A further strategy is trials with rapid battery exchanges.

Common to all the strategies for supplementing the existing infrastructure is that costs are so high that it may be difficult to find working business models for an expansion of the service if all the charging infrastructure does is to produce a charge. For simpler forms of expansion there are presumably already sufficient incentives, as long as cars appear to make use of the infrastructure.

Trials should therefore be held in areas where the interest in electric vehicles is considerable, and in this way the anticipated use of these is great enough for conclusions to be drawn about different ways of supplementing the existing structure.

The trials of the 1990s with electric vehicles mostly had the local environment as their primary motive. The aim of electric vehicles today is instead greater energy efficiency and a reduction in climate impact both within and outside the city environment – even if the relatively major gains will presumably occur in driving in town. Benefits from greater energy efficiency and a reduction in climate impact in the urban environment will also occur through charging conducted outside the urban environment.

Trials should, therefore, be conducted with different forms of expansion of supplementary infrastructure for both normal charging and different forms of more rapid charging. These trials should, what is more, be supplemented with investigations into areas where the infrastructure is not developed in order to evaluate the projects.

The expansion of supplementary infrastructure contains several problems such as, for example, where and with which technology charging could be carried out, how payment should be made and whether the expansion is in the public environment, what players may or should invest in the expansion, and what the business models for recouping costs should look like.

The problems may be exemplified by the expansion of rapid charging or normal charging on-street being so expensive that it can be difficult to recoup the costs merely by selling electricity. This service therefore may need to be supplemented by, for example, charges for parking or lighting.

For public rapid charging there are problems in that initially there will be too few vehicles making use of the opportunity, at the same time as there is no standard for what the charging equipment should look like. Support for expansion of extra infrastructure should preferably not be made until at least a European standard is in place. For normal charging a standard of this kind is planned within a year or so, whilst different forms of more rapid charging will be standardised later. Between European power companies and vehicle manufacturers close corporation has been going on for a while, and an initial standardisation proposals for rapid charging exists today, which is compatible with the existing Swedish voltage levels of 400 V.

In order to benefit from supplementary infrastructure expansion this expansion needs to be carried out in environments where it may be assumed that there is a need for it, and where there will presumably be a large number of electric vehicles and plug-in hybrids. What is more, there should be an opportunity of drawing conclusions about how the expansion should be achieved at the least possible cost. These support the idea of conducting trials at a limited number of places in Sweden, at the same time as local initiatives to produce large numbers of vehicles may mean that it is motivated to evaluate trials in several places.

There are also reasons for developing the infrastructure in several different environments, as Sweden, for example, is a country where vehicles are tested in a cold climate. All vehicle types need to operate in a cold climate too, and for this reason there has for a long time been a well-developed test environment in northern Sweden.

Another reason for evaluating several different environments is that the vehicle, subcontractor and component industry may need to analyse both the vehicle and the infrastructure close to the development location.

The greatest difficulties in supplementary expansion is presumably in the urban environment, at the same time as rapid charging in the longer term may be a solution for transport between cities.

Trials with extra infrastructure should also be conducted for both passenger cars and buses and different sizes of truck.

A number of companies have already taken an initiative to extra expansion. Vinnova, commissioned by the government and later with the participation of both the National Road agency and the Energy Agency, has developed TSS, Test Site Sweden. The aim is to coordinate tests of the infrastructure for active safety within the vehicle field and later also projects for expanding the infrastructure for electric vehicles. TSS is based in Göteborg as its primary area of work in western Sweden and northern Sweden. The intention is, apart from tests benefitting Swedish business, also to attract foreign players to locate trials in Sweden like those already carried out for cold climate testing.

Within the framework of the bilateral collaboration with the USA in the energy field there is an agreement on exchanging information about how electric vehicles and plug-in hybrids are used. TSS already acts as a coordinator of this information. In this way Swedish companies can obtain information about how electric vehicles, plug-in hybrids and different forms of infrastructure trial are conducted in the USA. This is with the aim of facilitating the export of products and services to the USA, at the same time as information about how the expansion is going on in Sweden will create an interest in supplying goods and services in this country.

Based at Chalmers University of Technology but with operations also at the University of Lund and at the Royal Institute of Technology in Stockholm is the Swedish Hybrid Vehicle Centre, SHC. The aim is to pursue non-competitive hybrid vehicle research in collaboration with the Swedish automotive industry. The results compiled by TSS camera will be used within SHC.

A joint project trialling the expansion of the charging infrastructure will, from the arguments given above, take a number of years before a joint strategy for expansion has been drawn up and can be implemented.

The trials should be carried out a number of places and should take cognizance of the following:

- charging rates
- payment systems
- technological solutions (the basis of standards etc)
- climate
- on-street location
- business models (including charging at shopping centres etc)

The aim is to be able to recommend how an exapansion nationwide might be carried out.

The work should be closely linked to those processes for standardisation of the infrastructure which are ongoing.

12.1.3 Innovation, coordination and procurement

With the aim of strengthening new business, the development of companies and a reduction in costs, the programme should contain support for innovative ideas and methods of working which may be able to reduce the cost of vehicles or infrastructure, or an ncreasing acceptance of electric vehicles and plug-in hybrids. Coordination of the entire project is also required not least bearing in mind later stages such as evaluation, conclusions about infrastructure investments etc.

One kind of innovation may be business models for expanding infrastructure and for apportioning battery costs. The programme should therefore be proactive in providing incentives for innovation and trials with, for example, different business models.

In order to reduce costs and support buyers the programme should also contain elements of coordinated procurement or technology procurement. If coordinated procurement shows that there is a major interest on the part of buyers, this may also be a stage in clarifying to the suppliers that there is a market for these products in Sweden.

12.1.4 Follow-up and evaluation

The description above indicates a major need for evaluation and following developments. An R&D project should be initiated to follow up and evaluate trials with the aim of understanding which customers choose electric vehicles and plug-in hybrids, and why they choose these vehicles. What is more, the projects should be aimed at studying the conditions in which the use of electric vehicles and plug-in hybrids may increase, as well as the vehicle characteristics and the infrastructure that is important for a greater use of these vehicle types.

This is required with the aim of assessing the size of the potential for greater energy efficiency and reduced climate impact as a result of an expansion of electrification of road vehicles.

12.1.5 Information and international cooperation

Developments within the field are occurring worldwide, and a national trial should therefore follow and analyse international developments, at the same time as the programme should participate in international developments within the field with the aim both of boosting the development generally and of aiding Swedish industry with knowledge and networking so that existing and new companies can develop.

12.1.6 Budget and timescale

If the programme is to be able to aid development within the field, then both a relatively large number of vehicles and a real trial of the expansion of the charging infrastructure are needed. What is more, support is required for information, communication, evaluations, and not least industrial development. To evaluate and follow up the process of a change in society such as the introduction of electric vehicles takes a long time. The Energy Agency is therefore initially proposing a four-year electric vehicle programme. The budget proposal below is based on a programme start in 2010. From those projects carried out by KFB in the 1990s it is understood that one should presumably aim at several thousand vehicles in order to be able to draw any real conclusions concerning infrastructure. Several years will also be needed to develop and follow the infrastructure expansion.

If the additional cost of vehicles initially is between SEK 50,000-150,000, and the number of vehicles required in order to draw conclusions about the expansion of infrastructure needs to be several thousand, then the resources for the vehicle support for the electric vehicle programme need to be SEK 100 million - 300 million. Precisely how much support needs to be apportioned via the framework of the electric vehicle programme depends on the proportion of additional costs, which should come from the electric vehicle programmes and how the environmental classification system is designed. Beyond this resources may be needed for trials of developmental vehicles and heavy vehicles, whose additional costs are considerably higher.

The expansion of the infrastructure is more difficult to assess, but support should be possible for additional costs.

One rapid charger may cost several hundred thousand kronor. SEK 20-50 million is a cautious estimate of the scope of the support.

Innovation, coordination and procurement are from a budget viewpoint less expensive if the technology to be trialled is either aided through the support for vehicles or the infrastructure. The processes in themselves, however, require some aid, and are assessed here as requiring a framework of SEK 30 million over a four-year period.

Follow-up and evaluation will to a great extent need to be financed by the electric vehicle programme. The scope can be compared with the projects from KFB in the 1990s, and are assessed here at SEK 50 million over a four-year period.

Information and international cooperation are assessed as needing less in the way of a natural resources, but the scope is nevertheless assessed over a four-year period as being SEK 20 million.

In total this is a question of between SEK 250 and 600 million for the first four-year period.

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