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Summary and Recommendation of the
14th Assembly of the Energy Forum at SNI

Electric and Hybrid Vehicles

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ELECTRIC AND HYBRID VEHICLES

Summary and Recommendations of the Energy Forum Discussion No. 14

Samuel Neaman Institute, the Technion

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Cover photographs - courtesy of Alon Buchnik and Sharon Goldrath

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Chapter 1: Introduction

The Samuel Neaman Institute for Advanced Studies in Science and Technology, within the framework of its activity in the field of Energy, holds "Energy Forum" meetings, devoted to discussions and debate over subjects of national importance in this area. Focused discussions are held in the Energy Forum on specific subjects, with the participation of a panel of experts, who are invited according to the subject under discussion. The aim of these focused discussions is to deliberate over relevant and specific questions, to enable dialogue and coordination between participating bodies and to arrive at recommendations regarding implementation strategies to promote the subjects, which can be presented to decision makers.

The meeting at which electric and hybrid vehicles were discussed was held on June 1st, 2009, at the Technion, with the participation of experts on this subject from the industrial, entrepreneurship, academic, governmental and public sectors. The forum participants who were selected carefully for their thematic expertise, constitute, undoubtedly, a unique group of first-rate professionals in the areas of transport and electricity in general, and on the subjects of electric and hybrid vehicles in particular.

In the first part of the meeting, some of the participants presented information on the subject of electric and hybrid vehicles and their different aspects. The participants' presentations can be found on the website of Samuel Neaman Institute: http://www.neaman.org.il (events). In the second part of the meeting, an open discussion was held on the information that had been presented and on the operative conclusions that should be drawn from it.

The essence of the discussions is summarized in this report, and as with the previous discussions, it will be submitted to decision makers in an effort to put the subject of the introduction of electric and hybrid vehicles on the public agenda, since it is expected to have a significant influence on the Israeli motor system, as well as on the aspects such a change could have on Israel's electricity sector, environmental quality and more.

Chapter 2: Background

Developing means of transportation that are not based on fossil fuel is of high priority on the public agenda of many countries around the world. This is an efficient and necessary means to prevent air pollution, reduce pollutants and eliminate the emission of greenhouse gases.

The term "electric vehicle" refers to four major systems of propulsion:

- Hybrid vehicle (HEV) –already present on the Israeli highways. The vehicle is equipped with an electric battery and an internal combustion engine along with an electric motor, which can also be used in the reverse mode as a generator. Vehicle drive is supplied by the electric motor, with the help, if necessary, of the combustion engine; the battery is charged by the electric motor when it operates as a generator while the vehicle is being propelled by the combustion engine. A computerized system controls the vehicle performance, bringing the usage of the two propulsion devices to an optimal state.

- Plug-In Hybrid Vehicle (PHEV) – a vehicle that has two power systems like the HEV, but enables the electric battery to be charged directly from the electric grid.

- Full Electric Vehicle (EV) – with an electric motor only.

- An electric vehicle that produces the electricity required to propel it by fuel cells.

In hybrid vehicles, the internal combustion engine is smaller than in conventional vehicles, working at nearly optimal conditions. As a result, it is more economical and less polluting. On the other hand, its power is relatively low and it does not have high acceleration ability. When acceleration or uphill driving is needed, the electric motor joins the combustion engine and they both provide the necessary power. A common property of all four types of vehicles is regenerative braking, that is, exploiting the braking energy to charge the battery by turning the electrical motor into a generator. As a result, a lot of energy is saved – actually, most of the energy that is dissipated by the brakes of conventional vehicles.

It is estimated that the order in which these vehicles will enter the market will be dictated by their technological maturity: hybrid vehicles, which already exist in Israel, then next generation Plug-In vehicles followed by the completely Electric Vehicle, and finally vehicles that produce their own electricity.

In addition to the clear advantages of introducing the electric vehicle into the market, the benefit of reducing the dependency on oil for economic and strategic-political reasons should be taken into consideration.

The disadvantages of electric vehicles, at present, are mainly in the areas of the amount of electricity that can be stored in the battery, which is expressed in a limited driving range, and, of course, in the vehicle's price, of which the battery cost is the main component.

In November 2007, the Israeli Government resolved to encourage non-fuel transportation. The resolution is cited in Appendix 2, and includes several major objectives. A lot of criticism was leveled at this resolution,[1] mainly concerning the fact that the government resolution was not backed by an appropriate budget, that it did not take into consideration the government's power as a dominant buyer in the market, and that it was based on questionable data such as driving range of the future vehicles, their relative share in the Israeli automobile fleet and the existence of vehicles with an independent electricity production source. The green taxation program, introduced formally only recently,[2] will grant buyers of electric vehicles tax benefits, so that their retail cost will be similar to that of a standard, conventional vehicle. Such an affirmative action will truly encourage the introduction of such vehicles into the market, as is already the case with hybrid vehicles. The tenets of the green taxation reform on the subject of electric vehicles are presented in Appendix 3.

[1] Follow up on the implementation of resolution 2580 by the Government regarding the encouragement of non-fuel transportation, The Knesset Center of Research and Information, March 2009, http://www.knesset.gov.il/mmm/data/docs/m02235.doc

[2] The green tax reform will be put into action on August 1st. YNET Vehicles, 8.6.2009

Chapter 3: Information regarding electric and hybrid vehicles

This part of the report provides a summary of the information presented by some of the participants, each according to his choice and expertise. The presentation made by the speakers can be seen, as already mentioned, on the website of the Neaman Institute (http://www.neaman.org.il). Naturally, there is some overlap between the different speakers; however, the report editors decided to present the information as it was presented at the meeting and in the same order (see Forum Schedule in Appendix 1). This information is important and constitutes the basis for the open discussion held afterwards, as presented in Chapter 4.

Dr. Dan Weinstock, Better Place Ltd.: The Electric Vehicle Project – Overview

A comprehensive global survey held recently indicates that about 70% of the world population thinks that the government in the country in which they live should replace oil as the main source of energy. Oil, which is a major force in the global energy market in general and in the transportation market in particular, is today at its peak usage level and according to all the forecasts, beyond the point of saturation it is expected to slow down and reach a global lower usage level. The right point for a substantial change in the nature of the market is the moment before the slump.

The electric vehicle is not a new or revolutionary idea. Already years ago, in the early days of motor vehicles, early attempts were made to develop and launch electric vehicles on a massive scale; however, the conditions at the time were unsuitable and the technology was not sufficiently developed. Now we think that the conditions are more favorable. All over the world, consumers are pushing for alternative transportation, because of economic and political reasons, and, of course, to aid the global struggle against the processes of climate change.

Better Place Ltd. was established in 2007, with an initial investment of about $200 million, having at the present 150 employees globally. Better Place is not an electricity-generating company, nor a car-producing company. The Company actually constitutes a middle interface between these two factors: it executes infrastructures to deliver electricity from the Israel Electric Corporation (IEC) (or any other electricity producer, for that matter) to the cars themselves, hoping to expand the market and penetrate other niches in this market in the future.

The basic assumption is that about 90% of the people driving an electric vehicle would be able to charge their cars 90% of the time using simple infrastructures (such as night charging at their private parking, charging at public parking lots, and so on). Still, in case of long range driving, when the driver cannot stop for three hours mid-journey to charge, battery replacement stations will be needed.

The global market of electric vehicles, which was a miniscule niche in the past, is gathering momentum at present and almost every large automobile-producing company in the world today has one or more electric or hybrid vehicle model.

Up to the present, 400 charging stations (or 800 charging points) have been installed in Israel in public car parks, and a prototype of a battery replacement station exists. Clearly, such a project could have broad implications on the electric grid in the country, which we will discuss later in detail.

The main problems involved in the introduction of electric vehicles are:

- The range allowed by the capacity of the battery is not large enough for certain populations; it could be a problem for taxi drivers, for example. It should be noted that there are solutions to this problem, such as battery replacement stations, for example.
- The battery is expensive – it increases the price of the vehicle.
- The battery waste needs to be treated.

Dr. Dan Kotek, Israel Electric Corporation: IEC's activity in the field of electric vehicle

I will briefly review the IEC activity on the subject of electric vehicles over the years. As already mentioned, there were a number of earlier attempts to address this subject. Already in the 1980's, IEC operated a purely electric vehicle, with lead batteries, that was able to travel about 100 km without recharging. Later, during the 1990's, there was another wave of activity, while at present we are witnessing a global surge of activity by Better Place, among other companies.

The advantages of electric vehicles are:

- Reduced air pollution and noise in urban centers
- Diversification of energy sources
- Relatively low operating costs
- Relatively low maintenance costs
- Effective exploitation of the electricity production systems, and especially by encouraging nighttime consumption.

Main disadvantages:

- High initial purchase cost
- Short and problematic driving range
- Heavy investment is required for developing infrastructures for recharging.

During the 1990's, a company by the name of Electric Fuel (Delek Hashmali) was operating in Israel, developing zinc/air batteries. These batteries had some good qualities, but suffered from problems resulting from a much more complicated infrastructure for recharge than the system discussed at present. The batteries were not charged directly from the electricity mains supply but through a process of electrolysis. This is a complicated process and developing an infrastructure to support it would require great investments. At the time, the IEC purchased the franchise for this technology in Israel and in the entire Middle East. The focus was on vehicles for long range, not necessarily short range driving.

In terms of air pollution, there is a significant difference between a vehicle with an internal combustion engine and an electric vehicle. The comparison presented in Table 1 (in units of gr/km) is based on electricity production for charging batteries in a combined-cycle power plant using natural gas.

Table 1: Levels of pollution emitted from different vehicles

Pollutant	Vehicle with internal combustion engine gr/km	Electric vehicle (combined-cycle electricity) gr/km
SO_2	1.65	0.03
NO_x	0.54	0.51
CO	14.3	0.16
CO_2	285	173
HC	0.65	0.017
Particles	0.10	0.007

IEC is interested in the subject for several reasons. Primarily, the fact that the subject is popular and a useful public relations tool cannot be ignored. In addition, IEC views electric vehicle owners as good consumers, because it would enable the company to "flatten" its demand curve and direct a higher consumption level to the night hours. Such a bias in electricity consumption is an advantage in terms of the national system: it allows to regulate the great consumption differentials existing today between the peak hours during the day and the off-peak hours at night.

Dr. Tzvi Rosenman, Energy Consultant: Electric power availability and price for electric vehicles in Israel

The speaker examines energy consumption for power in an electric vehicle in comparison with that in a gasoline-powered car. The energy consumption of a car with electric power is 0.25 kWh/km. This value includes the electricity consumption for power during driving together with electricity losses during battery recharge. The data are presented for a standard vehicle, with an engine displacement of 1.8 liters, consuming one liter of gasoline for each 10 km. The comparison was based on the current tariff in the energy system in Israel. Electricity tariffs in Israel change according to the season and the hour of the day.

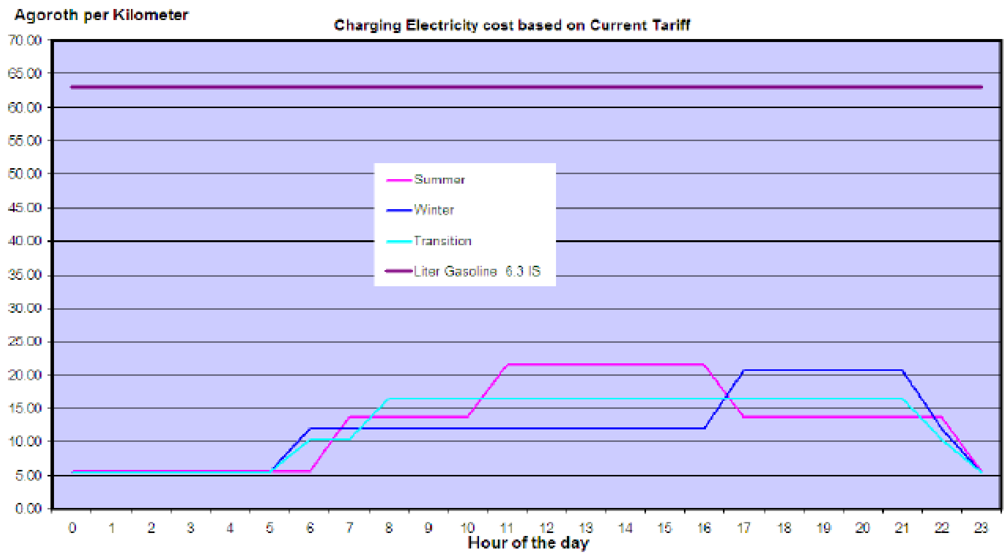


Figure 1: The cost of operating vehicles with gasoline and electricity (Agoroth per km).

Figure 1 presents the energy cost of a vehicle with electric power only, according to the battery charging hours. If the battery is charged during the night, the cost of the electric "fuel" is 5 Agoroth per km, in comparison with 63 Agoroth per km, the cost of gasoline. If the vehicle is charged in the summer during daytime, the cost of the electric "fuel" increases to 22 Agoroth per km. Indeed, this cost of the gasoline vehicle includes a high tax rate on gasoline. If we take the gasoline cost in the USA at $2 per gallon, which is about 2 Shekels per liter, then the cost of fuel per km in a gasoline car is very close to the cost of electric "fuel" during daytime hours in the summer (it is assumed that the cost of electricity in the peak of summer in the USA is almost equivalent to that of Israel).

The peak demand for electricity in Israel in the summer months is during the daytime. During these hours, the electricity tariff is considerably higher than at other hours. Since there is a significant difference in prices between the different consumption hours, the timing of charging is a critical factor for sustaining the advantage of the "fuel" price in an electric vehicle, even before considering the availability of electricity during peak hours. If charging during nighttime is possible, we will have a significant advantage. However, charging during peak hours and connecting the vehicle to an electric charger at the work place or in a shopping center could lead to a situation in which the vehicle is charged when the electricity tariffs are so high that the advantages of using it (only in terms of price) diminish.

Figure 2 presents the reserves existing in the electricity system for the year 2015 (according to a development plan by the Ministry of National Infrastructures, without building power plants designated to provide electricity for electric vehicles). Figure 2 indicates that during the summer, days 180-280 (day 1 is January 1st, 2015), the electricity reserve will be less than 1000 Megawatt and there are days on which the reserve will be reduced to 200 Megawatt. This analysis of the expected load on the electricity mains supply in 2015 shows that for the capacity installed in the country, during daytime in the summer there will simply not be any available electricity to charge electric vehicles.

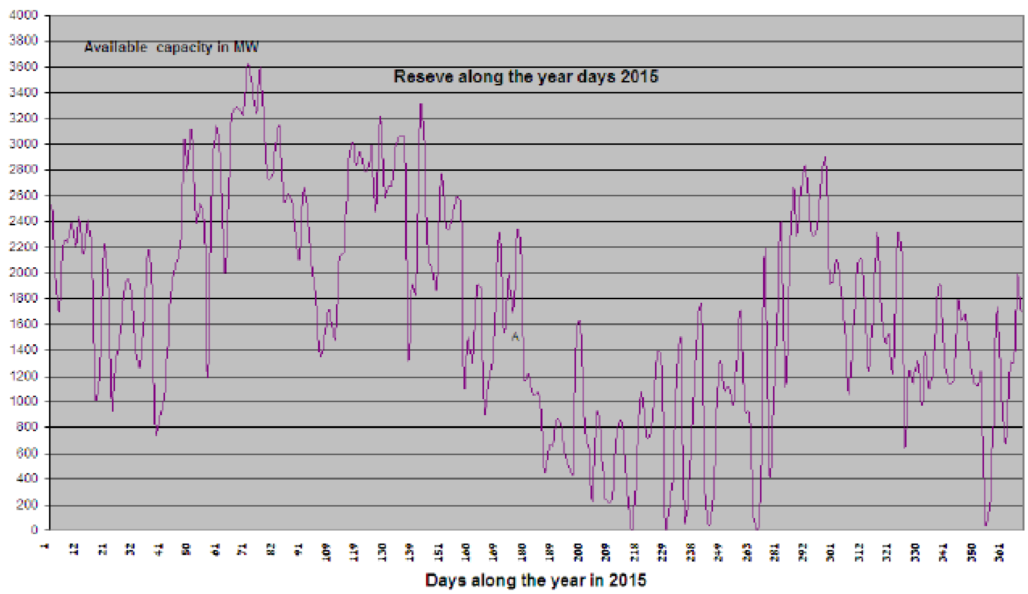


Figure 2: Available reserve in electricity system in Israel during 2015

Prof. Emanuel Peled, Tel Aviv University: **Cost and properties of batteries for electric and hybrid vehicles**

I would like to discuss the major properties of the hybrid vehicle (HEV), plug-in hybrid electric vehicle (PHEV) and full electric vehicle (EV). The battery size determines the driving range without having to use an internal combustion engine.

Figure 3 describes the use of the charge stored in the battery (SOC=State of Charge). The total energy content in the battery is indicated on the right. Each of the batteries has a charging capacity that is not used directly by the motor (indicated on the left, in red). In PHEV type vehicles, we are interested in exploiting the possibility of charging from the electricity mains in order to improve the driving range. In this situation, we are using most of the battery's energy, leaving only very little for charge and discharge (bright yellow). When the vehicle is a fully electric one, about 80% of the battery capacity is charged and discharged every day (bottom line).

When charge and discharge cycles of batteries are examined, a significant difference can be seen between the different types of batteries (Figure 4). Clearly, the charging cycles limit the battery life and it is evident that, from this point of view, the most efficient (for 2003) is the NiMH battery. Assuming that a battery is depleted and needs charging on a daily basis, the indicated longevity of 4000 chargings is equivalent to 15 years. Today, several Lithium-Ion batteries provide more cycles than the NiMH battery.

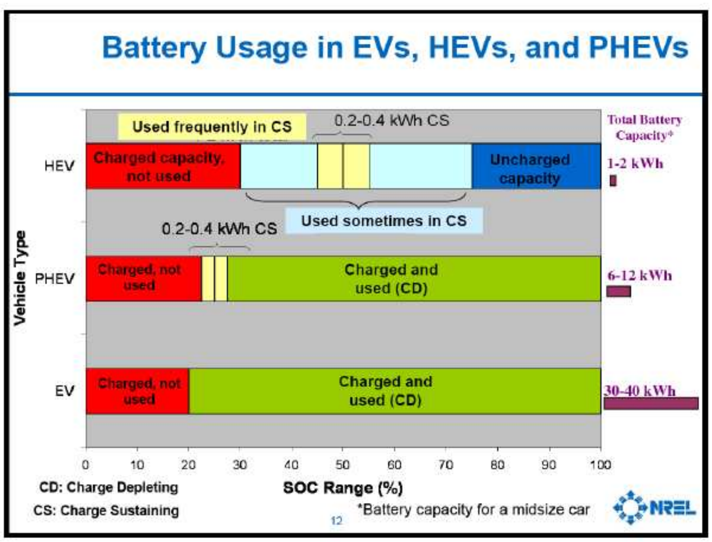


Figure 3: Division of charge in the battery by battery type

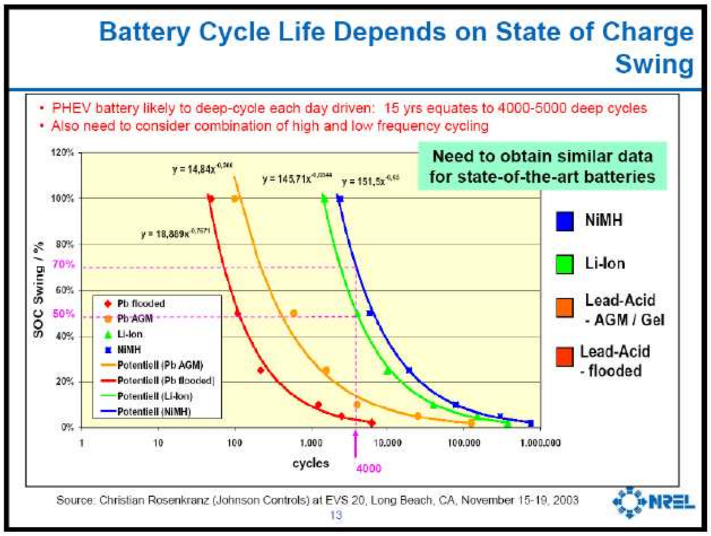


Figure 4: Charge and discharge cycles of batteries of different types (2003 data)

Table 2: Advantages and disadvantages of batteries of different kinds:

Battery	Advantages	Disadvantages
$LiNiCoO_2$/Graphite	Energy density	Low safety, high price
$LiMn_2O_4$/Graphite	Reasonable price, high safety, power density	HT longevity
$LiFePO_4$/Graphite	Life cycles, power, high safety	Low energy density (about 60% of LNCO)
$LiMn_2O_4/Li_4Ti_5O_{12}$	Life cycles, power, safety	Lowest energy density (about 40% of LNCO)

Table 2 describes the advantages and disadvantages of different types of Lithium battery. The types marked with green and underlined are safer, with the battery of the type **$LiMn_2O_4/Li_4Ti_5O_{12}$** being the safest.

With the existing technology, expanding the driving range of a PHEV vehicle from 10 miles (PHEV10) to 40 miles (PHEV40) could double the car price. It can be expected that, with improved technology, the prices will decrease.

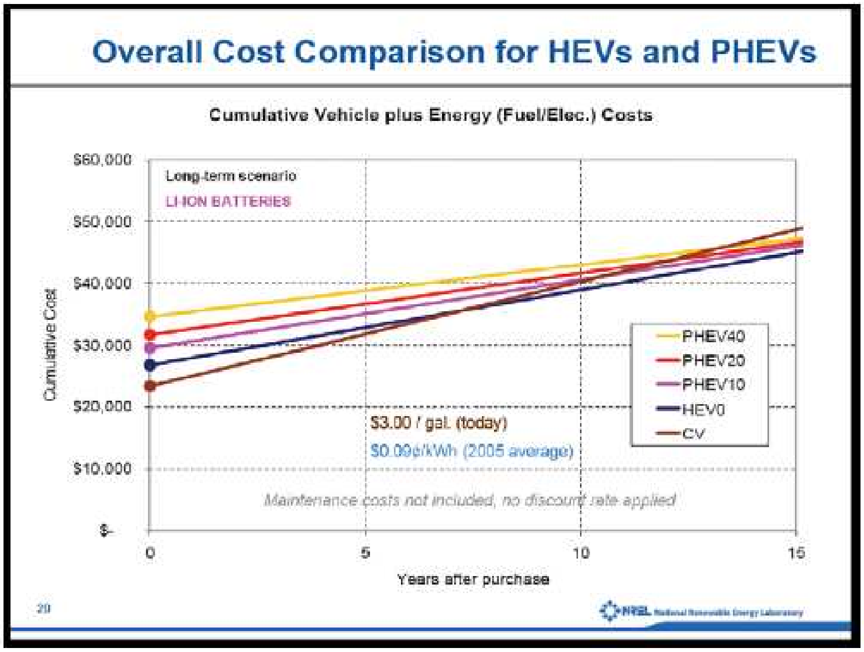


Figure 5: Overall cost comparison for conventional, HEV and PHEV vehicles

Figure 5 presents a comparison of the overall retail price of vehicles over the years. It is evident that the usage duration in which it is economically cost-effective to purchase an electric vehicle of any kind in comparison with a conventional (CV) one is between 7 and 12 years. Figure 5 indicates that for the known purchase prices in the USA today, ranging between $22,000 and $35,000 for CV or PHEV40 vehicles, respectively, with the cost of a gasoline being around $3 per gallon, an electrically charged vehicle will be more cost-effective after about 10 years. On the other hand, assuming an increase in the gasoline price up to a level of $5 a gallon, a cost-effective price will be achieved after 4-7 years only, depending on the model (Figure 6).

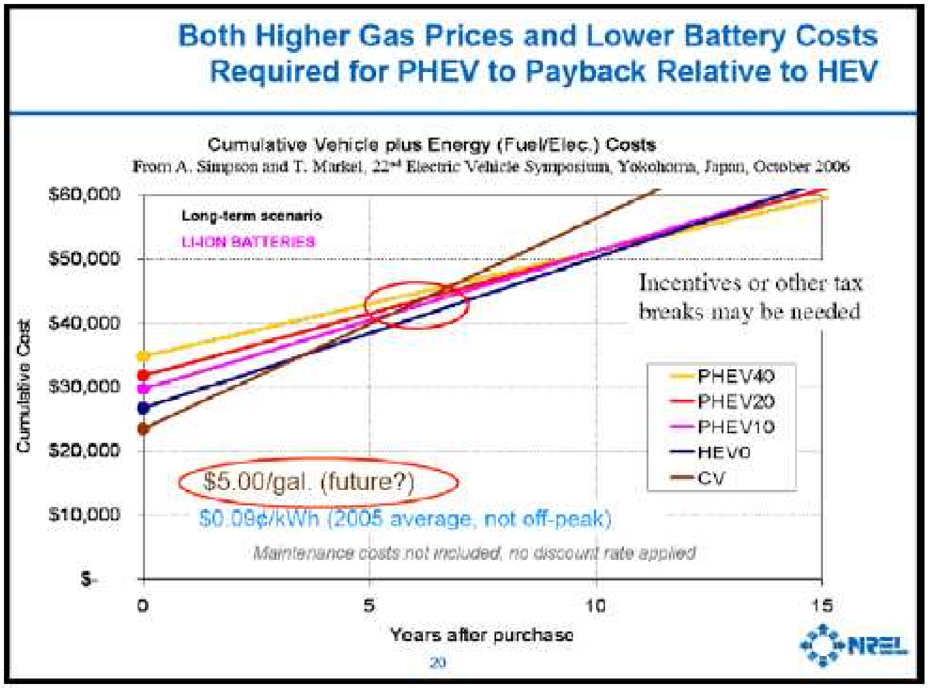


Figure 6: A comparison of total costs for fuel price of $5.00/gal

The main question, however, is what will happen in the future? At the end of the technological development, what will be the market share of each type of vehicle? This will depend, of course, on the price, which determines the penetration rate into the market. For example, it is expected for PHV60 that a price addition of 70% and 30% (beyond a conventional vehicle) will lead to a market penetration at a rate of 10% and 50%, respectively. Clearly, targeted subsidies and regulations will promote the process of market penetration, as well as promoting the issue of renting small vehicles in the cities.

Ofer Ben-Dov, Assif Strategies: The potential of improving air quality in an urban environment

In the Dan metropolitan area, there is a problem of nitrogen oxides, whose origin can be traced to transportation-related pollution. We would like to reduce the vehicle impact on the air quality in the city. There is great potential for improving the air quality in the city, as demonstrated when the level of pollution is measured during Yom Kippur, for example, when the volume of traffic is reduced dramatically.

Similar findings were obtained in a study conducted by Yuval et al., analyzing the data obtained in the Haifa region during the Second Lebanon War.[3] The study indicates that the reduction in the level of measured pollution is higher than the relative part associated with the transportation sector, and this is probably related to the proximity of the measuring stations, and of the public, of course, to this source of emission. Thus, it can be concluded that the improvement in air quality in an urban environment due to extensive usage of electric vehicles will be significant.

Figure 7 presents different vehicle technologies and their emission levels per driving mile, with the electric vehicles hardly visible in the Figure; that is, the massive entry of electric vehicles will lead to a reduction of almost 100% in the emission of classic pollutants from transportation within the cities.

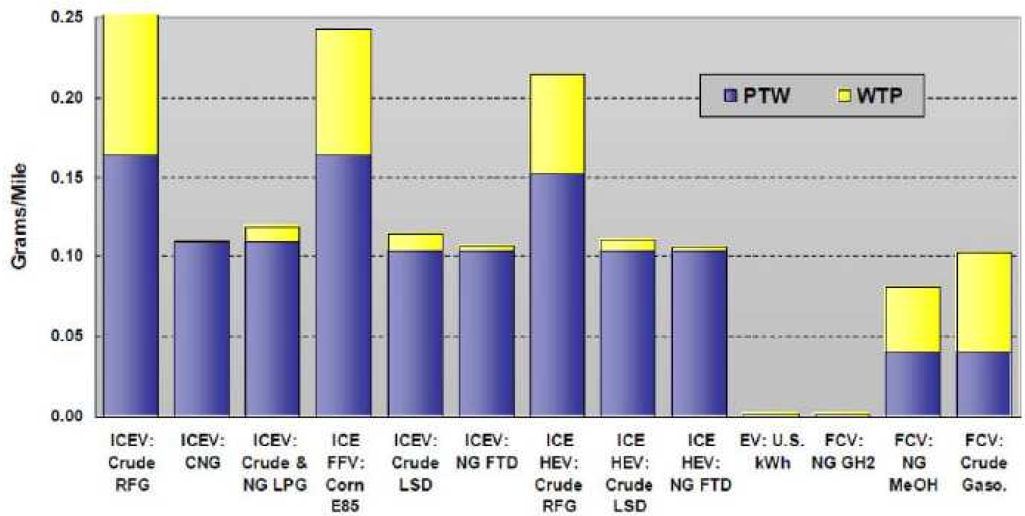


Figure 7: Emission levels of VOCs for different vehicle technologies

Source: Well-to-Wheels Energy and Emission Impacts of Vehicle/Fuel Systems, Center for Transportation Research, Argonne National Laboratory, presentation at the California Air Resources Board Sacramento, CA, April 14, 2003.
http://www.transportation.anl.gov/pdfs/TA/273.pdf

Abbreviations used in Figure 7:

[3] Yuval, Flicstein B., Broday D.M. (2008), **The Impact of a forced reduction in traffic volumes on urban air pollution**, *Atmospheric Environment* 42 (3), pp. 428-440, 2008.

PTW – Pump to Wheels

WTP – Well to Pump

ICEV Crude RFG - Internal Combustion Engine Vehicle, using reformulated gasoline

ICEV CNG - Internal Combustion Engine Vehicle, using compressed natural gas

ICEV Crude & NG LPG - Internal Combustion Engine Vehicle, using natural gas- based liquefied petroleum gas

ICE FFV Corn E85 - Internal Combustion Engine flexible-fueled vehicle, using ethanol (E85) blend

ICEV Crude LSD - Internal Combustion Engine Vehicle, using low-sulfur diesel

ICEV NG FTD - Internal Combustion Engine Vehicle, using natural gas based Fischer-Tropsch diesel

ICE HEV Crude RFG - internal combustion engine with hybrid electric technology, using reformulated gasoline

ICE HEV Crude LSD - internal combustion engine with hybrid electric technology, using low-sulfur diesel

ICE HEV NG FTD - internal combustion engine with hybrid electric technology, using natural gas- based Fischer-Tropsch diesel

EV US kWh – Electric vehicle based on US electric grid mix

FCV NG GH2 - fuel cell vehicle, using natural gas- based gaseous hydrogen

FCV NG MeOH - fuel cell vehicle, using natural gas- based methanol

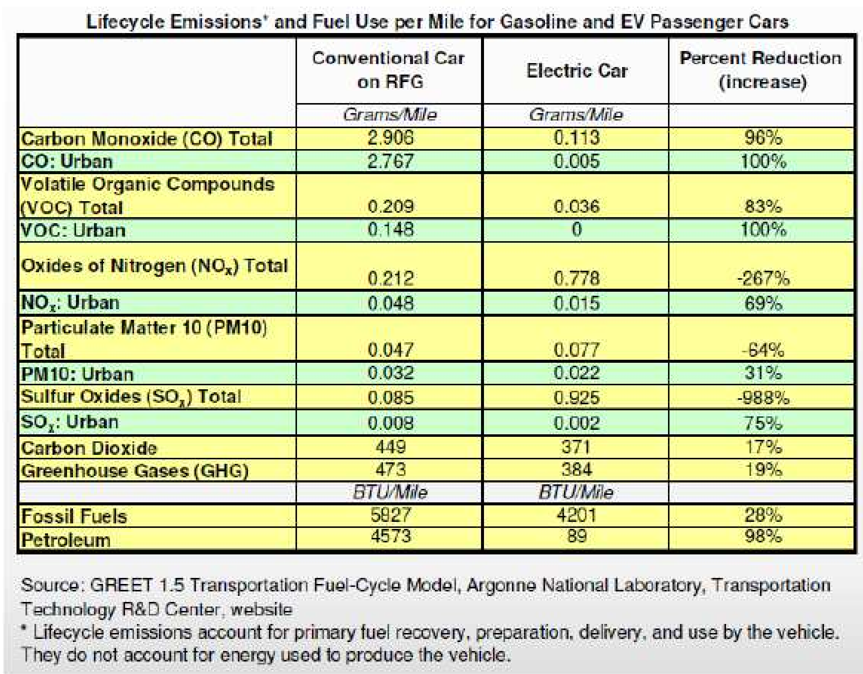
FCV Crude Gaso - fuel cell vehicle, using crude gasoline

In order to examine a case of sweeping treatment of a large vehicle fleet, (for example: a fleet of small taxis – diesel vehicles that drive many kilometers, most of them within the city) the data of the Israel Central Bureau of Statistics were used to calculate the extent to which emissions could be reduced between 2015 and 2020. The outcomes of this scenario indicate that in this way, it is possible to cause a significant reduction in the emission of pollutants in an urban environment.

It should be remembered that there is an element of pollutant diversion here. We are not getting rid of the pollution but diverting it out of town, where the power plant is located.

Table 3 describes emission data from conventional vehicles vs. electric ones, based on data from the USA. The electricity mains supply in the USA is not significantly different from the Israeli grid in terms of production sources. Although the Americans use sources such as hydro and nuclear power, the ratio of production from coal and from gas is similar to that in Israel.

Table 3 – Pollutant emission from different vehicles


Lifecycle Emissions* and Fuel Use per Mile for Gasoline and EV Passenger Cars

	Conventional Car on RFG	Electric Car	Percent Reduction (increase)
	Grams/Mile	Grams/Mile	
Carbon Monoxide (CO) Total	2.906	0.113	96%
CO: Urban	2.767	0.005	100%
Volatile Organic Compounds (VOC) Total	0.209	0.036	83%
VOC: Urban	0.148	0	100%
Oxides of Nitrogen (NO_x) Total	0.212	0.778	-267%
NO_x: Urban	0.048	0.015	69%
Particulate Matter 10 (PM10) Total	0.047	0.077	-64%
PM10: Urban	0.032	0.022	31%
Sulfur Oxides (SO_x) Total	0.085	0.925	-988%
SO_x: Urban	0.008	0.002	75%
Carbon Dioxide	449	371	17%
Greenhouse Gases (GHG)	473	384	19%
	BTU/Mile	BTU/Mile	
Fossil Fuels	5827	4201	28%
Petroleum	4573	89	98%

Source: GREET 1.5 Transportation Fuel-Cycle Model, Argonne National Laboratory, Transportation Technology R&D Center, website

* Lifecycle emissions account for primary fuel recovery, preparation, delivery, and use by the vehicle. They do not account for energy used to produce the vehicle.

The table shows positive numbers in the right column, representing a reduction in the rate of pollutants, while the negative numbers represent an increase.

In measurements of pollutants of the type NO_x and So_x, an absolute increase in emissions was obtained, mostly in electricity-producing, sparsely populated areas. This finding has to be examined vis-à-vis the question of the emission standards from power stations, what measures for monitoring and controlling them are installed and what is the level of control over the emitted pollution. It should be remembered that the emission occurs at a high altitude and outside the city, in contrast with the emission from vehicles occurring close to the ground and in the cities.

Sigal Shusterman, Tel Aviv University: **Electric cars: A blessing or a problem for the environment?**

The subject of our research was a comparison between the emission of carbon dioxide from conventional vehicles, in their different types, and the emission of pollutants from an electricity production site for Plug-In Electric Vehicles (non-hybrid).

An average car today emits about 162 gr of CO_2 per one km driving; estimates of the hypothesized future scope of emission have been made for the forthcoming years (see Figure 8).

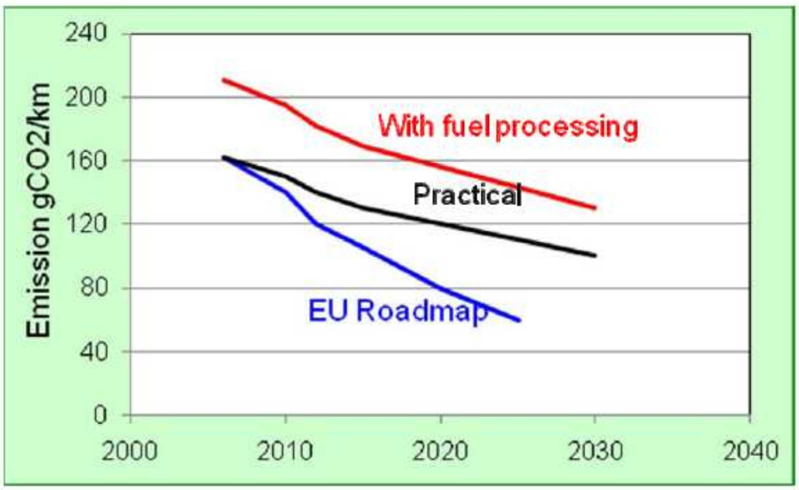


Figure 8: reduction objectives for CO_2 emissions for the next 20 years

In Figure 8, the blue line describes the declared objectives of the European Union for a reduction of 20-30% in emissions. Up to now, there were many delays in the schedule set for these objectives, and therefore the scenario was updated for a more realistic prognosis, described by the black line. The red line represents the total level of pollutant emission, including pollutant emission due to fuel processing up to emissions resulting from car driving. For this comparison, pollutant emission data from electricity production is required. A global scenario by the IEA organization examined the global electricity consumption, assuming that no policy changes will occur. According to this scenario, most of the electricity production until 2030 will originate from non-renewable sources. An alternative scenario by the same organization examines an environmental policy that will contribute to the development of renewable energies. In this scenario, there is a slight decrease in electricity consumption; however, most of the electricity system will still rely on non-renewable energies - 78%.

For the sake of analysis, the source of the additional electricity required for electric vehicles should be stated:

In the basic scenario (Mix) – a mix of energy sources for electricity production according to IEA analysis with a small contribution of renewable sources.

In the middle scenario (Fossil) – the mix of energy sources for electricity production will include non-renewable sources only, because the increase rate of renewable sources is not sufficient to contribute to the additional amount needed for vehicles.

In the strict scenario (Coal) – all the additional electricity for the electric vehicles will originate from coal, because this is the most available and cheapest source.

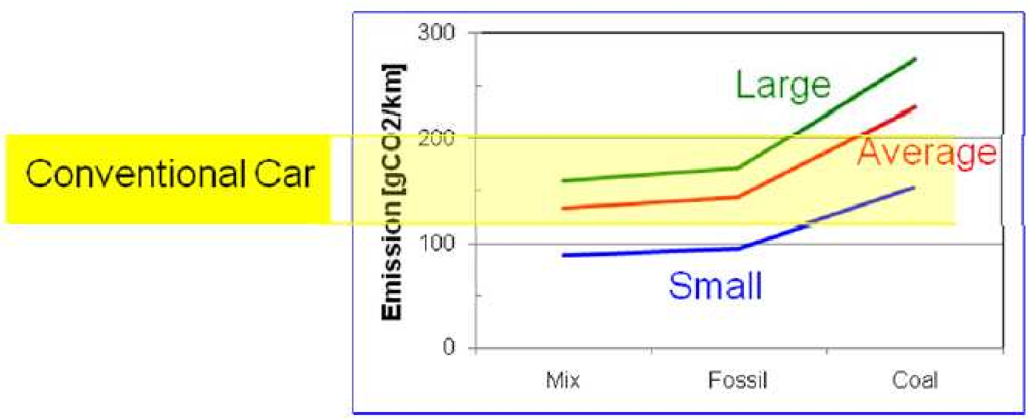


Figure 9: Emission levels under different electricity production scenarios

Figure 9 describes the emission levels of carbon dioxide from different cars (small, medium, large) under three different scenarios of electricity production. In most of the cases (except for a small car with a combined energy mix), we will receive emissions that are essentially similar or relatively higher than the emission range of conventional vehicles (marked in yellow).

In summary, there is a possibility of reducing the emission of greenhouse gases because of the penetration of electric vehicles into the transportation system; however, this reduction potential is limited and depends on vehicle improvements, as well as on the rate of the renewable sources used for the additional electricity production. We maintain that massive introduction of electric vehicles into the market should be postponed until sufficient provision of renewable energy sources at a significant level in the electricity system is obtained. Otherwise, environmental damage may result in terms of production of greenhouse gases.

Dr. Dan Weinstock, Better Place Ltd.: The implications of electric vehicles on segments of the electricity system: Production, transmission and distribution, and electricity consumption of electric vehicles

The influence of electric vehicles on the electricity system was examined in a study conducted by the Ministry of National Infrastructures. The main conclusion of this study was that charging all the private vehicles in Israel (if they were electric vehicles) would require a 14% expansion of the electricity production system. This study did not examine the expected influence on the transmission and distribution systems and did not take into consideration the existence of a company such as Better Place, which manages the charging system.

In our view, there are three charging options:

- Random charging
- Time-directed charging, driven by a graded price
- Charging managed by a control center (such as that of Better Place).

The expected electricity production for 2020 is dictated by the scenario. The company's estimates indicate as follows, for the above three scenarios:

- Scenario 1 – an addition of 2345 MW is required
- Scenario 2 – an addition of 1770 MW is required
- Scenario 3 – no addition to the production system is necessary.

The transmission system will also require changes. In scenarios 1 and 2, significant monetary investments will be required, while in the case of scenario 3, nothing has to be added.

Upgrading the electricity distribution system will require expenses in all three scenarios; however, the expenses in scenario 3 are minimal, relative to the two other scenarios.

The above data lead to the conclusion that managed charging does not require significant costs in upgrading the electricity system, in contrast to the two other scenarios.

Dr. Perry Lev On, Levon Group: **Overview of U.S. Federal Vehicle R&D: PHEV, EV and Charging Infrastructure**

I would like to review briefly the history of the developments in the USA in this area. Due to concerns on the subject of climatic changes and air pollution, new ways are being sought to reduce fuel consumption, although for many years there was no substantial change in the efficiency of vehicles, since the day they were invented. The electric car model EV1 was presented for the first time in 1990. There were three models of the vehicle then, and in total, 1117 vehicles were produced. The program was stopped in 2003, for obscure reasons and is shrouded in mystery and in conspiracy theories to this day. The vehicles were actually crushed, for no known reason to this day.

In hybrid vehicles (HEV), such as Toyota Prius, the predetermined standards for fuel consumption were unrealistic to begin with. Calculating the economic cost of such a vehicle is problematic, because it depends largely on the nature of driving, type of charging, climatic influences and many other uncontrolled variables. The next generation of the PHEV type opens up new possibilities. There is no doubt that with time we are going to see a replacement of the use of fuel, and charging from the electricity mains during off-peak hours. There is already an extensive use of batteries today in the range of 40 miles. This driving range satisfies most people. The batteries are a major element in the vehicle and there are new generations of batteries, which constitute the development basis of electric vehicles. As for now, the price is still high and more changes and technological improvements are necessary.

It is estimated that the essential change will take place now, following the new policy of President Obama. It is estimated that heavy investments will be directed to promote the above vehicles and the elements of advanced batteries.

On the subject of reducing and managing the load on the electricity system, there are solutions today, such as devices that manage electricity consumption according to the load and hourly cost. There is also a shock absorber whose goal is to prevent all the consumers charging at once and creating a sudden overload on the system.

Chapter 4: Discussion

In the second part of the Forum, an open discussion was held about the information presented and the operative conclusions to be drawn. To focus the discussion, several questions were presented in advance, as follows:

- What is the expected cost of an electric vehicle to the private customer?
- What would be the cost of driving one km, considering the costs of electricity, maintenance and depreciation?
- What would be the driving range of an electric vehicle between battery recharges/replacements?
- How to cope with the huge increase in the electricity production capacity that would be required as an infrastructure for the electric vehicle?
- How to cope with the safety problems expected during battery replacement (see criticism by Mercedes).
- What is the life cycle of the batteries (for electric and hybrid vehicles)?
- What is the expected benefit in improved air quality in towns due to the use of electric vehicles?

The participants' responses are presented here in the order in which they were heard and without editing. The next chapter presents the summary and conclusions of these responses.

Eddie Beit Hazavdi: Further to what has been said up to now, I recommend conducting an economic examination of the hybrid vehicles that are already in existence. These vehicles are currently on the road and, and in our experience, are highly efficient.

In the already existing vehicles, it is possible to reach a driving ratio of 18-20 km for one liter of fuel. No infrastructure and no technological change are required for their current operation, and a considerable percentage of the national fuel consumption is saved.

Due to preferential taxation, there are no significant differences in cost to the consumer between hybrid and equivalent conventional vehicles.

Dr. Shlomo Wald: First, we have to speak about the comprehensive perception of the future transportation system. It is necessary to devote true and correct thought to the introduction of a "clean" public transportation system, free of charge, in the city, which will provide a cheap and convenient way of moving from one place to another. In this perception, private vehicles stay out of the city. In this scenario, there is no point in promoting electric vehicle projects, because electric vehicles for out of town driving are only a partial solution and in most cases, an inconvenient one. When driving out of town, the batteries could reach a state of full discharge, which will affect their longevity to a considerable degree. If the total transportation solution means that the private vehicle would not be driven in town, the entire perception is changed, and there would be no need to promote vehicles of the Plug In type.

In general, a clean vehicle by definition can be chargeable or have an independent mechanism for electricity production. In total, when all things are taken together, there is no significant difference when electric and conventional vehicles are compared, from the aspects of pollution level or economy; the only advantage left is that of energy independence and reducing the dependency on oil. Due to the difficulty of Plug-In vehicles to provide an efficient solution for interurban driving, I tend to think that this is not the desirable solution.

Prof. Joseph Prashker: In general, urban transportation and urban transportation systems are a very complicated problem. Research indicates that reducing the fares of public transportation, and even making it free of charge, does not change the amount of passengers using public transportation very much. On the other hand, the quality of service does encourage travelling by public transportation. In general, the questions of public transportation systems are separate and very complicated, and do not concern our discussion.

On the subject of electric vehicles that are mechanically powered, I came across a technology in the literature that was not mentioned here: an internal combustion engine that is disconnected from the transmission and powers a generator, works at the optimum point and produces electricity. Electricity is what powers the car, in most cases through direct connection to the tires. It is claimed that this kind of system saves fossil energy, to the point that the vehicle consumes only 35% of the fossil fuel consumption of conventional vehicles. In such a system there are no losses due to distribution, there is no range limit, and there are no mechanical complications.

Eddie Beit Hazavdi: Regarding the investment in infrastructures, it is clear that in the case of the hybrid vehicle or a vehicle that produces its own energy, there is no need for additional infrastructure. In the case of an electric vehicle, a huge investment is required, in the scope of billions, in infrastructure. In addition, I would like to focus again on the subject of Israel's electricity system. The system has today, and is expected to have in the future, many customers and consumers – including the electrification of Israel Rail, suburban trains and more, in addition to electric vehicles. It should be ascertained that the system is capable of supplying the required electricity.

Ilana Teler: The charging stations that were described in the background discussion could satisfy 90% of the charging requirements. I would like to ask about the stations for battery replacement. Will they have any environmental implications? Where will they be installed? What type of area are we talking about?

Dr. Dan Weinstock: The natural location for battery replacement stations is, of course, in the existing gas stations. In terms of area – this is possible; a small area will have to be cleared within the gas station area. Other possibilities for the location of the replacement stations are the car parks of shopping centers, rest areas along highways, and so on. In an open space, we could allow ourselves to spread over a larger area. Clearly, we would prefer to use the existing infrastructures. Regarding the subject of the impact on the environment, standards and so on, because the subject is technologically new, there is still no knowledge or experience in this field. We are racing against time to define needs, required regulations and suitable standards.

Dr. Miriam Lev On: I would like to discuss two main subjects:

Fuel Cells – the subject of Freedom Car in the USA began with fuel cells. As of today, most research efforts in the USA are directed at the development of fuel cells, and huge funds are being poured in to promote the subject. This mechanism allows extremely low emissions, although the fuel cells themselves are powered by diesel fuel. Hydrogen is produced from the diesel fuel and it activates the fuel cell.

Air pollution in the cities: if electric vehicles will be introduced extensively, pollution might be reduced but not the congestion. There will still be traffic jams. It should be remembered that the main pollution resulting from Volatile Organic Compounds (VOC) comes from the evaporation of gasoline, not from the combustion emissions. Clearly, when there is no fuel, we would expect to see a decrease in VOC; however, when there is no internal combustion engine, VOC evaporation will remain, and we will not have succeeded in eliminating it altogether.

Prof. Emanuel Peled: At the forefront of development in Japan today is a vehicle of the PHEV type for a range shorter than 40 miles. With such a vehicle, those who are driving less than 40 miles will not have to refuel at all. The main problem is the price, and despite preferential taxation, there will still be a significant difference in prices between conventional and PHEV vehicles. Actually, in the first stage it would be for the rich only. People in this population level have in most cases houses with adjacent parking, and under slow pace night charging you can connect the vehicle to an electric outlet. Until we reach the stage of market penetration, when we get an overload on the network, there would be smart plugs to manage domestic consumption from the electric grid.

Another subject to consider is battery replacement and the safety of the entire system. Today, batteries of the Lithium-Ion type dominate the market, to the extent of 6 billion dollars a year. According to statistics, the probability of fire or battery explosion during work ranges between 1 to 10 for each million cells a year. In a battery that includes 5000 cells one cannot ignore the risk, which could reach 1:200 up to 1:2000. A fire or an explosion of this kind of battery in a laptop computer or a mobile phone is not pleasant, but not life risking. In a vehicle that is driving on the highway, it is a serious safety problem. The technology of a safer battery (for example **$LiMn_2O_4/Li_4Ti_5O_{12}$** or **$LiFePO_4$/Graphite**) exists today with 40% to 60% of the driving range of a regular Lithium-Ion battery. The technology, as mentioned already, did not prove itself yet. However, there is no doubt that in terms of safety it would be advantageous. Any step of unloading or installing a battery in a vehicle has the potential for a safety problem, because if a short circuit occurs by accident, the temperatures rise very quickly and an immediate explosion could occur. While a laptop battery could ignite a spark of 50A, the spark of an electric vehicle battery is hundreds to thousands Amperes and is highly dangerous.

Vehicles powered by fuel cells currently cost 2 or 3 times more than a conventional vehicle. A significant reduction in price should be expected if and when people will start to purchase and use these vehicles. It is possible to use conventional fuel as a source of hydrogen for the fuel cell through a reformer. It is expected that the efficiency of a vehicle powered by a fuel cell will be double that of a vehicle powered by an internal combustion engine. This will fully compensate for the high cost of hydrogen relative to fossil fuel. Today, most of the vehicle producers in the world develop vehicles powered by fuel cells with a driving range of more than 400 km between refills (and are expected to reach 600 km). European studies indicate that if one takes into consideration all the different aspects (including environmental), the cost of using fuel cells fed by hydrogen for transportation will be similar to the cost of using fossil fuel.

Dr. Shlomo Wald: The engine of the fuel cell with hydrogen is large and heavy and therefore not applicable to private vehicles. On the other hand, it could be used to power buses, with large hydrogen tanks located on the roof of the bus that will provide power for a whole day's itinerary. Safety wise – comparing the combustion of such hydrogen tanks with an equal amount of gas or fuel – despite the myth – hydrogen will burn in a less risky manner.

Dr. Perry Lev On: I would like to quote a Mercedes expert (Thomas Weber) from the newspaper *The Marker* – who claims that Better Place battery replacement is dangerous and cannot be implemented.[4]

According to what they say today in the USA – the increase in electricity consumption in the economy due to the introduction of electric vehicles is a myth. They are not expecting any problem with the electricity mains supply meeting the loads of excess charging. It is a problem of demand management.

Dr. Shlomo Wald: In the case of a full electric vehicle, such as the model suggested by Better Place, my estimate is that the average driver will not be ready to accept a situation in which he connects the car for recharging and the vehicle is not charged because of load diversion considerations.

Dr. Dan Weinstock: Regarding the concern of overload on the electricity mains, it should be remembered that the Light Train does not constitute a significant load (about 500 kW for each wagon) and the same holds for an electric train (the engine needs only 5 MW).

Regarding the requirement for immediate charging – the problem of needing urgent charging is not really important. Statistically, most people do not leave their homes on the

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4 http://www.themarker.com/tmc/article.jhtml?log=tag&ElementId=skira2009310_1069865

spur of the moment. If the need arises for urgent charging, it would be possible to use the "charge me now" mode, allowing immediate charging, independently of the load on the electricity mains.

The driving range of the vehicle is limited and to overcome this problem, 120 replacement stations will be built to meet this need exactly and to allow quick battery replacement.

The business plan of Better Place includes also selling such vehicles to transport officers of large transport fleets. We are not in contact only with the end user. We are talking here about a massive replacement of a very large number of vehicles, through the work place, that is, a significant penetration into the market within a very short time.

Sa'ad Omri: The state of Israel is characterized by a relatively low level of motorization and transportation annually, relative to data from developed countries. At the same time, we witness heavy traffic loads in the Dan metropolitan region that will continue to increase without a real solution to the problem of transportation.

One of the solutions suggested by the Ministry of Transportation is using public transportation instead of private vehicles. We welcome the development of non-polluting, electric vehicles as a supplementary solution to the massive use of public transportation for daily travelling.

Dr. Dan Weinstock: Better Place is interested in commercial success in Israel, but this is not our only focus.

Regarding larger vehicles, the company made a decision not to enter this market segment; however, we have to understand that this market does exist, and is probably developing. In the Beijing Olympics in the summer of 2008, the entire transportation from and to the Olympic village was based on electric buses, and the batteries were replaced with robots within 7-8 minutes, while fueling a bus with diesel takes 12 minutes. This is a relatively easy project to implement, and the same is true of any vehicle driving in a closed route. In such a situation, the vehicle could be left at the charging station, and the driver could move to another bus and continue his work.

Regarding vehicle replacement – many people tend to replace their car every three or four years anyway. Our goal is to convince them to choose for their next car an electric vehicle.

Prof. Gershon Grossman: Regarding the evolution of vehicles, we could use an example from the field of refrigerators: in the old refrigerators, the cooling systems used Freon gas of the CFC type. When the CFC gas was banned due to its impact on the environment and because it affects the ozone layer, an alternative cooling gas was introduced in the new refrigerators. Clearly, no one throws away his old refrigerator in an instant, but when the day comes and the need arises to replace the refrigerator – the customer can decide what is cheaper and what is better, especially when specific regulations are in place that remove the inferior refrigerators from the market completely.

Dr. Bernanda Flicstein: We are in the midst of a study about the influence of removing pollution out of town, and its actual transportation to electricity production plants. Our preliminary results indicate that for most pollutants, a decrease in concentration was observed; however, for some of them we observed an increase. In addition, there is a problem of quantification and the economic weighing of a ton of pollutant. We are relying on the estimates of the European Union, which allow us to assign a cost to each pollutant. Therefore, we are trying to make a total estimate of the total environmental change that could occur because of the introduction of electric vehicles. Such a study will eventually provide us with better knowledge.

In the emission of pollutants from a power plant that is equipped with a high chimney, there is dispersion and dilution and this should be taken into consideration when pollution is removed from the city.

In addition, it should be remembered that reduction of fuel consumption reduces also the activity at the gasoline filling stations, a polluting agent in itself. We could expect to see an improvement in the pollution resulting from the stations themselves, from the transportation of fuel to the stations and from the activity of the refineries.

Zeev Shadmi: Taxation has two major objectives – creating income for the State but also demand and load management. Taxing fuel directly influences the marginal cost of travelling, and could encourage people to travel less, or to choose other alternatives, such as public transportation. Electric vehicles free of tax or with reduced taxation encourage people to drive their car and create highway congestion. We have to make people think properly about vehicle usage, and pay for the driving costs in full, including external costs. It is impractical to have two electricity tariffs – one for battery charging and one for domestic use. We could impose direct taxation on transportation such as toll roads or overload toll. In some countries there are advanced preparatory processes for general taxation on transportation with different tariffs, different hours, etc., so that the user incurs the external costs of travelling.

Regarding the decision to encourage and promote electric vehicles, the state could grant a significant tax reduction when there are only few such vehicles. When the penetration into the market becomes massive, a decision will have to be made to change the tax structure or to abolish the reduction.

Dr. Tzvi Rosenman: Regarding the fuel cells – I was involved in a study in which the energy efficiency and pollutants emitted from fuel cells or electric vehicles were compared – for all types of emissions and on the entire subject of energy efficiency, from fuel sources to the use in driving. In all the cases examined, the electric vehicles were more efficient and caused fewer emissions than vehicles powered by fuel cells. This is our conclusion. Regarding the interaction between electric vehicles and the electricity infrastructure in Israel – towards 2015 the IEC is preparing itself for the expected demand, and as for now, the forecasts did not take into consideration electric vehicles. We want to see whether a large-scale effect by electric vehicles is expected. There is a problem in the summer and there is no other way but to employ some control system. There is a huge advantage to the introduction of electric vehicles as customers of the electricity market, because this will entail a reduction in the average price of electricity for all the customers of the electricity system. The average price will be lower because the current electricity tariff includes all the power stations, most of which are not working during off-peak hours. If we could manage usage so that the stations will work more hours for the above vehicles, mainly during off-peak hours, we could actually lead to a reduction in the electricity price. The average tariff will be lower because the existing stations will produce electricity in much better ways and will generate additional income. All this holds only in a situation in which demand management is enabled and situations of demand surplus during peak hours are avoided, that is, if there will be no need to expand the production and electricity transmission systems just because of the vehicles, and they will be charged through the already existing system.

Prof. Emanuel Peled: I seem to disagree because the fuel cell has zero pollution. That is why it is better.

Prof. Gershon Grossman: If the IEC knows that it has a large consumer for the nighttime, it could operate a power plant of the base- load type, which is more efficient and less polluting. This is a great advantage.

Dr. Dan Weinstock: There is another advantage here, reserved for customers with maximal flexibility: during an unexpected failure of a substation, it would be possible to employ a program of load shedding. Such a mechanism certainly suits Better Place because we can control the charging load immediately and simply. A simple calculation shows that for 100,000 vehicles waiting to be charged, each charging at 6 kW, we are talking about a total load of 600 MW. This is actually the load of a power station, which the IEC could manipulate according to production convenience and load.

Another possibility to consider is the reverse operating mode of delivering electricity to the grid, by discharging the batteries, when there is a fault or a problem initiated by the IEC. It should be remembered that electric vehicles are moving for about 1.5 hours a day and standing still for 22.5 hours. This is possible when it is pre-planned by the IEC and Better Place.

Zeev Shadmi (notes made following the meeting):

1. In my opinion, we cannot state that electric vehicles have an advantage without any reservation or stipulation: there is surely no economic advantage, because with the price ratios existing today, the cost of driving electric vehicles, which includes also the cost of the vehicle purchase, is expensive in most of the scenarios. The scenario of high kilometrage was not examined in practice! I doubt that electric vehicles can perform high kilometrage without degradation of the batteries, and therefore the calculation done is theoretical and needs the accumulation of experience and proof. In addition, the economic considerations were made based on gasoline prices that include almost 100% tax, in comparison with electricity prices that are off-peak prices with the addition of VAT only.
2. The battery replacement mechanism is by my estimate inapplicable and is expected to fail. The vehicle producers will not be willing to invest in a designated vehicle, because of uncertain demand, and therefore there will be no vehicles in the market with removable batteries. I also assume that the buyers and users of electric vehicles will be those whose needs do not require high kilometrage, and at the same time

have convenient charging possibilities (for example, automobile fleets of service providers, high-tech companies that provide free parking to their employees, individuals with private parking near their home).

3. Although standards and regulations could be established to enforce electricity charging only from certain installations and at certain hours, thus pricing uniquely electricity for vehicles, which will be different from the price of electricity for industrial and domestic consumption, in my opinion, it would actually be impossible to enforce them (there will always be a way to circumvent the regulations). Many will do what the electric vehicles producers indicate (rightfully!) as one of its marked advantages – charge from any domestic socket.
4. The limitation of the electricity production capacity is a real problem: there has to be a solution to enlarge the reserve between production capacity and demand by (1) increasing the capacity (2) energy efficiency and (3) extensive usage of TOU (Time of Use) mechanism in order to transfer usage from peak to off-peak hours.
5. A different kind of electric vehicle might evolve, carrying the generator (gasoline or diesel) in its trunk, which produces the electricity to charge the battery. Such a vehicle has many advantages, and some say that it could provide travelling that is similar to that of a common gasoline vehicle for 20% of the fuel consumption.

In summary, I would try to summarize the document by saying that electric vehicles should be given a chance, but at the same time other developments should be followed, in the fields of conventional driving which has not had its last word yet (it is claimed that there is a potential to achieve an improvement of up to 50% in fuel consumption for 1 km with a gasoline engine!), of different combinations and methods of electric power with an internal combustion engine and of full electric vehicles.

Tal Goldrath and Dr. Ofira Ayalon (data processed and delivered following the meeting):

Undoubtedly, the entire subject under discussion, whether about hybrid or electric vehicles, does not concern the major problem of the increased usage of private cars versus the usage of public transportation systems. This is a subject to be discussed separately. The Samuel

Neaman Institute had discussed the subject of the load and congestion on the roads in the document of national priorities on the quality of the environment.[5]

The leasing and the company car mechanisms forming part of the salary benefit, which are common today in Israel, actually offloads the charging costs onto the employer. In such a case, just as in the case where the driver does not incur the fuel costs, the car user is indifferent to the price, and therefore also to the charging hours and the tariff.

To calculate external costs of using this type of vehicle or another, we used the data presented during the discussion, as well as cost coefficients used by the Tax Authority to estimate external costs of different pollutants emitted from vehicles. Table 4 below describes the results.

The table shows that the external cost according to IEC calculations indicates a gap of almost two times in favor of electric vehicles (21 versus 11.41 Euro for 1000 km driving distance). On the other hand, in the calculations presented by Mr. Ben-Dov, the differences indicate that for some pollutants there is an increase in the emissions with electric vehicles and therefore the price of the external costs is similar, with a small gap in favor of the conventional vehicle.

Dr. Perry Levon (notes delivered following the meeting):

The problem of electromagnetic radiation, which exists in both electric and hybrid vehicles, cannot be overlooked. See overview in Appendix 4.

Dr. Dan Weinstock (notes given in response to the participants views after reading the draft of this report):

Contrary to a laptop computer, the disassembly and installation of a battery are not done by the end user but by a robot in an unmanned environment. Battery replacement is certainly doable. A demonstration facility in Yokohama demonstrated to thousands of Japanese engineers (who know a thing or two about robotics) the feasibility of replacement.

[5] National Priorities on the Subjects of the Quality of the Environment – Position Paper No. 6 – Vol. C – Transportation and Environment in Israel 2008 – Follow Up Report.

Table 4 – A comparison between pollutant emissions from different vehicles

Pollutant	Cost coefficient[6] (Euro/ton)	Pollutant concentration (gr/km of driving distance)				
		Pollutants emitted from internal combustion engine vehicles		Pollutants emitted from electric vehicles		Urban air pollution (USA data)
		According to IEC[7]	USA data[8]	According to IEC (combined cycle station)	USA data	
SO_2	2304	1.65	0.053	0.03	0.58	0.001
NO_x	10000	0.54	0.132	0.51	0.48	0.009
CO	500	1.43	1.806	0.16	0.07	0.003
CO_2	30	285	279	173	231	
HC	900	0.65	0.13	0.017	0.02	
PM	20000	0.1	0.029	0.007	0.05	0.014
Total cost (Euro/1000 km driving distance)		21.05	10.59	11.41	14.09	0.37

In response to the comment that the average driver will not agree to wait for charging in the off-peak hours: the reasonable driver does not insist on the amount of energy in the battery increasing every time he returns to his car, just as he does not fuel a gasoline car every day. What is important to the driver is to arrive safely at his next destination.

It was said that the cost of driving electric vehicles, which includes also the vehicle purchase cost, is expensive in most of the scenarios. If we take into consideration the differences in taxation and a model in which the battery is not purchased by the car owner,

6 According to a press release on behalf of the Tax Authority

http://www.mof.gov.il/TaxesPage/Lists/List2/Attachments/1/2009-701.doc

7 Data were taken from a lecture by Dr. Kotek

8 Data were processed from the lecture given by Mr. Ofer Ben-Dov, Table 3, above.

the cost of driving an electric vehicle is significantly cheaper than that of a gasoline vehicle.

Regarding electromagnetic radiation: Better Place conducted an extensive study with the leading consultant in Israel on the subject of electromagnetic radiation, Oren Hartal – the former Chief Scientist in RAFAEL. The study indicates that there is no resemblance between the level of electromagnetic radiation of electric and hybrid vehicles due to dramatic differences in the location of the different electrical components in the two vehicles. The level of electromagnetic radiation from electric vehicles is equivalent to that which is emitted from a conventional gasoline vehicle (it originates from the steel fibers in the tires) while the radiation level from hybrid vehicles is higher.

Regarding the emission of carbon dioxide: the advantage of electric vehicles over conventional ones depends on the mix of fuels used for electricity production. There is no doubt that the whole world, including Israel, is moving in the direction of increasing electricity production from renewable energy sources and therefore the energy source to drive electric vehicles will be less involved with the emission of carbon dioxide.

Chapter 5: Conclusions and Recommendations

Before summarizing the discussion held on the subject of electric and hybrid vehicles, we have to remember that the mere usage of private vehicles, whether equipped with an internal combustion engine, or being hybrid or electric, is not compatible with the principles of sustainable development, due to the need for roads and infrastructure, and due to the congestion caused by the vehicles in the center of towns and so on. The discussion held in this forum is not dealing with these issues but is considering different alternatives for private vehicles only.

Electric vehicles of all the four types mentioned (EV-FC, EV, PHEV, HEV) have several marked advantages to the state and society, which justify the encouragement and support of the government. These advantages include reduced air pollution in town centers (but not necessarily a total reduction in air pollution), the possibility of using a variety of energy sources – including renewable energies – and reducing the dependency on imported oil, and low maintenance costs.

All four types of electric vehicles feature regenerative braking, that is – using the braking energy to charge the battery. As a result, a lot of energy is saved – actually, most of the energy that dissipates in the brakes of conventional vehicles.

The hybrid vehicle (HEV), which exists already in the market, does not require any special, costly infrastructure, and saves fuel to a significant degree in comparison with a conventional vehicle. A hybrid vehicle could save up to 40% under driving conditions where all of its advantages come into play. Some of the time, driving is not done under such conditions; however, a conservative estimation would show a rate of saving achieved in practice close to 20%. If all conventional vehicles had been replaced by hybrid vehicles, which does not require any special preparation, about 20% of the gasoline and diesel fuel for driving vehicles in the country would have been saved! According to the Israel Central Bureau of Statistics, fuels for transportation constitute 45% of the energy end use in Israel, about 13.5 million ton of oil equivalent (TOE) a year. This figure includes also ships, airplanes, trains and trucks, but even if we assume that only half of the above amount is destined for passenger cars – the saving is most significant.

Regarding PHEV and EV, there is another advantage – that of efficient exploitation of the infrastructure of electricity production due to the system utilization at nighttime – most important for the state of Israel which is an "island" of electricity. Along with the advantages, some of the disadvantages should be mentioned, mainly the high price which results mainly from the cost of the batteries. Regarding full electric vehicles (EV), one has to mention the limited driving range.

Vehicles of the PHEV and EV type do not require the establishment of a massive charging infrastructure (except for specific improvements of the existing infrastructure). The battery replacement infrastructure is very expensive and its cost may amount to billions. The cost of charging infrastructure is incurred by the private sector. What is relevant is the part needed to upgrade the existing electricity system, a cost eventually incurred by the public. This could be done gradually. Charging the vehicles has to take place during the off-peak hours to avoid overloading the electricity production system, and therefore control and monitoring mechanisms, as well as "smart" charging management, are crucial. The move to these types of vehicles holds in store many advantages, as noted above.

Electric vehicles have no economic advantage at present, because with the price ratios existing today, the cost of driving electric vehicles, which includes also the cost of the vehicle purchase, is expensive in most of the scenarios. The mechanism for replacing batteries is problematic, and some say that it is bound to fail. Although it is possible to set standards and regulations that will oblige electricity charging only from certain facilities and at certain hours, this would be difficult to enforce.

Scientists are currently working on the development of a different kind of electric vehicle, carrying the generator (gasoline or diesel) in its trunk, which produces the electricity to charge the battery. Such a vehicle has many advantages, and some say that it could provide travelling that is similar to that of a common gasoline vehicle for 20% of the fuel consumption. Many research efforts are currently under way worldwide to develop more efficient engines, fuel cells, and so on. Clearly, the last word has not been said in the field and the improvement efforts are at their peak.

Electric vehicles should be given a chance, but at the same time, other developments should be followed in the fields of conventional propulsion, which has not had its last word yet, of different combinations and methods of electric power with an internal combustion engine and of full electric vehicles.

Hybrid vehicles are already present on Israeli roads, and thanks to the green taxation reform, some of the economic barriers to importing these cars to Israel have been removed.

Recommendations:

1. During the use of electric vehicles and in light of the small reserve of electricity production in Israel, it must be ascertained that charging these vehicles will not be done during peak hours (through higher rates, for example).
2. The side benefits of using electric vehicles in terms of reducing the need for gas stations and reduced noise (mainly in the cities) should be considered. On the other hand, it must be ascertained that if a facility for battery replacement is established – it will not cause environmental damage.
3. One of the important parameters in electricity production for charging electric vehicles is the fuel used for generating the electricity. The above calculations by the IEC were based on a comparison with a combined cycle station operating on gas. It is reasonable to assume that if a comparison were made with a coal-fired power station, the results would be different. Therefore, a full comparison should be conducted, which includes the internalization of external costs, between using conventional, hybrid and electric vehicles. The calculation presented in this report is preliminary only.

Appendix 1 –Energy Forum program: Electric and Hybrid Vehicles –

13:00 – 13:10:	Foreword
13:10 – 13:20:	Dr. Dan Weinstock, Better Place Ltd.: The electric vehicle project – overview
13:20 – 13:30:	Dr. Daniel Kotek, Israel Electric Company: The IEC's activity in the field of electric vehicles
13:30 – 13:40:	Dr. Tvi Rosenman, Ariel University Center of Samaria Electricity availability and price for electric vehicles in Israel
13:40 – 13:50:	Prof. Emanuel Peled, Tel Aviv University: Cost and properties of batteries for EVs and hybrid EVs
13:50 – 14:00:	Mr. Ofer Ben-Dov, Assif Strategies, Ltd.: The potential for improving the air quality in an urban environment
14:00 – 14:10:	Ms. Sigal Shusterman and Prof. Avi Kribus, Tel Aviv University: Electric vehicles: A blessing or a problem to the environment?
14:10 – 14:20:	Dr. Dan Weinstock, Better Place Ltd.: The implications of electric vehicles on segments of the electricity system: production, conduction and distribution, and power consumption by electric vehicles
14:20 – 14:30:	Dr. Perry Levon, The Levon Group LCC: Overview of US Federal Vehicle R&D: PHEV, EV and Charging Infrastructure

14:30 – 15:00 Intermission

15:00 – 17:00: Open discussion, focusing on the following questions:

- What is the expected cost of an electric vehicle to the private customer?
- What would be the cost of driving one km, considering the costs of electricity, maintenance and depreciation?
- What would be the driving range of an electric vehicle between battery recharge/replacement?
- How to cope with the huge increase in the electricity production capacity that would be required as an infrastructure for the electric vehicle?
- How to cope with the safety problems expected during battery replacement (see criticism by Mercedes).
- What is the life cycle of the batteries (for electric and hybrid vehicles)?
- What is the expected benefit in improving the air quality in towns as a result of using electric vehicles?

17:00: Conclusion

Appendix 2 – Government Resolution no. 2580 on the encouragement of non-fuel transportation, November 11, 2007

Further to the decision of the Prime Minister and the Minister of Finance to review favorably the introduction of alternative technologies, non-polluting ones, for fuels and transportation, in order to reduce the dependency of the State of Israel on fuel and to join the global trend that is based on reducing the environmental damage in general and the damage resulting from using fuel for private vehicles in particular, it was decided to examine, within a short schedule, the possibility of initial implementation of these technologies in Israel, and for this purpose, to appoint an inter-ministerial Steering Committee, headed by the budget controller in the Finance Ministry and with the participation of representatives from the Prime Minister's Office, the Ministry of Transportation and Road Safety, the Ministry of National Infrastructure, the Ministry of Industry, Commerce and Employment, the Ministry of the Environment, the Justice Department, the Tax Authority, Israel Antitrust Authority and the Planning Administration in the Ministry of the Interior, to examine suggestions to encourage the use of clean and non-fuel transportation (below – Steering Committee).

In addition, secondary panels will be established regarding the following issues, to submit their conclusions and recommendations to the Steering Committee as follows:

1. Taxation incentives: A panel, headed by the Economy Assistant Director General at the Tax Authority, and with the participation of representatives from the Budget Department in the Finance Ministry, the Ministry of the Environment, the Ministry of Transportation and Road Safety and the Ministry of National Infrastructure, will devise ways to encourage alternative technologies that are not polluting, for fuels for transportation and to reduce the congestion on the roads. The panel will submit its conclusions by December 1st, 2007.
2. Encouraging R&D with international automobile industries: The Chief Scientist at the Industry, Commerce and Employment Ministry will make recommendations, within the existing routes in the field of the Chief Scientist, concerning the correct government policy to encourage R&D of alternative technologies that are not polluting, for fuels for transportation. The panel will submit its conclusions by February 15th, 2008.
3. Planning and licensing on the matter of the establishment and operation of a charging network in country-wide deployment: a panel headed by the head of planning administration at the Ministry of the Interior and with the participation of a representative of the Budget Controller at the Ministry of Finance, a representative of the Ministry of National Infrastructure and a representative from the Justice Department, will devise a modus operandi in the field of licensing and/or planning, to the degree that these are required, for the establishment and operation of a charging network in country-wide deployment, used for charging electric vehicles (below – national network), in a way that uniform rules will apply, as much as possible, all over the country. The panel will submit its conclusions and recommendations by February 15th, 2008.
4. Influence on the electricity system: A panel headed by the General Director of the Ministry of National Infrastructures and with the participation of the Budget Controller and the General Director of IEC, will examine the implications of establishing the national network and its operation on the electricity system. The panel will submit its conclusions by February 15th, 2008.

5. Multi operator system: A panel headed by the Legal Advisor of the Ministry of Finance and with the participation of representatives from the Justice Department, Ministry of Transportation and Road Safety, Ministry of National Infrastructures, Israel Antitrust Authority and the Budget Controller will draft the regulation rules needed to operate the national network and to ensure accessibility to the network to other operators, as those might by, including for the matter of payment due to the use of the network, to users and other operators, ownership in the network and the rights in it at the end of the contract of license period, as well as the need for specific legislation to regulate the subject. The panel will submit its conclusions and recommendations by February 15th, 2008.
6. Environmental aspects: A panel headed by the Assistant General Director of the Environment Ministry and with the participation of representatives from the Ministry of Transportation and Road Safety, the Ministry of National Infrastructures, the Ministry of the Interior and the representative of the Budget Controller office will examine the existing environmental aspects of establishing and operating a national network for charging electric vehicles.
7. Transportation aspects: A panel headed by the Director General of the Ministry of Transportation and Road Safety and with the participation of representatives from the Ministry of the Interior, the Ministry of the Environment, and a representative of the Budget Controller at the Finance Ministry will examine the transport aspects of introducing vehicles in Israel driven by alternative technologies using fuels that are not polluting.

After discussing the conclusions and recommendations made by the different panels, the Steering Committee will submit to the Government's approval its recommendations about the appropriate modus operandi in each of the above issues and in any other matter that will be deemed right, not later than March 15th, 2008. The taxation issue will be brought for the Government's approval not later than December 15th, 2007.

Timetable for executing this resolution: As specified in the resolution.

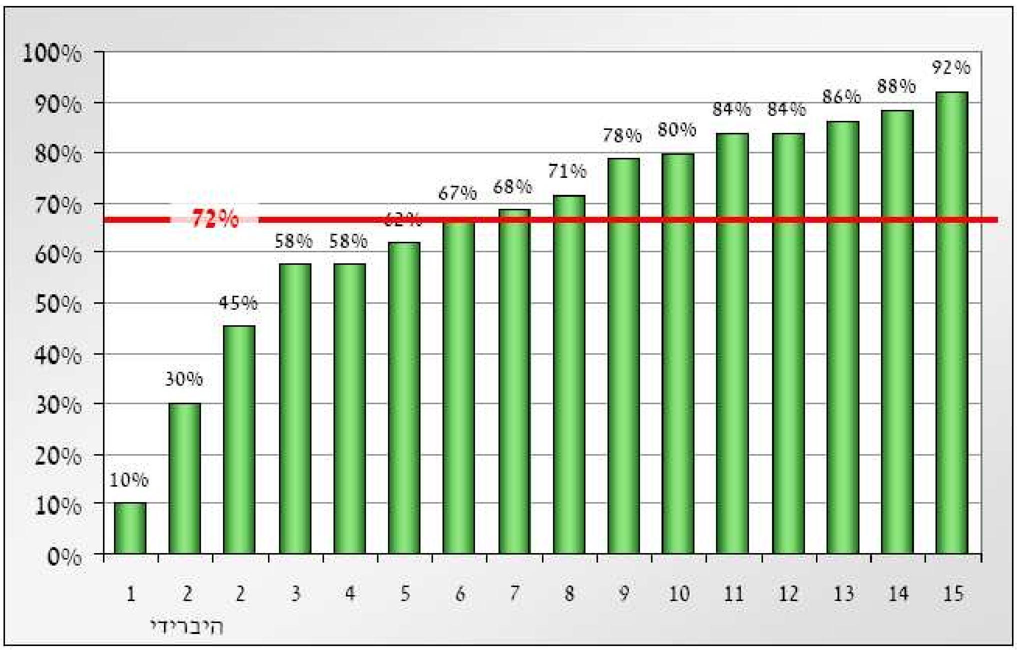
Appendix 3 – The Tenets of the Green Taxation Reform on the subject of Electric Vehicles, June 2009[9]

- Setting taxation incentives for less polluting vehicles
- Hybrid/emission-less vehicle

Purchase tax on private and commercial vehicle, which stands today at 75%, and from January 2010 at 72%, will be turned into purchase tax at a rate of 92% minus a "prize" according to a green score.

The green index, whose goal is to apply the mechanism of "the polluter pays" sets the tax rate designed for each vehicle according to the pollution level it emits to the environment.

Purchase tax rates are presented in the following figure:



For emission-less or hybrid vehicles, a program was defined for the years 2009-2020, with the tax rates exercised on these vehicles ranging between 10% for an emission-less vehicle until 2014, and for hybrid vehicles the following tax brackets were set:

Today – 30%

2009-2012 – 30% (for vehicles with a capacity lower than 3000 cubic cm and in pollution group 2, at the most).

2013 – 45%

2014 – 60%

[9] Based on the presentation "Structural Changes in the Tax System "Green Taxation", Conclusions and Recommendations, June 2009, delivered by Mr. Eran Ya'akov, Tax Authority.

2015 onwards – 92% with a deduction of a prize according to the green index

These tax brackets were set according to the assumptions about the penetration of these vehicles into the market, and their increasing frequency with time.

Appendix 4: Electromagnetic Radiation in electric and hybrid vehicles

Dr. Perry Levon, the Levon Group LLC, 16 August 2009

Background

Electrical currents create magnetic fields, and there are lots of electrical currents in any car, not just hybrids. It is not surprising that measurements of magnetic fields inside or near a car would give positive results and also highly variable results from location to location depending on proximity to electrical wiring associated with the different electric circuits in the body vehicles such as: inside and outside lighting, radio/CD player, turn signals, blower fans for A/C and heaters. Each of the circuits in a vehicle carries several amperes of electrical current and so it creates magnetic fields.

The results of magnetic field measurements inside cars are somewhat tricky to interpret since meters are most likely calibrated to read accurately for magnetic fields created by the alternating current in household wiring (at 50 or 60Hz, as applicable). In a car the electrical currents are primarily direct current, not alternating current, in most applications, and are not expected to be at the grid frequency for which the meters are calibrated. So it is not surprising that a magnetic field meter would read positive measurements inside a car, but those reading have to be interpreted with caution.

For reference it is important to note that the earth's static magnetic field has strength of about 0.5 gauss (or 500 milligauss) more or less, and varies with location on the planet. For comparison, the European public exposure standard is about 100 µT (1 gauss), the average measurements in apartments in Sweden have resulted in values 0.1 µT (1 milligauss). The field under a high-voltage power line ranges from 3-10 µT (30 to 100 milligauss).

International Commission on Non-Ionizing Radiation Protection (ICNIRP)

The ICNIRP published comprehensive guidelines both for occupational and public exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)[10].

Previous Measurements

Some limited test results for magnetic fields in some popular cars were taken in Sweden from 2002 and are presented in Table 1 below[11]. The cars include a mix of conventional gasoline cars and hybrids. (Note: we are providing this for reference but were not able to independently verify the data for a authoritative source).

The data are presented in units of micro-Tesla (1 micro-Tesla = 10 milligauss), which are common units for measuring magnetic fields. In Table 1 below the two entries provided for each column represent measurements when the car is standing still with engine idling, on the left hand side, with measurements when riding in 90 km/h on the right.

[10] http://www.icnirp.de/documents/emfgdl.pdf

[11] http://www.greenhybrid.com/discuss/f13/emf-hybrids-546/

Table 1: Measurements of Magnetic Fields in Various Cars in Sweden (2002)

	BMW 5-serie*	Ford Focus	Mercedes E-Klass	Saab g-3	Saab g-5	Toyota Prius	Volvo S40	Volvo S60	Volvo V70	Volvo S80 original	Volvo S80 ombyggd	VW Golf
Front Seat												
Left foot	12/4	0.2/0.6	2/1.3	0.7/1.4	0.3/2	0.2/1.3	0.3/1.3	15/14	18/7	12/12	2/1.9	0.3/3
Right foot	4/5.5	0.2/0.9	3.5/2.3	0.6/0.9	0.4/1.5	0.2/0.5	0.9/1.3	2.5/2	3/1	2/2	0.5/0.5	0.2/0.8
Floor	6/2	0.1/0.3	2.9/2.1	0.3/0.5	0.3/1.5	0.3/0.7	0.4/0.7	5/3.5	5.5/1.9	4.5/4	0.4/0.5	0.09/0.8
Threshold	5/3	0.07/0.3	0.9/0.5	0.7/0.8	0.3/1.4	0.2/1.5	0.2/0.7	14/10	11/5.5	8/10	1.7/1.2	0.08/1.1
Seat	1.3/0.7	0.03/0.2	0.6/0.3	0.2/0.4	0.05/0.9	0.05/0.7	0.1/0.2	2/2	3/0.8	2/1.8	0.1/0.2	0.04/0.3
Chest height	0.7/0.3	0.02/0.1	0.2/0.2	0.1/0.3	0.05/0.6	0.03/0.5	0.05/0.2	1/0.8	1.2/0.4	0.9/0.7	0.1/0.2	0.03/0.3
Head height	0.6/0.4	0.03/0.1	0.15/0.1	0.1/0.2	0.02/0.4	0.03/0.5	0.05/0.1	0.8/0.6	0.8/0.3	0.6/0.5	0.1/0.2	0.02/0.2
Back Seat, left												
Left foot	3/1.2	0.03/0.3	2.4/0.8	0.2/0.3	0.05/0.3	0.2/0.3	0.04/0.6	7/5	10/3.3	5.9/4.5	0.3/0.3	0.02/0.6
Right foot	10/4	0.02/0.2	3/1.5	0.1/0.2	0.05/0.2	0.2/0.4	0.04/0.35	6/4.5	8/1.7	8/3.5	0.4/0.3	0.02/0.4
Floor	4/3.5	0.03/0.2	1.7/2	0.1/0.3	0.03/0.3	0.2/0.5	0.035/0.6	8/8	9/4.5	9/6.5	2.1/2	0.02/0.6
Threshold	15/6.5	0.05/0.4	0.8/0.5	0.6/0.7	0.1/1	0.15/0.4	0.04/1	3.5/2	3.9/1.5	2.9/2.5	0.1/0.6	0.04/0.9
Seat	2.5/1	0.02/1	0.2/0.2	0.09/0.4	0.01/0.8	0.1/0.6	0.02/1	3/2	6.6/2.3	3.5/3	0.3/0.6	0.02/1.7
Chest height	1/0.5	0.05/0.3	0.1/0.1	0.05/0.2	0.01/0.5	0.07/0.3	0.02/0.6	1/0.7	1.3/0.6	0.9/0.8	0.08/0.3	0.02/0.7
Head height	0.5/0.4	0.05/0.3	0.1/0.1	0.05/0.2	0.06/0.4	0.07/0.3	0.03/0.4	0.9/0.7	1/0.5	0.7/0.7	0.1/0.3	0.02/0.6

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