EV and PV: a winning combination with new potential

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Abstract

In future, the combination electricity produced from renewable sources and electric mobility is a winning combination. It replaces mainly fossil fuels by "green electricity", makes an EV driver independent from fossil fuels and dramatically improves the CO_2 balance of EVs.

A clean electricity mix will be decisive for the first market introduction phase of the new generation of EVs and PHEVs. In case the electricity mix is dominated by coal plants or nuclear plants, the first buyer groups, the "innovators" and "early adopters", will not accept electric mobility. In Switzerland, which was the pioneer in this field, we see since 1987 a strong synergy between users of electric vehicles and buyers of private photovoltaic installations.

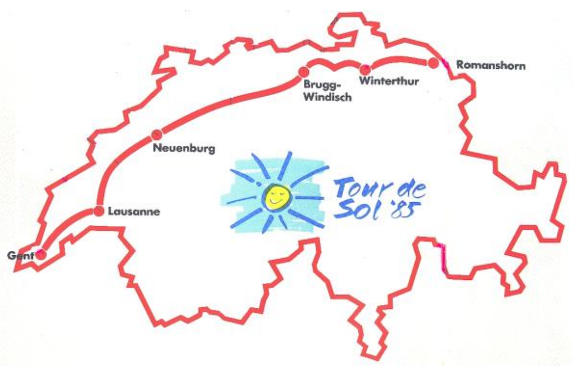
The random production of PV-electricity can be levelled by electric vehicle charging close to the PV-installation. This avoids peaks in a weak grid, the limitation of peak PV production and saves investments in the grid infrastructure. This also applies to other renewable electricity productions like wind, hydro and others.

The synergy of electric vehicle and photovoltaic has more than 25 years of history in Switzerland. 1985 the worldwide first solar car race - the "Tour de Sol", started as a PR tour for the use of solar energy. Today car dealers already offer PV-installations for their customers.

Keywords: *electric vehicle, solar electricity, solar car, smart grid, market introduction*

Introduction:

In 1984, the first solar car race, the "Tour de Sol", was launched as a promotion tour for the use of solar energy. The goal was to cross Switzerland with solar driven cars. The great success of the first race in 1985 showed the enormous potential of the electric drive in combination with solar electricity. Due to the lightweight construction and the high efficiency of the vehicles the consumption (2-5 kWh/100 km) was so low that even with lead acid-batteries a range of 100 km could be achieved. This motivated me to continue organizing similar races in the Swiss Alps until 1992.



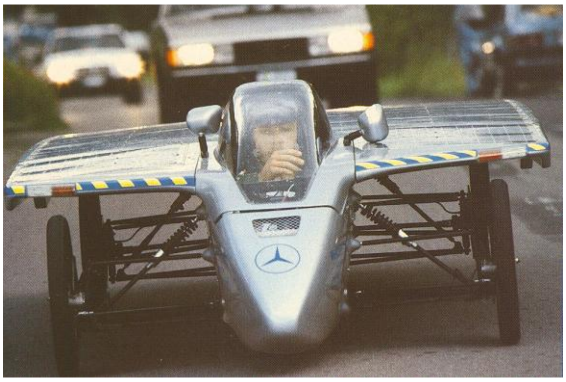


Fig 1: route of Tour de Sol 85, Tour de Sol 85 winning team alpha real/ Mercedes Benz

Lightweight EVs and grid connected PV developed in parallel

In the Tour de Sol 1985, all vehicles had the solar cells on the vehicles. This needed surfaces up to 6 m^2 (due to the regulation) and special lightweight modules. This technology was the starting point for integrated PV-modules. But these modules were fragile and expensive. Therefore, since the 2^{nd} Tour de Sol race from Freiburg im Breisgau (D) to Suhr (CH) in 1986, mobile "solar charging stations" for “series production vehicles” have been admitted; and already then the “Ökozentrum Langenbruck”, a Swiss “think tank” for an environmental life style and renewable energies, proposed a connected energy network fed by photovoltaic and wind energy.

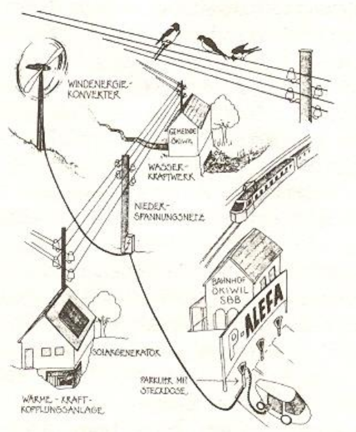


Fig 2: grid connection of electric vehicles (Ökozentrum Langenbruck 1986)

On this basis, the Tour de Sol-regulations have been adapted for two of the categories (prototypes and series production vehicles) in 1987. The popular Swiss Formula 1 driver Marc Surer won the series production category in a “Horlacher Egg”, one of the most popular electric vehicles at that time.

Fig 3: Horlacher company with grid-connected PV installation; Horlacher GL 88 (“Egg”)

This combination of feeding solar energy into the grid and using it for the solar vehicles by plugging in was cheaper than a solar surface on the car or a mobile solar charging station. The PV installation produced energy beyond the weeks of the solarmobile race. Most of them are still in use. In Liestal, a first “solar-charging station” near the railway station was established in 1989. Switzerland has been a pioneer in privately owned grid connected PV-installations at that time. Many innovations have been developed, e.g. the “feed-in tariff” in the city of Burgdorf near Berne. This “feed-in tariff” now is the basic financing method for renewable electricity production in many countries. The PV-boom in Germany is based on this financial instrument. Since then, the Berne University of Applied Sciences Burgdorf runs a big PV-lab that is well known for its PV-system tests. The mechatronic laboratory of the Berne University of Applied Sciences in Biel, is committed in the design of solar and electric vehicles, electric bikes and electric propulsion systems for the high performance glider “Antares” since its participation in the Tour de Sol 85. Two spin-off projects came out of the Berne University of Applied Sciences in Biel: The “Smart” car projects started by the Swiss clockmaker Hayek (“Swatch”) and the PV-inverter company “Sputnik AG”, one of the market leaders in this field.

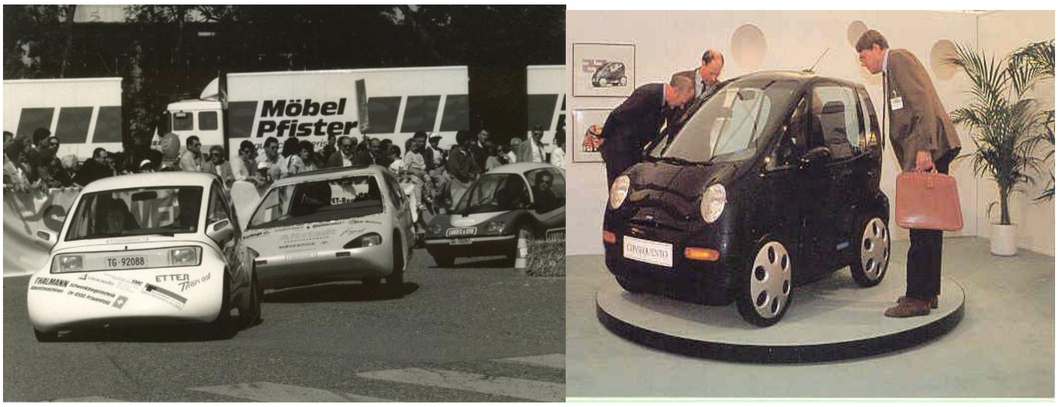
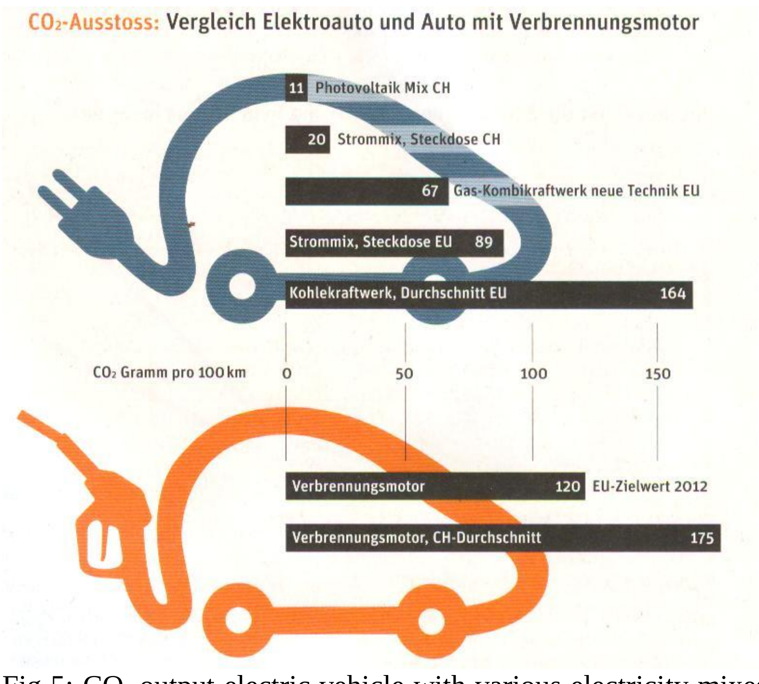


Fig 4: leading prototyps on Tour de Sol 91 (left) consumption between 10-20 Wh/ km were the standard. On the right a prototype the “Horlacher Consequento” which was a early form of the “Smart”.

Technology: decentralized combination EV and PV makes sense

Individual mobility is a huge challenge in the energy field. Electric vehicles reduce the energy consumption and the CO_2 emissions. The amount of additionally consumed electricity is small and can be covered by a small PV-installation on the roof of even a small house.



source: VCS

Fig 5: CO_2 output electric vehicle with various electricity mixes in comparison with ICE vehicles. The best version is the combination “PV with EV” with 20 gram CO_2/ km according to the VCS. Mainly no advantage in the CO_2 emission if the electricity is produced by coal

In future, we will see a high percentage of renewable electricity in the grid. Charging EV batteries is one of the possibilities to balance the grid. EVs support smart grid applications by storing the surplus electricity. Several member countries of the IEA IA “HEV” are specificly interested in EVs because of the high shares of solar and wind power in their grids (Denmark, Ireland, Spain).

A high synergy can be seen in the infrastructure for the PV-installation and the EV. EVs will be charged mainly at home during nighttime (studies IA HEV Annex XIV). The power of the EV charger will be below 10 kVA. Private PV-installations are mainly below 10 kWp, resulting in a feed-in power of less than 10 kVA. When charged at night, the maximum load goes into the EV battery. While the EV is unplugged at daytime, the PV installation produces the maximum of 10 kVA. Thus, the existing infrastructure – the grid - can be used three times instead of once (by the consumers in the house, by the

EV charging the battery, and by the grid converter of the PV installation). Although the household consumers, the EV and the PV installation are of about the same power, they do not interfere with each other, and the grid needs not necessarily to be reinforced – which was the case if the power for EVs would be produced in a central power station. This is similar to the production of renewable energies with high power as wind farms, centralized PV-plants and solar thermal plants. From the user perspective, a car driver can now produce the needed energy by themself. This is an interesting option for the marketing of EVs.

EVs for PV: superior energy balance
PV also does not compete in land use like the biomass production for cars against food. Small unproductive surfaces can be used, like roofs, railway tracks, noise barriers along highways etc. Even the land use is minimal compared to the land use of biomass production. Surfaces like deserts, steep hills in mountain areas etc can be upgraded for electricity production for EVs. Similar arguments can be found by using wind for the electricity production for EVs and other electric consumers

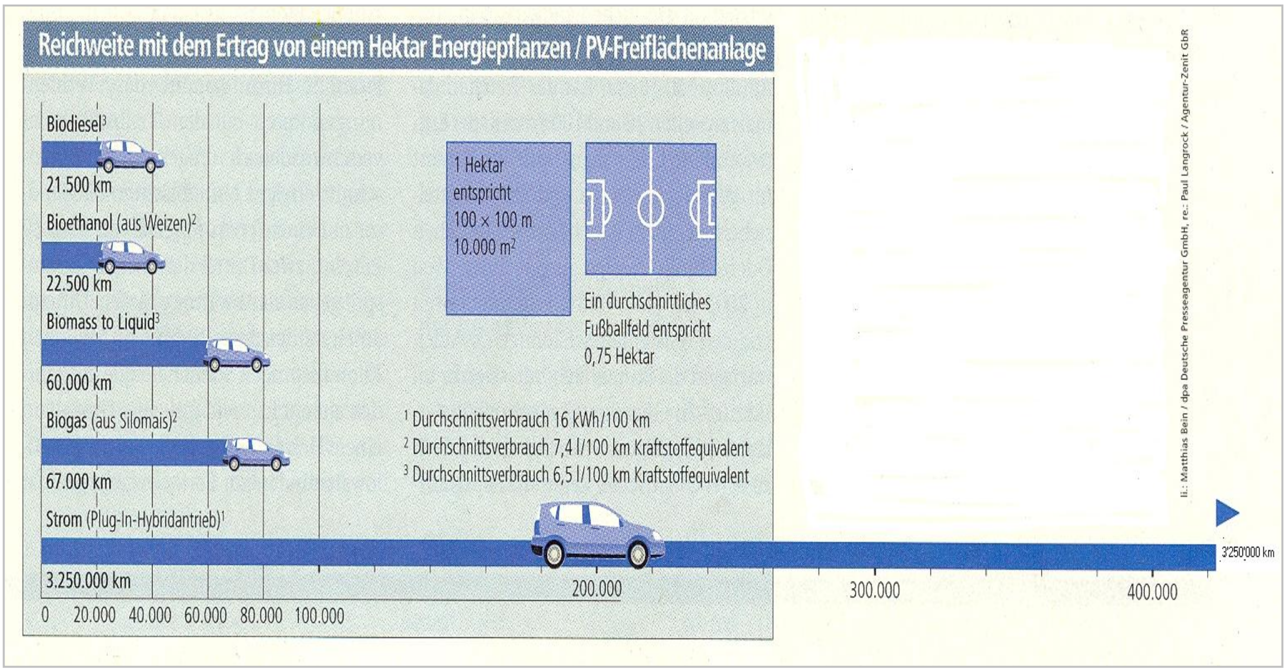


Fig. 6: the fuel equivalent produced on an area of 1 ha converted in various driving systems: PV is miles better than other technologies

Marketing of EVs/ PHEVs
According to marketing studies, the buyer segments of EVs and photovoltaic installations highly correspond. These are mainly private users or companies with a high interest in new technologies and/ or environmental issues. The first buyers are "innovators" and "early adopters" (reference Muntwyler EVS 13 in Osaka 1996). Early buyers of Toyota Prius indicated as the first argument, that the vehicle "tells something about me". This argument can be transferred to the highly visible PV-installation on the houseowner's roof.

In Switzerland, one of the most cited arguments against EVs is "that it needs more electricity which leads to more nuclear power plants". Nuclear power stations are emotionally and politically a "hot potato" in Switzerland and many western countries. Potential EV-drivers will avoid the feeling that they were "guilty" for new nuclear power plants, and consequently they will not buy an EV or PHEV. Utility companies place EVs as a very prominent topic because they can use them for a zero CO_2 balance. EV marketing must avoid this constellation. If the first buyer groups "innovators" and "early adopters" do not buy EVs because it was powered by nuclear energy the market introduction will fail again. I published a contribution about this question in the biggest car magazine, and had immediately contact with a car importer who plans to sell EVs in Switzerland.

This problem is solved now in Switzerland as the government decided in 2011 to phase out the five existing nuclear power plants after the accident of Fukushima. Scenario which shows how the electricity (40%) can be replaced by even a higher use of electricity (heat pumps replacing oil heating systems and EVs replacing IECVs) needs about 15% photovoltaic current in the grid[i].

Avoid the trap to force PV electricity for EV use: offer it as an added value option

EVs also run without a PV installation. Each EV is better than a gasoline car, even by using the conventional electricity mix. The fact that driving with clean electricity brings additional advantages should be used as an option in the sales process. EV-dealers should be prepared to act as intermediates between the electricity provider and the EV buyer, or even sell the relevant charging infrastructure. This creates an additional income. EVs will generate less service income, and the sales margins will be lower. This could finally lead to a new kind of "EV sales points" which provide mobility services plus the needed energy e.g. in the form of a PV-installation. It will be interesting to see who will take over this business. Many utilities are already ready to be first out of the gates.

Enough "green electricity" for the EVs

In 2011 the PV industry installed worldwide about 20 GWp PV modules. This creates enough electricity for 10 million EVs. But the lifetime of the PV-installations is 3 times higher than for a car. These 20 GWp stands therefore for 30 million EVs a year. These figures show that the market growth of PV is much faster than for the electric vehicles.

The slow growth in the market penetration of EVs should not be slowed done by the link to "green electricity". The green electricity is much quicker. The problems of the car- and supplier industry to produce and sell the needed number of components and car limit the production numbers of EV. The goal of Germany to produce 1 million EVs demonstrates this. The goal of the "Electric Vehicle Initiative EVI" with country members as China, India, US and many industrial states to produce 20 million in 2020 underlines these problems. For the 20 million EVs 40 GWp PV-installations will be enough. That's a quantity which will be installed in months in 2020 by the PV-industry.

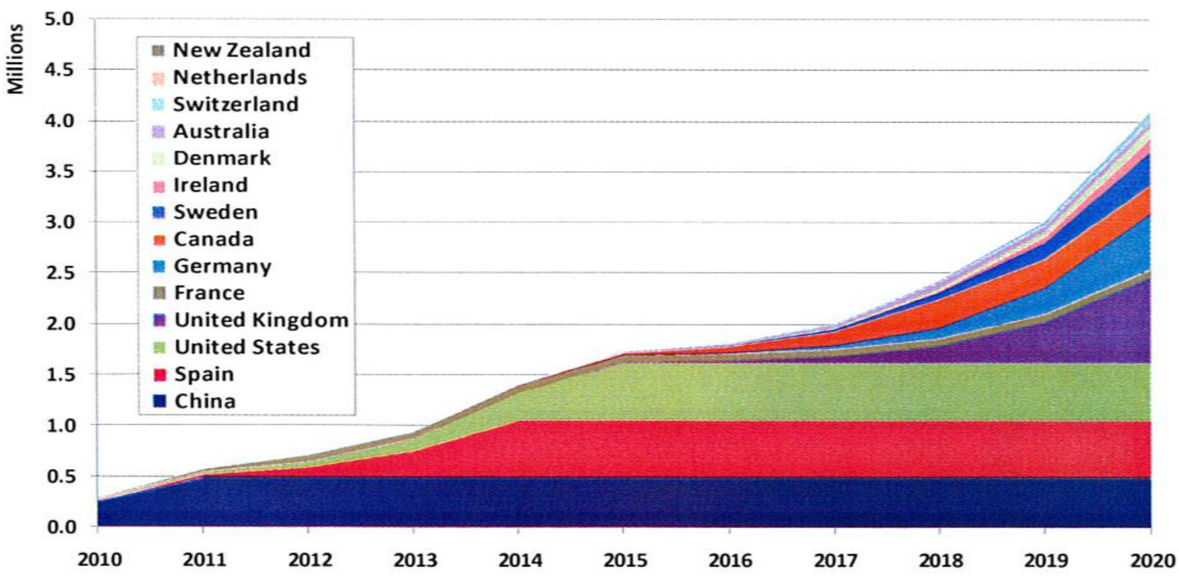


Fig. 6: Slow market introduction of electric vehicles according the "IEA EV roadmap"[ii]

Costs for EV operation and PV-installation cheaper than gasoline

Finally the overall operating costs including the costs for a PV installation are much lower than those for gasoline. Actually you get a 2'000 Wp installation for 8'000 € which produces 30 x 2'000 kWh in Central Europe. This is enough for 30 x 10'000 km – which makes about 3 €/ 100 km. For a small car consuming 5 Liter/ 100 km, the gasoline costs about 7 € (cheap Swiss gasoline price in winter 2012). Therefore the combination of PV and EV is cheaper than a gasoline car at the actual gasoline price. By using "feed-in tariffs", PV-owners can even make a small benefit.

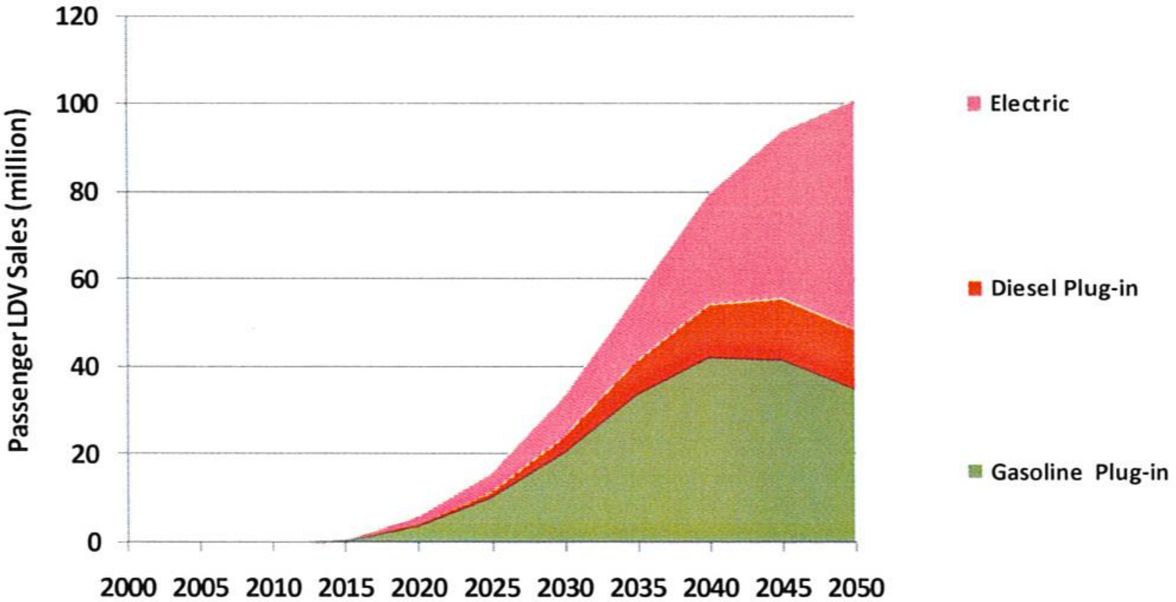


Fig. 7: The figure for 2050 seems ambitious but even this will be no problem for the production of solar electricity

The IEA roadmap predict for 2050 50 pure EVs and 50 millions plug-in hybrids. These would need PV - installations of about 200 GWp for this year. This should be possible only with PV in 2050[iii]. In reality other renewable electricity production as mainly Wind and hydro would contribute too. It can expected that EVs and PHVs are more efficient than today. This will lower the electric consumption.
In reality EVs and PHVs will offer another advantage. They can be use to balance the production of the new renewable energies especially Wind and PV. Some of the member countries of the Implementing Agreement “Hybrid- and electric vehicles” have a strong interest on this option. They produce electricity by high amounts of Wind and PV.

Synergies in the infrastructure for PV-installations and EV-charging stations
Some synergies can be found in the electric infrastructure for the EV-charging station and the PV-installation. With the right planning, the existing infrastructure of a house can be used three times. EVs will be charged with less than 10 kVA. This is in the range of a electric installation of a single house. The PV installation will be most probably not bigger than 10 kWp. The EV can be charged trough the day if high amounts of PV power comes in the grid. Now the same infrastructure can be used three times. With a central production of the charging electricity more probably we would need more grid infrastructure.
If EVs should be charged mainly through the day we need some charging stations on the working place. Here again some PV power would be advantageous. The utility company can now steer the charging process of the EVs. With 1 million EVs in Germany we could balance 5-10 additional GWp PV power.
How this can be done will be a part of the document of the task XV working group „plug-in-hybrids“ of the Implementing Agreements „Hybrid- and electric Vehicles“, The final report will be published 2012/ 2013 for the member countries.

Electric vehicles and PV-installations: Synergies in the marketing
With a PV installation the energy for the mobility can be produced by user of an EV. This is an interesting point for the marketing for the EV, the PHVs and the photovoltaic. According my experience with both technologies the first market segments of the customer are very similar[iv]. Some EV sales specialist try to use this for a higher profit for their sales channels.

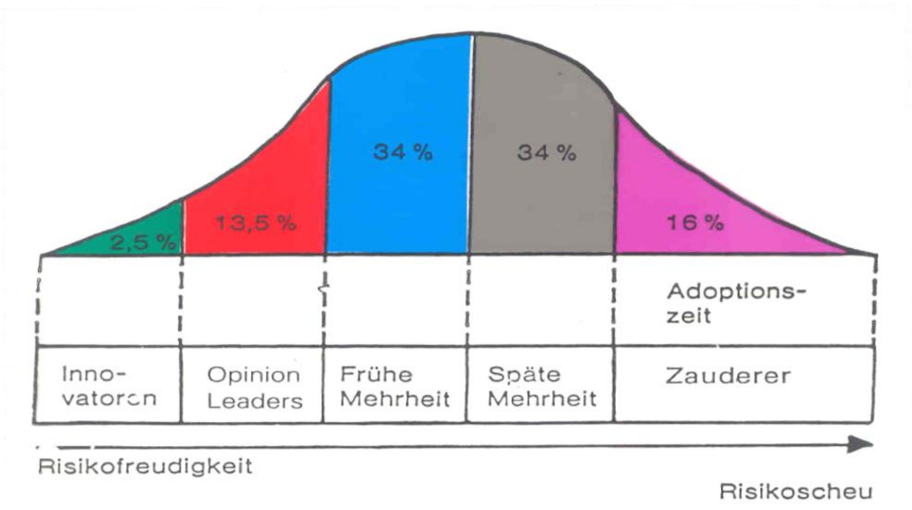


Fig. 8: Risik profile of buyers for new technologies (according Rogers) as they can be found for EVs and PV-installations. The market introduction starts with high risk buyers (innovators on the left) and goes over "opinion leaders" to the mass market of the "early majority" to the middle of the figure.

Conclusion:

The combination of EVs and PV has several advantages in the field of the energy, the efficiency of the energy and the use of surface, synergies between the technologies, the marketing of both technologies, and the use of high contribution of new renewable energies in the grid. Together they are a sustainable solution for the electricity production and the individual mobility. The idea of the "solarcars" from 1985 comes back now in the daily use in separated form of EVs and grid connected PV-installations.

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[i] Study Jan Remund (Meteotest AG), 2011, Berne Switzerland

[ii] IEA roadmap study for EVs/HVs and PHVs, International Energy Agency, Paris 2010

[iii] Study EPIA and Greenpeace estimates 21% of the world electricity production by PV

[iv] Verkaufserfolg mit erneuerbaren Energien, PACER, 1992 and „marketing of EVs" in EVS 1996 in Osaka.