

# Integrating Two Revolutions in Automaking and Electricity Supply: **GENERATOR POWER BY MILD-HYBRID CARS**

Revolutions in energy and mobility seem to be taking longer time to break out. In the short and medium terms, mild hybrid cars with liquid or gaseous fuel, a small battery, and a smart power splitting driveline could improve the efficiency of car systems and electric systems both in ecological and economical terms. In the car system, mild-hybrid cars would be more efficient than combustion engine-only or purely battery driven cars. In the electrical system they could provide, by means of combustion engine and generator (and not using large, environmentally harmful batteries!), a de-centralized output of 120-400V/AC \*) grid electricity for minute peak current and emergencies, ensuring reliable power supply with maximum capacity reserve. C-H combustion may seem at first glance to pose a problem. But investments (grids, large power stations), dissipation losses, costs, emissions, waste and damages could be reduced and efficiency levels could be increased significantly. Overall improvements of 20% for both electricity and cars could prove realistic. That would mean technology lead for the growing markets of car and electricity. An additional outcome would be – thanks to the flexibility of car fleets – powerful negotiation leverage on global energy markets.

*\*) This paper was initially drafted on the basis of German conditions. However, the estimated dimensions and hypotheses should fit similarly all comparably motorized and electrified regions. As is typical for the world market, the automotive and power industries will be able to adapt general technical solutions to national standards. Here the authors try to use terms for general understanding.*

## 1. Viable Interim Technologies Recommended

**Efficient storage and transportation of electricity are core problems that despite massive effort are a long way from feasible solutions. To enhance existing car and electricity systems, a realistic alternative path is described in the following. It uses only standard components, could roll out in 5 years, and would establish a technology generation of at least 30 years.**

A hundred years of basic research and ten years of intensive applied research and design development may have brought some progress in the areas of transportation and energy. However, *real* breakthroughs in renewable energies and electro-mobility *have not materialized*. Scope and timing of implementation remain unsure, especially with regard to several critical components. Long-distance electricity transportation and electrochemical electrical storage (batteries, accumulators) may not achieve the desired efficiencies, compatibilities and serviceability (e.g. capacities, charging facilities, times and places, range, winter operation, resources, disposal, recycling). Or these goals may prove too costly, less sustainable, or perhaps will only be developed many decades into the future.

This does not mean in any way that the widespread criticism of the harmfulness, inefficiency and incompatibility of existing electricity and car systems is unjustified. For any kind of progress technological utopias and basic criticism are called for. But just as important are viable engineering developments and the continuous, intensive competition of concrete and feasible ideas. Scientific, engineering and political discourses should therefore be opened up again for the development and evaluation of further technological paths. The following concept describes a realistic scenario for *concrete improvements* within 5-10 years. This scenario combines solely familiar, standard and cost-effective technologies. It would constitute a technological generation of at least 30 years for the future global «remainder» car fleet – be this 1/2 bn or 2 bn cars (today: 1 bn).

## 2. On the Car Side...:

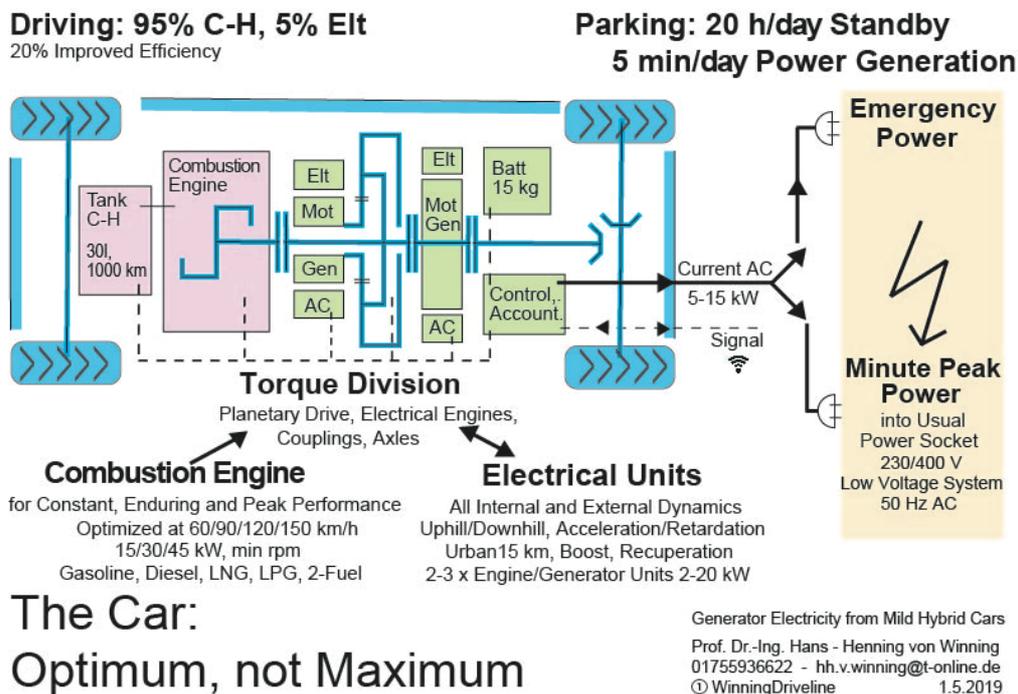
### **Mild Hybrid Vehicles for Sustainable Driving and Generating 120-400V/AC Electricity**

**Imagine a concept based on a car technology driven by a mild hybrid driveline. A hydrocarbons combustion engine delivers continuous, long-distance, and high performance. When parked, the vehicle is plugged in, on standby to feed grid electricity 120V-400V/AC from the car's engine**

and generator straight into the low-voltage grid: power for minute peak current, for unstable grids, and for emergencies. The combustion engine is constructed and operated at its optimum point. The electric components cope with all dynamics in driving requirements and city traffic, using – because of its poor environmental balance - only a very small battery.

The components are an integrated mild-hybrid driveline with a liquid or gaseous hydrocarbons combustion engine; a small electric device – electric motor-generators, which can also generate 120V-400V/AC; and a very small battery. By means of continuously variable power splitting, input and output will be operated, distributed, transmitted, fed back and stored in a highly efficient and sparing manner.

The combustion engine delivers high-level, even, long lasting and reliable output. It should be optimized to one or several output points and its operation concentrated on that point. That way its efficiency level would be significantly higher than the conventional elastic-powered engine mostly operated far off the optimum point. The main transmission is operated by efficient mechanical gear parts (e.g. planetary gear sets). *Liquid or gaseous fuel* made of hydrocarbons still is and will continue to be the energy that is by far the lightest, most lasting, low-effort, most easily and most securely stored, transported, refuelled and handled. 30l (or kg) for 1000km travel distance refuelled in 5 minutes via simple plastic devices – nothing compares with that; nothing will come close. Whether – and to what extent - petrol, diesel, LNG, LPG, or other hydrocarbons variants should be preferred, and from which fossil, synthetic and biological sources they are derived, will be constantly re-negotiated, in technical, political, economic and ecological terms. Pure hydrogen (regardless of whether it is processed by combustion engine or fuel cell) probably will hardly be competitive due to its nonviable handling. Currently a bi-fuel solution with significantly reduced consumption seems attractive: one that uses solely petrol/gasoline on long-distance journeys, whereas in city traffic (and when generating electricity, cf. Part 3!) the vehicle should preferably use fuel with high hydrogen percentage – e.g. out of PTG (Power to Gas, methanation, distributed throughout the existing gas system).



**Fig.1: The Car Side: Optimum Instead of Maximum**

The electric part manages and buffers – using its special qualities - all dynamics necessary: acceleration, braking, reverse, uphill/downhill, and boost. Continuously varying power output and input adapts continuously variable transitions of dynamic running operation. It keeps the combustion engine at the optimum point and charges the battery by means of regenerative braking and surplus work on the part of the combustion engine. A battery of around 15 kg is sufficient for this and for roughly 15 km city quick-trips powered purely by electricity.

Most importantly the generators *driven by the combustion engine* have to be capable of generating grid-compatible electricity directly (cf. Part 3). That suggests one or several (1-3-phase) electric motor-generators with 120-400V/AC, 2-20kW. Charging the car battery from the electricity grid might be an

additional but negligible benefit, because the battery is very small, and in particular, the system is meant to avoid grid electricity surplus.

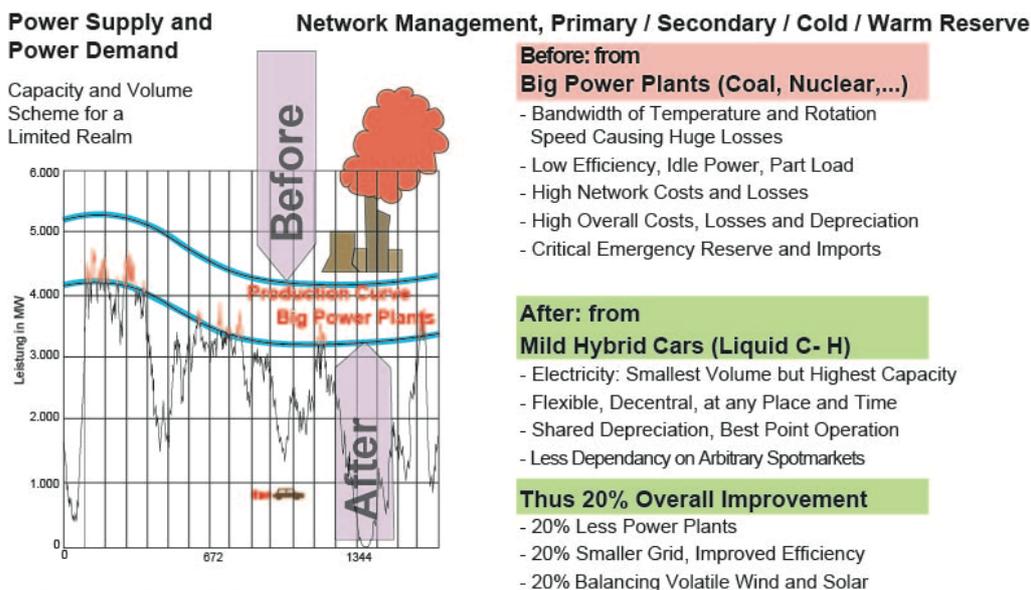
The car concept suggested seems currently to be economically and ecologically superior to all other approaches. Even manufacture by integrating motor, generator, starter and gearbox will become cheaper. All conventional vehicle types could be built this way: small cars, luxury limousines, sports cars, vans, city buses, private or company cars and trucks. Because basically all are capable of providing the output of around 5-15kW necessary for city driving and likewise suitable for grid electricity. This will work in the present car traffic based on maximum competition, speed and acceleration. It will work even better, if we manage to change to more steady flows of traffic. \*)

\*) It should be mentioned that the by far greatest efficiency reserve in car traffic would be steady and even-paced driving freed of competition with oversized engines: cars need to be modified so that traffic moves automatically with standardized, steady speeds and accelerations, and with the most economical, sparing and most compatible revolutions per minute and operation modes. That way, the crucial design criteria for engine, driveline and operation controls would no longer be competitiveness, acceleration, revs per minute and maximum speeds; instead ecological and economic efficiency, travel safety and climate protection, city compatibility, travel comfort, emissions and costs would become the goals of design and legal provisions. Travelling speeds could be defined according to road type e.g. to 30/60/90/120/(150?) km/h (the arithmetical symmetry for optimizing a powertrain!). Overall improvements of up to 50% have been estimated. For introducing «autonomous driving», that would be a necessary, particularly effective, and technologically simple first step.

### 3. And on the Electricity-Side....: Minute-Peak Current from the Combustion Engines of Mild-Hybrid Cars

Significant tasks in the electricity system could be fulfilled using the combustion engines and 120-400V/AC generators of mild-hybrid cars on stand-by: provision at moments of high demand of minute peak current, and as emergency generators. Car fleets are available in seconds, decentralized, everywhere, into every household socket available, with (cumulatively) maximum capacity, feeding in only for a short time just the very small volume required. So reliable supply will be guaranteed more cheaply and ecologically than by the present storing and buffering in grids and power plants, and significantly better than with batteries.

One particular challenge for electricity systems is short-term demand *peaks in a time frame of minutes*. Considered on a small local scale, these peaks are, even assuming sophisticated smart-grid management, high and beyond predictability. Today these demand peaks only are met with very high costs,



## The Electricity: Minute Peak and Emergency

Generator Electricity from Mild Hybrid Cars  
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Fig. 2: The Electricity-Side: Minute-Peak and Emergency Current

dissipation losses, and environmental damage. The mild-hybrid cars described could cope with this situation more cheaply and with less negative impact on climate and environment.

Here's what it could look like: Cars are parked more than 23 hours of every day. In many private and public garages and parking lots the cars with own on-board cables could be plugged into already existing or easily installed new sockets, producing normal 120-400V/AC (the cars easily adapted to regional standards and practice). On a demand signal from the electricity grid, *the combustion engine starts automatically* and feeds for a few minutes via its generator perhaps 5-15kW into the low-voltage grid. The vehicle's electronics are precise and reliable: They can synchronize voltage and frequency precisely; they can continuously analyze, coordinate and control (e.g. load, fuel tank levels, emissions, faults, and so on), electricity grid demand and capacity, vehicles and locations. And they can record accounting data for standby times and amounts of electricity delivered, and use them and process them in compliance with data protection requirements for de-centralized billing centers. Emissions are minimal, in spite of C-H combustion: The C-H driven engine runs *at most for a few minutes*, at its optimum point. That way, wear and tear, lifecycle and tank size remain practically unaffected. Even the ventilation capacities of garages are respected, e.g. because driving in and out is now electric-powered.

High payments should motivate car owners or fleet managers to make their vehicles frequently available. Then the sheer number of cars, available all over the place, will lead to a great deal of flexibility. In the end, only a small fraction of the car electricity capacity will actually be needed and delivered; but if necessary, it can be potentially everywhere, at the right place at the right time, within seconds and just in the required amount. Instead, with the present situation, large power stations, electricity grids and emergency current systems, inflexible in time and space, do this with very high investment and operational costs, dissipation losses and a great deal of environmental harm. This alone would justify *high payments to car owners* for availability and provision.

In addition, in case of grid outage, individual vehicles could provide *emergency current* for smaller units such as potable water plants or heating appliances. They could charge batteries or power lighting, tools or gas stations. For higher levels of output, cars could be hooked up together to form *stand-alone power networks*, using their ability to synchronize voltage and frequency. That would turn employee parking spaces, for instance, into a cluster of standby power plants: for hospitals, schools, data servers, infrastructure hubs or industrial plants. Brief power outages and emergencies could be automatically bridged. So, there is just one small step to securing continuous operation of a car manufacturing plant in Malaysia, Morocco, or Mexico using (their own employees!) company cars: much better and cheaper than any other peak electricity provisions or the standstill times experienced so far.

#### **4. Synergies Car - Electricity: 20% Fewer Costs, Effort, Environmental Damage; Global Emergency Current for Maximum Supply Security**

**Key to understanding the scope of chances are the dimensions. In highly motorized and electrified countries or regions you find installed in the car fleet an energy capacity 10-20 times of all power stations. Minute peak current, defined as 20% of maximum electricity demand, would roughly be equal to the number of new vehicles registered in six months. Even a small amount of this standby provision would safeguard adequate de-centralized supply anywhere, any time. Car traffic and electricity supply would be optimized. Hitherto oversized grids and power stations have guaranteed reliable supply. Savings here might bring overall efficiency increases of 20% - a plausible working hypothesis.**

Relating to a highly motorized and electrified country or region, the energy capacity of the car fleet can be estimated to be 10 up to 20 times higher than the capacity of all power stations combined. To estimate the effect of introducing the concept described here, an (extremely rough ballpark) figure of 20% gains for average improvements of the concept is suggested as working hypothesis, compared with the current situation or other scenarios. \*)

\*) *This hypothesis has to be subject of extensive audits and comparisons of efficiency, cost/benefit, and impact. One special difficulty will be to compare very different fields of impact, which will mean wide scope of observation: E.g. an electric engine by itself may have a high energetic efficiency – but what if you include the energy spent for production, dissipation and recycling of the batteries necessary? So it will be important that comparisons and balances include all internal and external effects (costs/interest/amortizations, environment, energy, space), the entire lifecycle (construction, operation, waste disposal, recycling), and all system parts (infrastructure, vehicle, operation modes).*

Currently, driveline construction design and operation modes have other goals beyond efficient mobility. The hitherto conventional multi-step transmission and elastic-powered engine may be fun to drive, thanks to the perfect interplay of dynamics, sounds of revs per minute, and maximum performance. By implementing the design as described, a much higher level of efficiency will become possible: realized by a continuously low rev per minute operation, and by means of point optimization of construction design. Thus the combustion engine will attain *much better levels of efficiency*, also for generating electricity, than today's average for vehicle operation. Finally, vehicle costs could be shared among actors operating in mobility and in electricity generation.

The benefits for the electricity system will be comparable, but less obvious; we need to look more closely. At the heart of the matter is the time lapse of a few minutes - the *unpredictable* gap between random, volatile demand and the sluggish production curve of big power stations regulated on the basis of forecast. These gaps are rare, but sometimes reach high peaks, and to avoid blackout crucially have to be bridged no matter what the cost.

We envisage bridging this gap as follows: existing cars, parked all over the world, standby, and for some minutes feeding in electricity, could bring about the following saving conditions:

- Today the maximum output ever demanded is hardly 2/3 of the maximum possible capacity, e.g. for Germany some 90GW of the total combined capacity of all power stations which amounts to 120-200 GW (without/with volatile sources such as wind/sun). This means providing and running big surplus power plants (producing either no current, or sometimes producing current immediately to be destroyed) at very low efficiency levels. This reserve would no longer be necessary. For many years into the future, *fewer power stations* would have to be replaced or built new.
- Today, too high or too low production is buffered by accepting higher or lower voltage and frequencies. The wider bandwidths in rotating masses and system temperatures are permitted, the more dissipation loss is caused. The bandwidths of the remaining large thermal power plants could be streamlined. Their *level of efficiency would increase* significantly. And consumers would benefit from more even voltage and frequency.
- Today large-scale (even intercontinental, tendency growing) power grids are meant to level generation and consumption and even out peak gaps. This also causes huge costs and energy losses. Instead, grid size and capacity could be greatly decreased. For many years into the future *fewer power lines* would have to be replaced or built new.

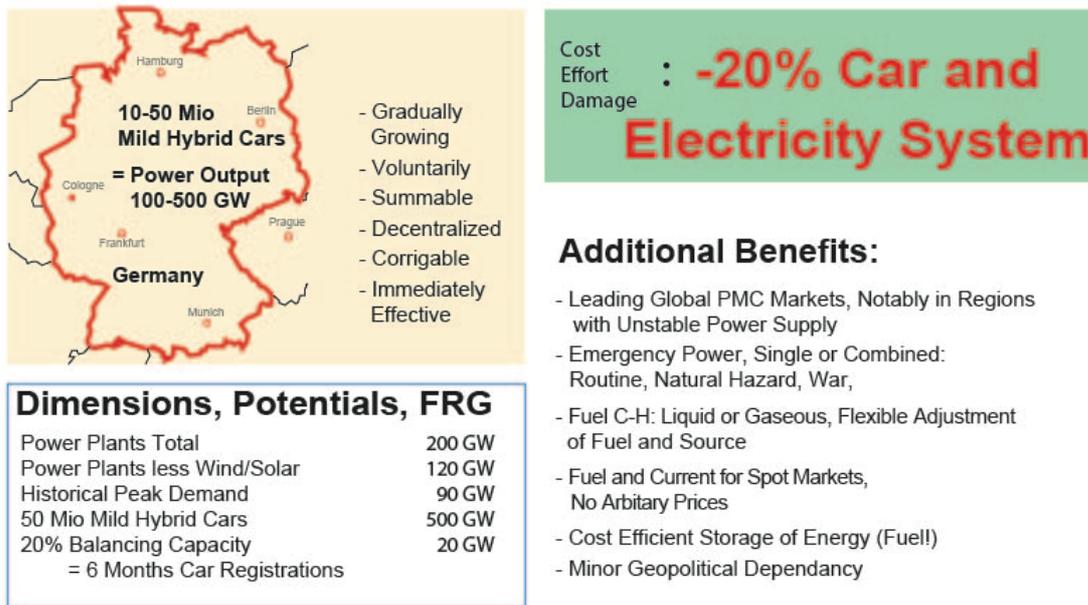
Cost, losses and environmental damage of the present minute peak and emergency current strategies are extremely high, but well hidden: Sometimes minute peak current cost increases of grid charges; sometimes it is hidden in too high average prices per kWh, and decreases average efficiency levels of plants; sometimes it is caused by power lines misused to destroy surplus power production by warming the air on purpose or by chance. Minute peak current is traded on electricity spot markets: prices may reach *factors of 10-20* and more and have to be capped by policy. Apparently, this cost is difficult to calculate, and buzzwords like «peak current», «grid management» and «supply security», are used to pretend that exorbitant prices are inevitable. But even extremely rough estimations elucidate the big difference that could result if in future cars gradually took over electricity generation. The need for new investments and operating costs of power grids and stations could be reduced for many years by many billions of €/\$. There is some evidence that a working hypothesis of 20% profit may even be conservative. That would leave *plenty of money to share*: for electricity companies and consumers, and for car owners and fleet managers, as additional income in return for making their vehicles available and for feeding electricity to the grid.

There are further benefits, as follows:

- Mild hybrid private cars form giant de-centralized, clusters of emergency current generators. In case of *war, terror or natural hazard*, they would offer maximum supply security for critical users such as hospitals, security services, or banking servers. Separate emergency generators would no longer have to be afforded, maintained and operated. This also would enable continuing normal operation for all kinds of private or commercial electricity purposes, regardless of how unstable grids all over the world may be.

- De-centralized availability guarantees a certain *de-centralized autarky*, autonomy, responsibility and resilience concerning the basic needs electricity, mobility and possibly heat and refrigeration. That applies to private homes, to country villages, as well as urban quarters, in good times or bad times.
- New mild-hybrid cars can be adapted, quickly, in a flexible manner, to fuels of a wide range of origins on changing global spot markets: Whereas conversion of big power stations would take 20 years or more, the car technology can react in 2 years. That enables influential, politically stabilizing *negotiation positions on regional and international energy markets*.

Those who make their private cars available for separate emergency current generators could be contracted and paid by those companies or institutions who benefit – in view of the globally rather unstable electricity grids, that poses significant potential. For civil defense, aid organizations, or armed forces, the making available of vehicles could be regulated by private, cooperative, nonprofit or state framework rules, supported in «serious cases» by public administrative law.



## Cluster Gas Power Plant: 10 Mio. Mild Hybrid Cars

Generator Electricity from Mild Hybrid Cars  
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**Fig.3: Cluster Gas Power Station: 10 Million Mild-hybrid Cars**

The cars described are precisely the de-centralized «mini gas power stations», that might complement volatile electricity (wind, solar). The *sheer number of cars* is overwhelming: every 10 million mild-hybrid vehicles could potentially output 100 GW of electricity; put another way, theoretically, some 20% of the cars licenced could compensate for an outage of an entire power plant park in a highly motorized and electrified country or region. The technological components are all standard; the level of innovation is modest and the detail design could be enhanced step by step. Introduction is effective from the get-go in both economic and ecological terms, and can be started up using the existing infrastructure. Even the very first mild-hybrid vehicle to hook up to the electricity grid statistically will have an effect. Remuneration of 300\$/€ monthly for the vehicle owner is a realistic prospect.

Continuous power-supply security for extreme peak demand and emergency situations is a very important criterion, but not a fixed figure. It consists of reserve capacity and technical condition of surplus power stations and networks. These at any moment are more or less random outcome of very long-term corporate investment, political interventions, and technical or natural hazards, in some cases decades ago. So, statistically supply security varies a lot for different regions and periods. Prognoses are uncertain, overly austere saving is dangerous. Deficits are experienced as random sudden blackouts, and can only be reduced over decades with huge investment. In our scenario, *big surplus capacity* will be guaranteed by the existing car fleet. This capacity can be used immediately and amplified within only a few months or years. 1 million vehicles in 6 months is a relatively small lot production by the

standards of the car industry, but could offer some 10GW electrical capacity, and so would have significant effects on the security of electricity supply.

Above all this is a *mere theoretical* capacity reserve. In reality, car engines will generate only very small amounts of electricity, but exactly the amount necessary. But maybe the very fact that the output reserve exists at all will lead to cheaper prices and/or more ecological innovations on the part of competitors who provide minute-peak current: whether in the form of better consumption management, decentralized mini pump storage stations, foreign cheap offers, or breakthroughs in storage technology.

## 5. Efficiency Innovation, Technology Management, Geopolitical Implications, Actors

**The concept has great potential on the global market. It contributes to global, political, economic, demographic and climatic challenges. The spot market viability opens up scope for international discussion on energy. Next steps would be more intensive research and development. Such endeavours could be driven by big or small companies, public or private institutions, or associations and administrations in all sectors.**

It's all about *efficiency innovations* and driving cutting-edge technology with maximum potential on the global market. Globally there are currently some 1 bn cars (some people estimate there will soon be 2 bn, some environmentalists would prefer ½ bn), and the global electricity market is growing vigorously. The international risks are increasing – buzzwords: global trade and climate change. There is great uncertainty surrounding the question of which technological innovations will be appropriate for a global population soon to reach 10 bn people. No matter what ecological scenarios suggest, there will still be a massive «remainder» car market. Renewable energies and electro-mobility do not seem to be able so far to replace 200 years of C-H combustion. With regard to car mobility and on the electricity spot markets, the benefits of hydrocarbons gas or fuel are so convincing, that conversion to renewals should at first widely be focussed on of all stationary units. If you master the technologies suggested, for many decades you will increase sustainability and resilience of highly sensitive infrastructures («Blackout»), and you will have *great scope of influence in geopolitics* and energy politics.

Finally, I would like to make a few more remarks on the most important players. The greatest challenges will be dealing with the traditional delineations and claims of political fractions, industry sectors, and specialist areas in science, business and politics. For the sectors electricity and automotive, there is the prospect of new opportunities in what is a difficult phase of change and upheaval for both industries – with relatively little disruptive interference. The automotive industry can likely expect growth, because it will serve parts of the electricity market and can utilize their core competences while doing so. Maybe the innovation path this time is not the trickle-down from premium vehicles: maybe the winner this time constructs and sells just drivelines for worldwide mass automobiles. On the electricity side, distribution operators, such as municipal companies will be the winners. Step by step, they can take over minute-peak electricity and supply security into local and *regional responsibility*. Political players and regulatory bodies still will retain a great deal of responsibility for technological-economically standards (supply security!) and price momentum (peak current). Legal frameworks, tax collection and returns, emissions trading, fleet consumptions and many more must be re-adjusted and made less complicated.

And finally, the different specialists and experts – individually and in their organizations – could launch *a new deal of cooperation*: viable prospects for performance desired, aiming at maximum efficiency level, instead of marginally increasing output by vast growing input. The idea is picking the proverbial cherries from all the different technological components and their spectrum of average efficiency levels. So the initial presumption may harden into concrete prospects. The hypotheses about the positive overall effects can be realistic, and minutiae problems, pilot projects, realization, and gradual introduction can be technologically and economically resolved. And that certainly justifies significant research and development efforts. A suitable test area could be a big island – be it Bali, Sicily, or Vancouver Island. We are all invited: physicists and engineers, economists and legal experts, businesspeople, social scientists, politicians and civil society. It remains suspenseful which specialist areas and which institutions will grasp the nettle of initiative and competitive edge.