HYBRID CONCEPT FOR ENERGY REDISTRIBUTION WITHIN TRANSPORTATION SYSTEMS

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Abstract The appearance of new, high efficiency volume displacement machines in the low and middle power ranges, such as the Schapiro engine, enables revision and generalization of the hybrid principles. At the fuel station, the basic idea is to store energy from the electrical power grid in batteries and in other forms of stored heat energy, such as the overheated steam of various fluids or salt solutions, for example. A small amount of fossil fuel should also be stored. The primary energy source for transportation should be the stored heat energy. Extracting power from the heat energy store requires a temperature maintenance system for keeping energy extraction at peak efficiency. This temperature maintenance system can be powered by battery, by the chemical energy in a fossil fuel or by solar energy. This concept has advantages even though the overall efficiency of current heat utilization technology is no better (and for all practical purposes not worse) than the efficiency of the transportation technology employed today. A major advantage is that the energy sector is then divided into two almost independent blocs – the producers and the users. Technical and ecological improvement in both blocs can proceed independently. The article contains a methodologically sound comparative table capable of handling both objective and subjective factors in numeric form. Every observor can create a table reflecting his or her personal views.

1. The Energy Unification for Mobility Concept (EU M Concept)

That the EU in the abbreviation for Energy Unification for Mobility coincides with the EU abbreviation for the European Union is not only a gag but rather a meaningful congruence: The EU M concept is intended to be very much in keeping with the spirit of EU environmental policies.

The goal of the EU M concept is the substantially more efficient and environmentally friendly use of energy sources. To this end, we recommend basing the transportation energy market on electricity and restructuring the transportation energy market such that the interface between energy production and energy utilization is unified to a significantly greater extent.

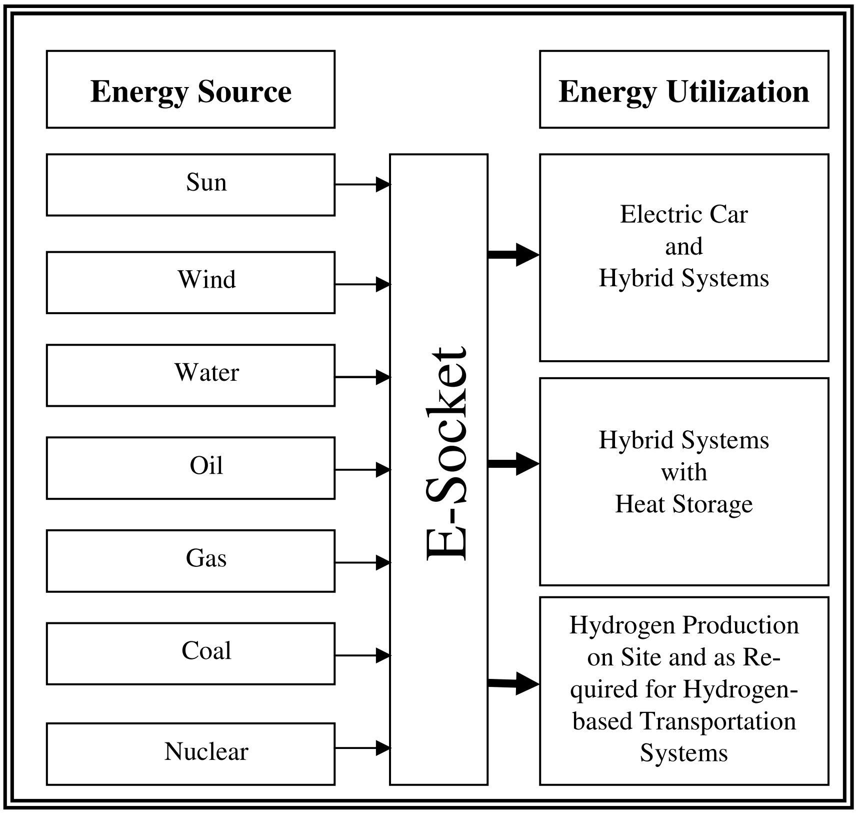

Fig. 1 Recommended Energy Flows for the EU M Concept.

Implementation of the EU M concept offers the following advantages.

Advantages:

- The energy efficiency of fossil fuels will increase by 10 – 15%
- The cleaning of waste gases, as well as heat and resource reclamation, can be made significantly more efficient and cost effective in an industrial production plant. Thus, even though the same amount of fuel may be burned, the environmental footprint can be reduced measurably.
- Transportation costs for fuel delivery will be reduced

- The infrastructure for energy distribution is already in place everywhere
- Future changes in the energy production sector can be implemented without resulting in undesirable costs for required technical changes in the energy utilization sector. The energy production and energy utilization sectors are uncoupled, resulting in greater utility for consumers and the economy as a whole.

To implement the EU M concept requires making changes on both sides of the e-socket. These changes should proceed in parallel, dynamically balanced. Currently, the energy production sector is better prepared for implementing such changes than is the energy utilization sector. The energy utilization sector does not command a diverse fleet with dynamic capabilities to use energy from the e-socket efficiently.

Research and development is already underway and pioneer products already available in the electric car and electric hybrid system sector. Transportation options based on hydrogen are at the stage of prototype development and the testing of small series. However, the potential of these developments meets but a fraction of the transportation demand, especially in the sectors of freight transfer, construction machinery of various kinds and agriculture.

Completely absent is the development of hybrid systems with heat storage for the ground transportation sector. In our opinion, hybrid systems with heat storage are eminently suited for this sector.

2. Transportation Systems with Heat Storage

A wide variety of ways for incorporating heat storage into the optimization of ground transportation systems can be imagined.

The combustion of one liter of diesel fuel in an industrial generating facility can provide 10 – 15% more effective power for the user than combustion of that same liter in a machine for personal mobility.

There will always be a need for on-site combustion of fossil fuels. But that share of the energy mix can be reduced substantially by implementing the EU M concept.

2.1 Heat Storage as a Secondary Energy Source

One possibility for employing heat storage in combination with conventional propulsion aims to increase substantially the efficiency of combustion in the engine. For all practical purposes, the engine should operate continually at peak efficiency. Load increases such as acceleration or driving up hill should be assumed by an ancillary steam engine. The steam engine would be powered by steam from the heat storage facility. In order to maintain the super-heated steam in the heat storage facility at constant operating conditions, heat captured from the main engine by a heat exchanger could be used; electrical power from a battery, from solar panels on the roof of the truck during the day, from electrical outlets at gas stations, chemical heating in case of need, etc., could also be employed.

Steam with its water exhaust is not the only medium that could be employed. Other heat storage and transfer media such as freons, saline solutions, etc., could be used in closed systems.

Reclamation of exhaust heat with an exit temperature of 600 °C for maintaining optimal operating conditions in the heat storage facility could raise the effective exploitation efficiency of the chemical energy stored in the diesel fuel up to 80%. Exhaust pollutants would be reduced correspondingly.

The use of heat storage facilities (heat accumulators) and ingenious steam generation processes coupled with advanced steam engines with thermodynamic efficiencies of approximately 40% should produce the following advantages:

- Considerable increase in the operating efficiency of the primary diesel engine as well as reduction of exhaust pollutants resulting from the engine operating continually at its optimal stationary efficiency while the ancillary steam drive takes over all acceleration and other short-term load increases
- The internal combustion engine can remain turned off from minutes to hours, with propulsion provided solely by the steam drive, should environmental conditions require completely exhaust-free operation such as in danger zones, cellars or underground garages or other enclosed spaces, congested areas, etc. The same holds true for acceleration from a stop (such as at a traffic light) or other increased load situations during which diesel motor efficiency is lowest and exhaust toxicity highest.
- Heat accumulators can be recharged with waste heat from the primary engine, as well as with solar energy, power from the electrical net or energy from other sources.

The combination of diesel engine plus steam engine with heat storage facility is particularly expedient for use with heavy-duty trucks for which efficiency optimization and reduction of exhaust toxicity is particularly important, not only for the environment for also for the energy economy.

2.2 Heat Storage as Primary Energy Source

3.4 tons of water at 375 °C and 220 atm, plus 25 liters of diesel fuel for maintaining optimal power output, can power a fully loaded 40-ton truck for 10.5 hours at 100 kilometers/hour under optimal conditions (level road and a 40% efficient steam engine) for a total range of 1000 kilometers.

In this scenario, 2.5 to 3 liters of diesel fuel per 100 kilometers travelled are required to maintain optimal power output, compared to 35 to 45 liters per 100 kilometers required to travel with the diesel engine alone.

As an example, let´s take a 40-ton truck, travelling a distance of 1,000 kilometers fully loaded. With conventional diesel technology, this 1,000 kilometer road trip will require approximately 425 liters of diesel fuel.

With the EU M concept, the same 40-ton truck would use only 25 liters of diesel fuel for the same stretch. Of course, one must also include the approximately 385 liters of diesel fuel required if the electricity used to heat up the heat storage system initially is generated industrially using diesel fuel only.

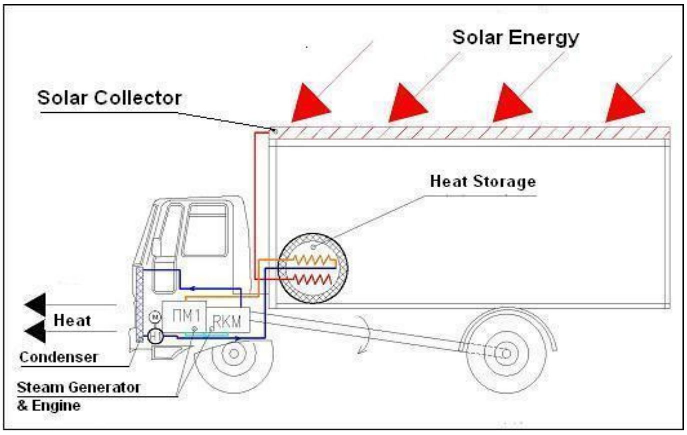

Fig. 2.1 Possible configuration of steam-driven vehicle with heat storage system and steam generator.

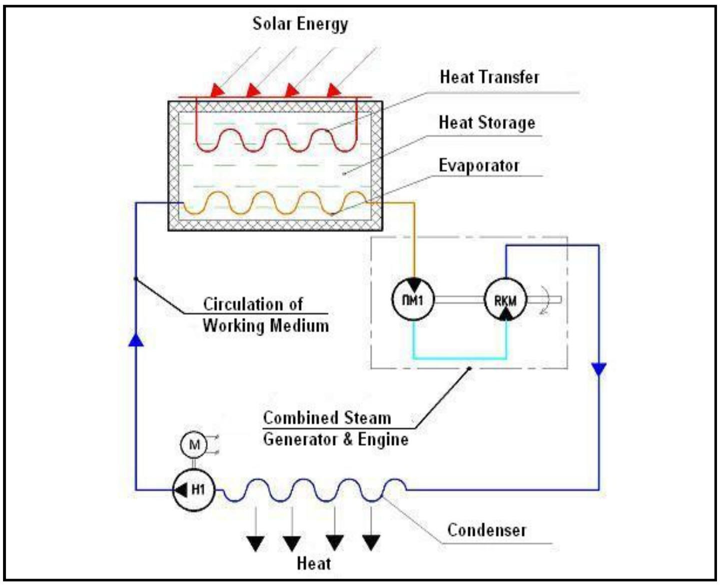

Fig. 2.2 Functional schematic of possible configuration.

Saving 15 liters of diesel fuel per 1,000 kilometers with the EU M concept may not seem like a major improvement. Although that doesn´t seem like much, it adds up quickly. In Germany, for example, with roughly 200,000 registered 40-ton tractor-trailers driving an average of 40,000 kilometers per year, that adds up to 120,000,000 liters of diesel fuel per year. At current prices, that is 132 million Euros needlessly burned, assuming that the electricity used to preheat the heat storage facility was generated using diesel only. A different electricity mix would result in even greater waste.

The greatest strength of the EU M Energy Unification for Mobility concept is that the energy delivered to the e-socket for preheating heat storage facilities, charging batteries or producing hydrogen on-site need not be generated by burning fossil fuels but can come from a variety of other sources.

Long-term changes in the current electricity mix (see Fig. 3) will certainly include reducing the burning of fossil fuels. If the EU M concept is implemented, these changes can be completely decoupled from further technological developments in the energy utilization sector (the right side of Figure 1). This could save the world economy many billions of Euros in avoidable costs without detracting from technological and ecological progress.

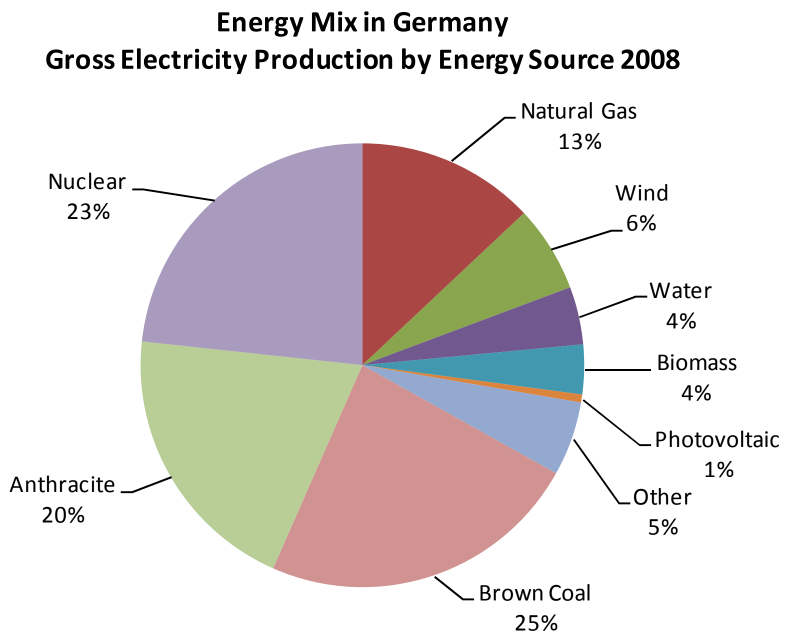

Fig. 3 German electricity mix from http://de.wikipedia.org/wiki/Stromkennzeichnung.

2.3 Heat Storage in Combination with a Porous Burner

The porous burner technology developed at the University of Erlangen enables high-pressure steam injection for the newest generation of steam engines at pressures comparable to common rail systems; porous burner fuel economy is similar to that of a 90 horsepower TDI motor (Emo-Auto 2009).

A scientific prototype based on the Škoda Fabia proves the great potential of porous burning, at least for steam generation. Steam temperatures up to 900 °C are created. The burner/steam generator system delivers steam with pressure, temperature and volume adjusted for load and rpm differences to meet power requirements. With the experimental facility called ZEE03, steam is injected at up to 500 atm – injector opening and closing times are under one millisecond. The injector's open time controls steam volume and, thereby, engine power output; the expanding steam drives the piston.

3. Conclusion

Traffic causes the lion's share of emissions (see http://www.stadtklima-stuttgart.de/index.php?klima_klimaatlas_6_emissionen - German only) harmful to man and climate in so many ways. In the energy balance (well-to-wheel) with the current power generation mix, electric drives are more efficient than internal combustion engines and can therefore contribute to decreasing CO_2 emissions. However, substantial advantages for our climate can be achieved only when electricity is generated with sources other than fossil fuels.

Achieving this goal with the least economic stress requires the maximum possible structural decoupling of the energy production and energy utilization sectors. Only then can development in both sectors proceed in parallel without imposing costly, reciprocally necessary decisions. This is a crucial element of the EU M concept.

The energy production sector's development strategy is not at issue here whereas that of the energy utilization sector certainly is. What we really need is a comprehensive study of the cost-benefit relationships, differentiated and weighted according to usage, emissions, type of engine, vehicle weight, mission, kilometers driven, substitutability of new technologies, operator adoption, user acceptance, political and social temper, etc. We could not conduct such a study on our own as it requires serious financing.

Instead, we have attempted an abstract comparison of technology development strategies for the energy utilization sector. By setting artificial values and multipliers (weighting factors) for the various strategies, we attempt to evaluate strategies difficult to compare (see the table in Figure 4).

The values reflect the current state of technology and the opinions of various experts in the respective areas. The choice of weighting factors expresses our subjective opinion which, of course, is considerably influenced by our own view of the world.

The comparative methodology is, however, quite transparent. Thus, anyone can generate his or her own comparative table as a decision aid simply by inserting personal priorities in the weighting factor hierarchy. Moreover, with the help of sociological data collection, a profile of various population groups' preferences could be generated to research the range of acceptance and estimate possible future buyer acceptance.

Based on our comparison, we conclude unequivocally that, if diesel and natural gas-based transportation technology is rejected for the greater good, then steam-diesel-electric-fossil hybrid technology has an absolute advantage (74 total points, 0.822 normalized value), with electric-fossil hybrid technology coming in second (65 total points, 0.722 normalized value).

We expect the efficiency-increasing utilization of Schapiro machines, rotating piston machines with a jumping instantaneous axis and other geometries (www.rkm-schapiro.org), to further enhance the advantages of both hybrid technologies.

Characteristic	Characteristic Weighting Factor	Ideal Technology	Conventional		Electric		Hybrid	
			Fossil-fluid Diesel	Fossil-gasf	Battery	Fuel Cell	Electric & Fossil	Steam & Accessory EU M Concept
Overall Efficiency	4	5	5	3	3	3	4	4
Drive Efficiency	4	5	4	3	5	4	4	3
Global Environ-mental Load	3	5	4	5	2	3	3	5
Local Environ-mental Load	2	5	3	4	5	5	4	4
Range	2	5	5	3	1	3	4	5
Cost per Kilometer Driver	2	5	4	5	2	1	3	4
Vehicle Cost	1	5	5	5	1	2	2	5
Absolute Weighted Total		90	77	68	55	57	65	74
Normalized Weighted Total*		1	0.856	0.756	0.611	0.633	0.722	0.822

* Rounded

Fig. 4 Qualitative estimates on a scale of 1 (disadvantageous) to 5 (very advantageous) weighted by factors from 1 (not very important) to 4 (very important) based on our subjective perceptions.

Other observers can construct their own comparative tables as decision aids by expressing their own priorities in the hierarchy of weighting factors. Although the ratings of various observers will become difficult to compare should a different absolute value for the ideal technology be calculated, normalizing the value ensure comparability.

The utility of normalizing weighted total value totals to 1 (one) is that the ratings of various observers coming to different total values can be correctly compared to one another in a uniform fashion. Such comparisons will be meaningful and could be a useful basis for constructive discussions.

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