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Silicon Fire methanol and Silicon Fire silicon: spearheads of a new renewable energy industry

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1. Availability and storage of energy

Our most important energy sources are the fossil fuels, coal, oil, and gas, waste and refuse, the renewable energies, primarily wind power, biomass, wind and sun, as well as, insofar as it is accepted, nuclear energy. Despite major promotion of the renewable energies over the last few decades, in Germany in 2010 fossil fuels still provided 78% of the primary energy requirement (renewable energies 9.4%) and this factor is giving rise to concerns regarding the security of supply on account of the dependence on imports and with regard to the environmental effects, in particular on account of the greenhouse effect caused by the carbon dioxide released during combustion.

Wind and solar energy offer great hopes for the future. The main problem with using these energies is their discontinuous accumulation since, as with all requirements, with energy requirements it is important not to have the required amount available at some time but at the time when it is needed.

The crucial problem is the storage of energy. The storage of different types of energy (e.g. thermal, kinetic, electrical energy) is certainly fundamentally possible using different methods (e.g. heat, flywheel, battery storage devices) but is very expensive and is therefore practically and economically unrealistic for large amounts of energy. Exceptions are the storage of positional energy (pumped storage hydro power station) and of chemically bound energy.

Chemical reactions usually take place with the absorption or release of heat. By appropriately cascading suitable energy absorbing and releasing reactions, by far the largest amounts of energy can be stored in relation to the volume or the mass of the materials, if nuclear energy is disregarded. All our fossil fuels contain solar energy stored chemically in the course of millions of years which is released again by its combustion.

The good old lead rechargeable battery used as an electric battery in our vehicles still has the best price-performance ratio as an electrical storage device for most applications, but relative to its mass stores only about one four hundredth of the energy released as heat in the combustion of petroleum or mineral oil.

Energy storage is the main problem with wind and solar energy. The present state of the art worldwide in the use of these energies on a large scale is the conversion into electrical energy and feeding it into the existing electrical integrated network. In the electrical integrated network however, production and consumption must be precisely balanced at every instant so that the mains frequency remains constant within the very small prescribed tolerance (0.4%). This means that for every wind and solar power plant which can drop out at any time, a reserve and regulating capacity of the same magnitude must be provided in the integrated network, which hitherto substantially consists of thermal power plants having steam and gas turbines whose performance can be suitably adapted. From this it follows that so far wind and solar power plants are hardly replacing thermal power plants but are merely saving fuel there.

As the proportion of wind and solar power plants in the integrated network increases, the problems of ensuring mains stability increase quite appreciably so that at the present time there is very serious discussion of the need for new powerful pumped storage hydropower stations and additional power highways spanning the whole of Europe and designed for very high transmission powers, whereby wind, solar and pumped storage power, as well as conventionally generated power can be distributed and exchanged all over Europe and the integrated network thereby stabilised.

Questions naturally arise as to the feasibility and economic viability of such gigantic storage and transmission systems which have not existed hitherto and which have not even been necessary hitherto.

As a consequence, the question emphatically needs to be asked as to whether there are not far better, more economical and ecologically more appropriate possibilities for using wind and solar energy than forcing them into the straightjacket of the electrical integrated network as is propagated and practiced hitherto with the associated enormous problems and costs.

Starting from the supposition that in the distant future, conventional energy sources including the fossil fuels will help to meet the energy requirements, albeit in substantially changed proportions, primarily those available energy sources which can be used to simply regulate production according to demand and generate power as locally as possible, close to the consumer with low transmission losses and costs, should be used for power generation for the electrical integrated network that must exactly follow fluctuations in consumption at all times. In the case of thermal power plants, attempts should also be made to utilize waste heat in the form of rational combined heat and power. These energy sources are water power but particularly fuels: fossil, biogenic and, as far as acceptable, nuclear.

The use of discontinuous wind and solar energy should be predestined for those applications in which the discontinuity plays a minor role and this is in particular conversion into chemically bound energy in the form of easily stored and transportable fuels such as chemical raw materials or new metal energy carriers such as silicon.

The annual consumption of petrol in Germany, for example, is 20 million tonnes and 30 million tonnes of diesel fuel. These fuels for driving vehicles therefore account for about 16% of the entire German primary energy requirement and substituting these by renewable energies is certainly a worthwhile goal.

2. Silicon Fire methanol as a renewable, climate-neutral and storage fuel

The new fuel should be renewable and climate-neutral, easy to store and handle as a liquid, have good fuel properties and offer economic and ecological advantages over the bioethanol and biodiesel fuels presently considered to be renewable.

All these properties are fulfilled by the natural substance methanol as the simplest alcohol CH_3OH (“wood spirit”, “first runnings” in alcohol distillation), which has already proved successful as a fuel for highly stressed model and racing car engines and as a petroleum substitute. Synthesis from synthesis gases of fossil origin has been industrial state of the art since 1923 (current annual production worldwide about 45 million tonnes).

A disadvantage of methanol is that its calorific value in relation to volume is only half that of petroleum; its advantages are higher antiknock properties (octane number RON = 105 compared with 95 for Super Petroleum) and higher internal engine cooling so that substantially higher engine performances and efficiencies are possible.

The idea of using methanol as engine fuel on a large scale is not new. Major government programmes for fossil methanol in the USA and Germany in the 1980s and 1990s were unsuccessful because of the rejection by the vehicle and mineral oil industry. Methanol fuel among other things received a new impetus as a result of the book “Beyond Oil and Gas: The Methanol Economy” of the Nobel Prize winner George A. Olah 2006 and the developments of the Swiss Silicon Fire AG.

In the last few years, on the basis of the known technologies, Silicon Fire AG has developed new process combinations, for which property rights have been filed in some cases, which give the renewable Silicon Fire methanol substantial competitive advantages compared with the other fuels considered to be renewable.

The energy supplier for Silicon Fire methanol is renewably produced hydrogen H_2 which, according to the state of the art, is obtained with the aid of renewable electrical energy by electrolysis of water:

H_2O -286 kJ/mol = H_2 + $0.5O_2$ (Reaction 1).

The carbon for the synthesis of methanol is not supplied by fossil fuels, as in conventional production but by carbon dioxide, CO_2, which is obtained from concentrated industrial sources (e.g. waste gases from chemical processes or large firing plants, lime kilns, CO_2 separation from natural gas), which otherwise emit the CO_2 into the atmosphere. At a later stage it is technically possible to wash out CO_2 from atmospheric air which increasingly tends to contain it, in some cases up to 385 ppm (0.0385 vol. %).

Therefore Silicon Fire methanol is renewable and CO_2-neutral.

The synthesis of methanol takes place catalytically on the basis of conventional methanol production in reactors, e.g. by low-pressure synthesis at 80 bar and 265 °C:

$$3H_2 + CO_2 = CH_3OH + H_2O - 49.6 \text{ kJ/mol.}$$

Silicon Fire AG has developed a corresponding mobile demonstration plant having a production capacity of 50 L per day and this has been in successful trial operation since Autumn 2010. Based on this, a Silicon Fire mobile station having a capacity of 1000 L/d is planned and will be delivered shortly. The pre-planning of major industrial plants having capacities of 3000-5000 t/d has been completed.

The manufacturing costs of Silicon Fire methanol can be drastically reduced if the requirement for 100% renewable origin is abandoned, which requirement is not satisfied by the competing biofuels by a long chalk.

EU Guidelines require a 10% share of renewable energy in the transport sector by 2020 but at the same time (valid until the end of 2016) envisage (only) a 35% potential reduction of greenhouse gases compared with the fossil fuels for these renewable fractions.

It is therefore possible to combine the synthesis of renewable methanol described above with the classical synthesis of methanol from fossil synthesis gas which can be carried out particularly advantageously by incorporating the oxygen released in the hydrolysis of water to produce hydrogen, in the production of synthesis gas (for partial oxidation or for autothermal reforming of fossil fuel).

Thus combined, costs are obtained for Silicon Fire methanol in large plants (3000 to 5000 t/d) that are very significantly lower than the costs for bioethanol and biodiesel.

In order to meet the EU requirement for a 10% renewable fraction in petroleum within the EU by adding Silicon Fire methanol, about 26 million tonnes a year would be required or 16 major plants each having a daily capacity of 5000 t.

3. Silicon as a metal energy storage system

The transport of electrical energy over distances of several thousand km is associated with very high costs and losses using the high-voltage direct-current transmission possible for this. A more favourable possibility for energy transport in many cases is the electrochemical reduction of a metal oxide to the pure metal at the power production site, transport of the metal to the location of the energy requirement and energy recovery by back-oxidation of the metal to the initial oxide e.g. to obtain hydrogen as an energy carrier.

Metals such as aluminium and especially silicon are suitable for this energy transport.

These metals require a high specific energy for reduction of the oxide which is then released again during oxidation of the metal. They also have the advantage that they are non-toxic and that their surface is protected by a passivating oxide layer so that handling and transporting the metals is safe.

Silicon has the particular advantage that it is available as a raw material in unlimited amounts. Silicon oxide SiO_2 is quartz (sand); 25.8 mass % of the Earth's crust consists of silicon in the form of silicates or quartz.

A large proportion of the silicon metal traded worldwide is already produced renewably by reduction of quartz sand in electric arc furnaces using charcoal, where the charcoal frequently comes from sustainable forestry and the electrical energy from water power.

For the synthesis of Silicon Fire methanol, the requisite hydrogen can advantageously be produced by reduction of water H_2O using silicon Si in accordance with the sum formula:

$$Si + 2H_2O = SiO_2 + 2H_2 \quad -339.5\ kJ/mol \qquad \text{(Reaction 2)},$$

where quartz (sand) is again formed as a product along with hydrogen.

If the reaction heat of the above reaction 2 and the calorific value of the hydrogen produced is assigned to the initial silicon as energy content, the energy content of the silicon relative to the mass at 29 MJ/kg is approximately the same as that of coal.

Reaction 2 does not take place directly because of the passivating oxide layer but only after dissolving the oxide layer, for example, using an alkaline solution. As early as during the First World War mobile Schuckert and Silicol plants were used to generate hydrogen for moored balloons “in the field” where the silicon was oxidized to SiO_2 and the water was reduced to H_2 using aqueous sodium hydroxide NaOH via sodium silicate as intermediate products.

On the basis of the known chemical reactions, Silicon Fire AG has developed and planned a Silicon Fire hydrogen plant operating with metallic silicon or ferrosilicon and 25% sodium hydroxide solution in which hydrogen and quartz (sand) are produced as end products via the formation of sodium silicates and the alkaline solution can be recovered. About 7.6 kg of silicon is required to produce 1 kg of hydrogen.