Energy Policy is Technology Politics - The Hydrogen Energy Case

(with an eye particularly on safety comparison of hydrogen energy to current fuels)

by
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We have no everlasting energy supply security,
and we have no everlasting supply insecurity.
Our energy supply interests are everlasting,
and following these interests is our duty!
(Lord Palmerston, paraphrased)

O. Abstract

Germany's energy supply status shows both an accumulation of unsatisfactory sustainabilities putting the nation's energy security at risk, and a hopeful sign: The nation's supply dependency on foreign sources and the accordingly unavoidable price dictate the nation suffers under is almost life risking; the technological skill, however, of the nation's researchers, engineers, and industry materializes in a good percentage of the indigenous and the world's energy conversion technology market.

Exemplified with the up and coming hydrogen energy economy this paper tries to advocate the 21st century energy credo: energy policy is energy technology politics! Energy source thinking and acting is 19th and 20th century, energy efficient conversion technology thinking and acting is 21st century.

Hydrogen energy is on the verge of becoming the centre-field of world energy interest. Hydrogen energy is key for the de-carbonization and, thus, sustainabilization of fossil fuels, and as a storage and transport means for the introduction of so far un-operational huge renewable sources into the world energy market. - What is most important is hydrogen's thermodynamic ability to exergize the energy scheme: hydrogen makes more technical work (exergy) out of less primary energy! Hydrogen adds value. Hydrogen energy and, in particular, hydrogen energy technologies, are to become part of Germany's national energy identity; accordingly, national energy policy as energy technology politics needs to grow in the nation's awareness as common sense! Otherwise Germany seems ill-equipped energetically, and its well-being hangs in the balance.

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I. Germany after 200 years of its energy history - bitter facts and a hopeful sign:

Facts - an accumulation of energy security risks, unsatisfactory sustainabilities

- The national energy efficiency ~30% (world ~10%)
- The national exergy efficiency ~15% (world a few %)
- Primary energy (raw materials) import dependency ~75%
- Dependency on crude oil imports for non-rail transport ~97%, on natural gas 84%, on hard coal 60%
- New power plants supplying ~40,000 MWe will be required in the next few decades
- A centrally organized national energy economy in operation; significant de-central energy potentials are lying fallow– more or less.
- No consistent future national energy concept visible
- In 20 years there will be no fission energy production
- Highly subsidized renewable energies and national hard coal
- Europe's second highest prices for electricity
- An environmental balance that is only just acceptable
- A climate change status which is—almost solely—only thanks to the post-unification de-industrialization of eastern Germany

A hopeful sign - virtual energy, unappreciated, but existent

- The important resource of the technology skill of the nation's engineers in a world energy market worth US$ 2,000 billion p.a., with an annual growth rate of 3%. Germany's energy industry provides all sorts of energy conversion equipment on the world market, such as highly efficient power plants, refineries and nowadays in addition fuel cells and wind energy converters, as well as efficiency-increasing technologies which, of course, are not energy in themselves, but are just as good as energy.

II. The energy history of humankind

- Never did humankind utilize only one energy form, and a novel energy never completely replaced the "old ones", the continuously growing demand needed them all; energy diversity increased—and continues to increase.

- Humans live and work in energy centuries: until far into the 18th century the renewable energies of the first solar civilisation were in use exclusively; the 19th century was the century of coal; towards its end and then in the 20th century oil, natural gas and nuclear fission were added. – And what will the 21st century bring? Three additions are clearly visible: (1) Energy and above all exergy efficiency gains from link to link along the entire energy conversion chain, (2) the renewable energies, this time of the second solar civilisation, and (3) the secondary energy hydrogen, before the 22nd century becomes the first century of full energy sustainability—perhaps. (Fig. 1)

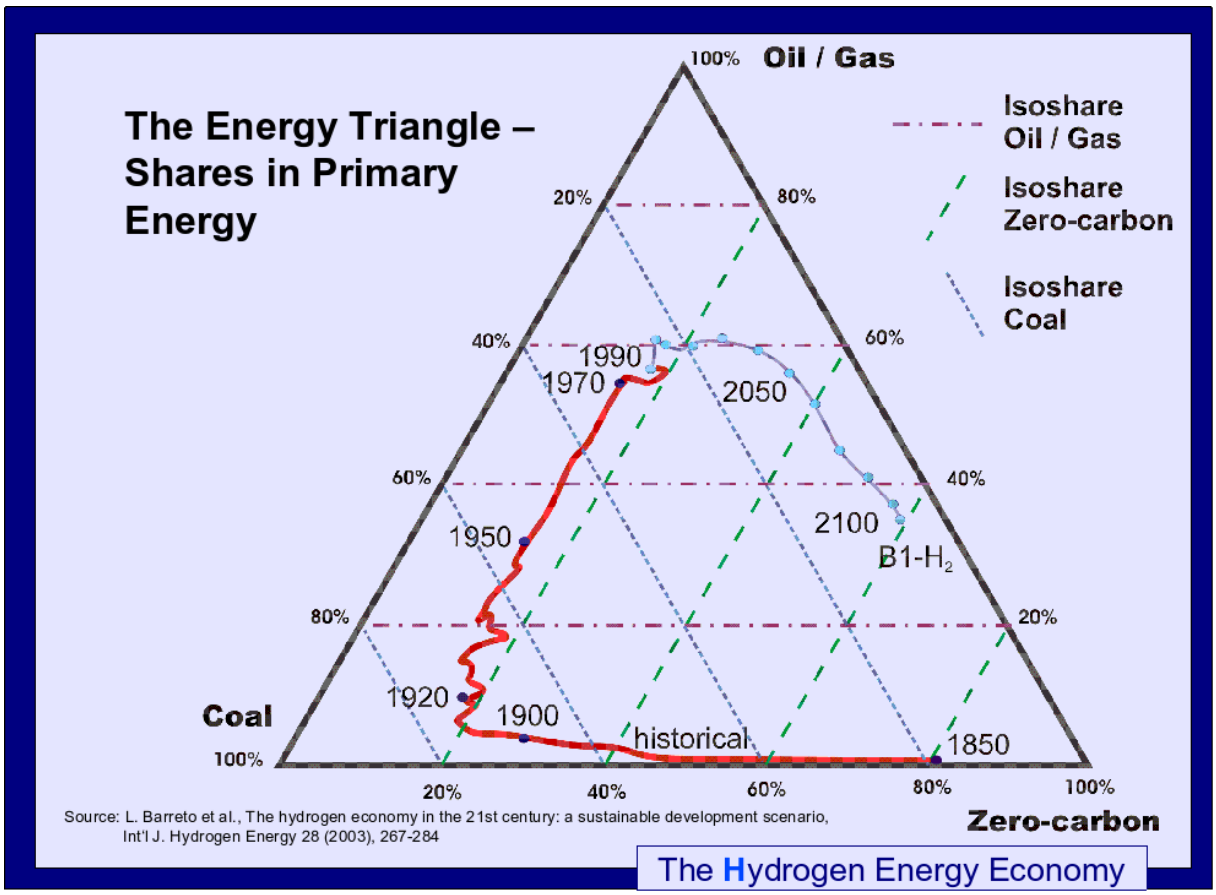

Figure 1

•The oligopolization of the fluid fossil fuels oil and gas grows. More energy sources in less responsible hands - a not too comfortable situation for the world economy at large! The bulk of the world's oil and gas resources are concentrated in the so called "energy strategic ellipse" spread out from the Persian Gulf via Iran, Iraq, and the central Asian states to as far as Siberia: It seems that energy and political stability are mutually exclusive!?

•Nations rich in both indigenous energy (raw materials) and energy technology skills are seldom. Germany and Europe are poor in energy (raw materials), but rich in energy efficient technologies; historically, the one was conditional for the other; technology wealth grew out of energy poorness: for example, Baden-Württemberg and Bavaria in Germany, both absolutely energy poor but technology rich, as well as Switzerland and Japan, all now belong to the wealthiest regions in the world!

•For long, energy globalisation has been a fact. Truly, the today's world energy supply is a global supply; contributions from regional or national sources steadily lose importance. The consequence: the challenges facing efficient energy conversion technologies grow, and so does the need for an environmentally and climatically clean, storable and transportable chemical energy carrier: hydrogen!

III. *"Technologies compete, not fuels" (D.S. Scott)*
The energy centuries of mechanization, electrification and hydrogenation

•It is the energy technologies which compete with each other, not really the energy raw materials: Technologies are the opening valves for fuels! No energy raw materials' entry

into the energy supply and utilization scheme without the appropriate technologies for their exploitation, storage and transport, and finally utilization!

- Coal was industrially un-mined and useless until James Watt's steam engine could provide mechanical energy for the workplaces of English industry in the later 18th century: hand labour in manufacturing died out, the **mechanization** of industry began.

- A good one hundred years later, at the turn of the 19th and 20th centuries, **electrification** came into existence with Siemens' electrical generator and Edison's light bulb.

- Oil markets did not begin to develop before the petroleum lamp, later the Otto and Diesel engines, were on the market.

- Natural gas faced an easy task, since its markets could build on city gas or coke gas infrastructures; natural gas burner equipment and the gas turbine were added, and in these days the fuel cell is being developed as another opening valve for natural gas or coal gas or biogas.

- Uranium was useless as long as the nuclear fuel energy cycle wasn't closed via uranium mining, uranium chemistry, uranium enrichment technologies, fuel rod production, nuclear reactors, to final storage or the plutonium extraction of spent fuel rods.

- On principle, renewable energies are without operational primary energy raw materials per se, their conversion technologies are everything, they dominate—such as the wind energy converter, the photovoltaic cell, the hydro turbine, the heat pump, the solar thermal power station.

- Most exciting, human technology skill makes possible energy conversions which do not take place in nature! Examples are the solar-electric photovoltaic cell or the chemo-electric fuel cell, which apply in new ways dormant physical principles to energy conversion, so far un-operational in macro-economic terms. It can be expected that further dormant novel energy conversion technologies await discovery - another mosaic stones in the "Energy Policy is Technology Politics" scheme!

- Technology-supported energy efficiency gains make more energy services from less primary energy sources: examples are the gas- and steam-turbine combined heat and power cycle (CHP) with 60% electrical efficiency and potentially more, or the solar-hydrogen operated zero-energy home (zero = operational energy from the market), or the 50% tank-to-wheel efficient hydrogen fuelled and specified internal combustion engine (ICE). In any case, it's the efficient technologies which reduce the amount of primary energy raw materials necessary for the generation of more energy services. The Enquête-Commission of the German Bundestag "Protection of the Earth's Atmosphere" in a unanimous decision stated that with relevant technologies on hand in Germany the country could well be "operated" at a national energy efficiency of 60% instead of today's 30%. That is not a matter of available technologies, it is a matter of political will and economic viability!

- And finally, the secondary energy hydrogen, like the other major secondary energy within the mix, electricity, will be invariably generated from any conceivable primary energy: the **hydrogenation of energy** starts**.** Again, the technologies are dominant for the generation of hydrogen, particularly for its storage, and for transportation, dissemination, finally for its end use. - "*Ecological reasoning not only asks for avoidance and renunciation, but also and primarily for unparalleled technological development";* no doubt, the road to the hydrogen energy economy is such an unparalleled technological development!

•Visions are the condition for any wise energy policy. Here, the vision reads: energy policy is technology politics! Albert Einstein's words, *"Visions are more important than knowledge because knowledge is finite"* are supplemented by Ernst Bloch's *"Visions need timetables!"* - in other words*: "Visions without action degrade to illusions!"* Truly, the introduction of the hydrogen energy economy is one of these actions!

IV. Hydrogen energy, really? - Hydrogen energy!

•Hydrogen stands at the end of the historical energy trend from coal via oil and gas to hydrogen, from solids to liquids to gaseous energies, from *high carbon via low carbon to no-carbon, and consequently from (almost) no-hydrogen via low hydrogen to high hydrogen!* Year by year, the relative carbon content of energy is continuously decreasing, the hydrogen content grows: The atomic hydrogen/carbon ratios for coal, oil, natural gas, and hydrogen are $<1 : 2 : 4 : \infty$. De-carbonization of energy (relatively less carbon) and its hydrogenation (more hydrogen), and, since the atomic weights of carbon and hydrogen are 12 and 1, respectively, its de-materialization are in full swing. In the last 100 years the tonnage of carbon relative to the unit of energy used came down by 35% worldwide. Already today, two of three atoms of fossil fuels burnt are hydrogen atoms. Grid delivery of energy is further increasing, it has become a standard.

•Taking on hydrogen is not really new: for long, the hydrogen economy which uses hydrogen non-energetically as a material commodity is a profitable business. Particularly active are the commercial gases industry, hydrogen chemistry, and refineries. Clients are legendary: ammonia or methanol production, de-sulfurisation of Diesel fuel, re-formulated hydrogenised gasoline fuel, glass manufacturing, the electronics or food industries, and many others. – Now, the switch to the **hydrogen energy economy** is ante portas. So far, only one industrial branch uses hydrogen energetically (and depends on it!), the space launching business (and German submersibles propelled by hydrogen and oxygen fuelled fuel cells), both of which wouldn't even exist without hydrogen as the fuel.

•Hydrogen contributes to the benignity of the environment and climate; hydrogen has the absolutely lighter ecological footprint: Hydrogen, like electricity, once generated is environmentally and climatically clean over the entire length of the subsequent energy conversion chain. And, hydrogen is environmentally and climatically neutral, if generated from renewable energies or from fossil fuels, in the latter case **with** capture and sequestration of co-produced carbon dioxide and its usage or final storage or mineralisation without release into the atmosphere. Electrolytic hydrogen comes from water and recombines to water again. The hydrogen energy economy concentrates the capture and sequestration of pollutants and greenhouse gases in one, the first, development step, the primary-to-secondary energy conversion step at the beginning of the hydrogen energy conversion chain. All the following steps down to the very end of the chain are environmentally and climatically clean! Clean secondary energy carriers make it unnecessary to burden the energy end user—in many cases a lay person—with ecologically responsible disposal. There will be no more widespread atmospheric or surface dissemination of pollutants.

•Hydrogen stimulates an innovation impetus par excellence: hydrogen supported fuel cells add to the accustomed thermo-electric conversion (turbines, reciprocating piston engines, and others) a novel technology principle of energy conversion: chemo-electric conversion. Hydrogen fuelled fuel cells are compact with a rather small geometrical footprint, and their module output ranges from watts to a few megawatts over six orders of magnitude;

they are highly efficient, with low noise, without moving parts and, thus, with no major dynamic forces or moments, they are environmentally and climatically clean. They are being developed for portable electronics, for stationary combined heat/cold and power tri-generation, for mobile on-board electricity delivery to the electrical on-board grids and the drive trains of autos, buses, trucks and lorries, locomotives, later also for airplanes. Most of the technologies are already in their demonstration status, thousands of demonstration vehicles are on the road; the next steps into decisive economic viability are ahead, they need their time, though (Fig. 2).

Figure 2

•Both secondary energy carriers, hydrogen and electricity, move the centre-of-gravity within the energy conversion and utilization chain towards its back end: "all's well that ends well." But here, at the end of the chain, energy cannot remain in the hands of 82 million lay persons (in Germany); professionalization is urgently needed. Professionalization as we are accustomed to have it at the begin of national energy conversion, where the mines, the refineries, the power stations and the like are in the reliable hands of professionals.

•Hydrogen decentralizes the energy system: hydrogen-supported fuel cells provide heat/cold and electricity where it is asked for - on the spot. Nationwide electricity wiring and cabling, sometimes over thousands of kilometres, which in Germany stands for a loss of some 4%, and sometimes much more in other parts of the world, becomes unnecessary. Electricity capacities from the back end of the conversion chain start to compete with electricity from the front end. IT-controlled virtual power from millions of small sized fuel cell electricity generators easily sums up to the 100,000 megawatts in Germany centrally on-line today: a thought experiment. Thought experiments seldom become real, but a real kernel is always in them somewhere. Here, that kernel reads: is it really

responsible vis-à-vis urgently needed energy sustainability to negate a virtual electricity capacity of an amount equal to the centralized on-line capacity?!

•Hydrogen enables an entry into the world energy trade for the huge renewable energy potentials of the world not operational so far: Patagonian wind sources, Canadian hydropower, Australian solar power and the like will be freed from their exclusive local, at most regional, utilization: Electrolytic hydrogen stores them and transports them worldwide; they become globally available.

•Hydrogen offers the chance of de-carbonization of fossil fuels already at the mine mouth or the oil or gas field (Fig. 3). Via hydrogen, shipping of coal, oil, or gaseous or liquefied gas over global distances will become environmentally and climatically clean. The energy seller takes over from the energy buyer the task to clean up the fuels intended for global trade. Henceforth, only hydrogen energy, gaseous or liquid, will be traded. Catastrophic oil tanker accidents with their devastating consequences will become a thing of the past. A diplomatic masterpiece is foreseeable, moving the guarantee for environmental and climatic cleanness from the energy buyer to the energy seller. The seller may be compensated with the added value related to the hydrogenation and, thus, sustainabilization of his product.

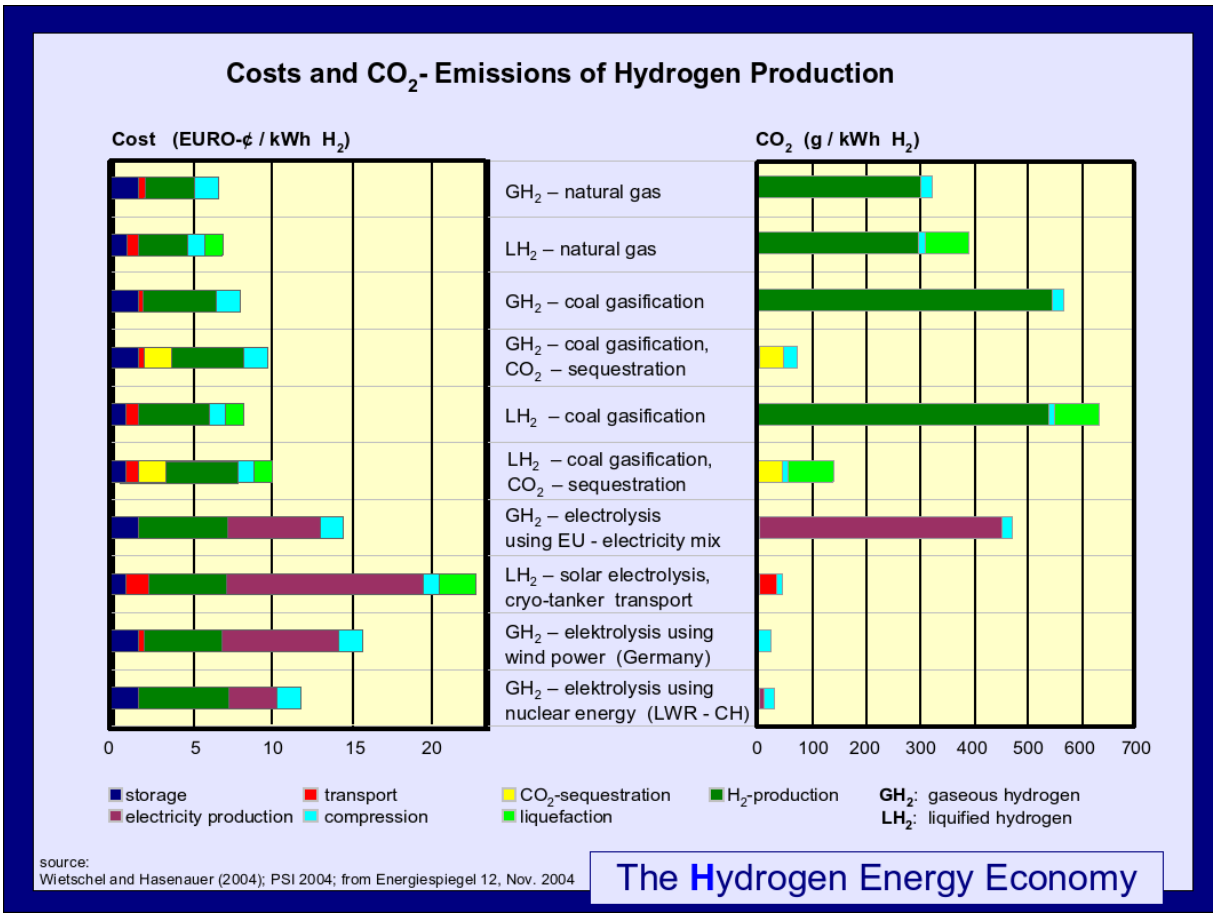

Figure 3

•Hydrogen from coal offers coal a renaissance, returning—now in gaseous hydrogen form—to the two end user realms of transport and residential energy (which in Germany sum up to two thirds of the end energy demand!) from where it had to almost completely withdraw with the advent of oil and gas. Today, electricity and steel keep coal alive, tomorrow hydrogen will be giving clean coal a new life!

•Nature doesn't alter its laws, following them needs no justification. Hydrogen slows down the physically unavoidable entropy increase (= the energy degradation accompanied with each and every conversion step). Hydrogen is the better half of the hydrocarbons, and for renewable energies it is a storage and transport medium for continental, oceanic, even global distances. The two secondary energies, hydrogen and electricity, are interdependent via electrolysis and fuel cell. Shipping electricity is shipping electrons; shipping hydrogen is shipping electrons with a proton attached to it.

•In short: hydrogen is a century's enterprise; hydrogen needs courage, not cowardice; big money, not small change; continuity, not ups and downs; and, perhaps the most important, conviction, not ambivalence!

V. Exergy, a few minutes of applied thermodynamics: it is needed here!

•Energy = exergy + anergy. Exergy is the ability to perform technical work, exergy can be converted into any other energy form, anergy cannot. With a national exergy efficiency of c. 15% in Germany what we have really achieved is an anergy economy in some 200 years of history of anthropogenic energy—truly a bitter lesson!

•Hydrogen exergizes the energy system, hydrogen makes available more technical work (exergy) out of energy, it minimizes anergy.

•Examples: Central heating system boilers are energetically excellent, almost 100 % of the chemical energy of the fuel are converted into heat. They are exergetically, however, miserable. It is exergetically absurd to generate 1000°C combustion temperature simply in order to provide some 60 to 70 °C room radiator temperature! Hydrogen fuelled fuel cells instead efficiently generate electricity firsthand (= pure exergy!), and the leftover heat still suffices to heat the house most of the year. - Likewise, it is absurd to run on standstill at a red traffic light the on-board electrical generator of, say, 5 to 10 kW with the help of an internal combustion engine of some 100 kW; replaced by an engine-independent hydrogen fuelled fuel cell, the electricity supply is guaranteed even if the engine is cut. Again bitter to say, even after 100 years of automobilisation the modern automobile generates mechanical traction (= exergy) with only 20 to 30% of the fuel's energy, the rest becomes heat. In reality the auto is a mobile stove which with at best some 20 to 30% of its on-board energy is also able to move humans or freight from A to B. Generally, when buying auto fuels it's done for kilometres not for energy! And hydrogen stands for more kilometres.

VI. Rebuttals, arguments

•At a standstill, the energy of motion is nil. Concentrating only on preserving assets leads to being overtaken. Innovations are the rule, deviating from that rule means slipping back.

•Energy needs time. Examples: the development of nuclear fission began with Otto Hahn's first nuclear fission experiment 1938 in Berlin, and has reached—now after almost 70 years—some 7 to 8% operational primary energy equivalent worldwide. Or another example, the gas turbine had its first application in the 1940s as the jet engine on-board Junkers' or Messerschmitt's aircraft; down on earth it delivers today together with a steam turbine in combined cycles an impressive 60% energy efficiency or even more. And further, when in due time a high-temperature fuel cell will be added the triple HT-fuel

cell, gas turbine, steam turbine combined cycle's energy efficiency of some 70% will not at all be illusive!

•As a rule, many decades up to half a century are needed for novel energies in the mix to deliver significant irreversible contributions. Making a resolute start is almost always to late!

• *"Energies*-of-change," "*Technologies-of-change" are the rule, preservation of what came down to us is the exception.* An exception with sometimes immense negative consequences (the German wharf industry, the clock industry in the Black Forest or today's cell phones, cameras, portable electronics and the like are hurting lessons!).

• *"Politics-of-change"* must anticipate and be visionary, but seldom are. *J.A.Schumpeter's "Innovations are the driving force for economic growth"* was valid, is valid, and will be valid—and seems to be forgotten!

•The consequence for the hydrogen energy economy: www.itsHYtime.de! It is almost always too late to start innovations and see them through. It is hydrogen time, it is high time to embark on the hydrogen energy economy and further its build-up! The invariable market results can be expected in some decades at the earliest, perhaps even mid 21st century. These are the typical time constraints of novel energies.

VII. Added value

•Innovations achieve a breakthrough on the market if they demonstrate affordable added value. The triangulation of academia, industry, and politics is key.

•The added value of the hydrogen energy economy and its technologies is wide ranging and can be summarized as

-its undoubted environmental and climatic benefits and its contribution to energy sustainability,
-the exergizing of the energy system: obtaining more useful technical work out of energy,
-the slow-down of thermodynamically unavoidable energy degradation (= entropy increase),
-making "national" energy operational in the form of national energy technology skills,
-the reduction of primary energy raw material import dependency and, thus, the avoidance of price dictate, at least partially,
-stimulating the export of innovative efficient energy technologies,
-decentralizing the national energy system and thereby activating so far dormant energy capacities and enabling competition with the existing centralized system,
-the introduction of huge, so far untapped renewable energy sources into the world energy trade,
-the decarbonization of fossil energies which, thus, become climatically as clean as renewable energies,
-and last not least, the professionalization of the energy potential at the end of the energy conversion chain.

VIII Safety of Hydrogen in Comparison to Current fuels

Is hydrogen safe? - First of all it is necessary to remind ourselves, even the engineers among us, that never and under no condition are technologies absolutely safe. That applies to energy technologies, too. Each and every energy material or energy technology follow specific relative safety attributes. Positive and negative safety aspects are related to more or less all elements within the anthropogenic energy scheme. In addition, these aspects are dependent on time, location, and special conditions: E.g., coal mines in one country may enjoy an extremely high safety standard, whilst the standards another country suffers under may be disagreeably low; or, a double-hull oil tanker's safety level is much higher than that of mono-hull tankers, but, so far the latter make up nearly 100% of the entire fleet; or a last example, renewable energies have a very low impact, if any, on the anthropogenic greenhouse effect, but their contribution to the world mix grows rather slowly.
Now, how about hydrogen energy? - Its safety relevance compares well with that of more or less all of its other competitors: it has safety advantages and disadvantages. Two overruling advantages are its lack of impact on the anthropogenic greenhouse effect, and its lack of radiotoxicity and radioactivity. Electrolytic hydrogen comes from water and recombines with oxygen (from the air) to water again. On principle, hydrogen from fossil fuels with carbon capture and sequestration or hydrogen from renewables compare well with respect to environmental and climatic cleanness. The comparatively low ignition energy of hydrogen, its wide ignition range, and its very high diffusivity in air, all have specific safety relevance (Fig. 4).
Since hydrogen, like electricity, is secondary energy, the energy chain's front end converters (the power plants, the reformers, the electrolysers, the liquefiers and the like) have to be taken into the safety considerations, too!
Of particular indirect safety relevance is the fact that hydrogen-fuelled fuel cells exergize the energy scheme. They make more exergy out of less primary energy, or in other words, the exergy production needs less primary energy. Less energy is a positive safety aspect per se.

And a last very specific indirect safety aspect is allocated to solar hydrogen, i.e., to hydrogen from renewable energies. The primary energies are sunlight, wind, hydro, etc. Water for the electrolysis is taken from the earth's water inventory and is, after recombination with oxygen, returned to that inventory. The solar water-to-hydrogen-to-water cycle is the only closed material cycle of any human energy scheme (Fig. 5). All the others are open systems: they take something irrecoverable from the earth's crust, convert it chemically and nuclearly, and return it to the biosphere, sometimes toxic, sometimes radioactive, and sometimes of negative environmental or climatic influence. -

VIII. In summary

Never is energy a mono-pole, energy is a dipole consisting of the primary energy raw materials **and** the technologies which make a maximum of energy services out of a minimum of those materials. With Germany dependent on imports to meet three quarters of its energy demand, wise energy related foreign policy is vital. All in all, the "forgotten pole"—efficient energy technologies along the complete energy conversion chain—compares well with energy, it is "energy" for the energy poor country. The technology pole enables the country to compensate for the imponderabilities of foreign energy markets. Efficient energy technologies are almost part of Germany's national identity. Wise and farsighted national energy technology policy needs to become national common sense.

Does hydrogen energy matter? – Does it matter that hydrogen energy doesn't matter—so far? What has to happen in order to create an affordable market from all the aforementioned technology related, in particular hydrogen energy technology related, arguments within a reasonable time? Democratic communities require informed and aware voters, enterprises, and—not least—politicians. Getting there is a long term process. It's necessary to keep the dispute on the hydrogen energy economy boiling gently, though continuously, and with an upward pointing positive gradient. Thinking and acting in terms of energy raw materials is 19th century, thinking and acting in terms of efficient energy technologies is 21st century! And hydrogen energy technologies belong to the 21st century!

Germany is on the verge of taking a back seat in establishing the hydrogen energy economy. Japan, the USA, Canada are the forerunners. In Germany the federal states of North Rhine-Westphalia, Bavaria, and Baden-Württemberg are at the forefront.
Nature's laws don't change. Nature's and the German Bundestag's laws increasingly diverge, and it is not reasonable to expect that nature's laws will be the ones to yield. In the search for technological knowledge the state can certainly lend a helping hand, but in any case, it should not block the way! Wise German national energy policy asks for energy politics which give hydrogen energy its due.

To close, in more than one sense "anticipate the coming farewell as if it were already behind you, just like the winter now departing" (Rainer Maria Rilke)

PS: Regularly in the springtime of even-numbered years an International German Hydrogen Energy Congress is scheduled; the next in the series will be in Essen, Germany, in 2006. The 18th World Hydrogen Energy Conference 2010 will also be in Essen. For more information visit www.itsHYtime.de (Fig. 6). www.18WHEC2010.de (Fig.7), and www.H2Congress.de

Figure 7