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## Inevitably, ... it's Hytime!<sup>1</sup>

By  
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### Hydrogen energy is

- ... clean** over its entire energy conversion chain when produced from renewable energies or from fossil energies with carbon capture and storage
- ... abundant** and can be considered the forever fuel, since, literally, it can be produced from any primary energy fuel - coal, oil, natural gas, nuclear, or renewable energies
- ... non-oligopolizable** since a hydrogen energy-“OPEC” is highly improbable and hardly imaginable
- ... technology driven** because along the complete hydrogen energy conversion chain hydrogen production, storage, transport, and utilization technologies are well understood and marketed or on the verge to be marketed; hydrogen fueled fuel cells are compact, quiet, clean, and, as chemo-electric converters being not Carnot heat engines, highly efficient. Modularized, their unit capacity ranges from Watts to Megawatts over 6 orders of magnitude with temperatures from some 80 up to c. 900°C; they serve as long-life power packages in portable electronics, as stationary heat/power blocs, as topping modules in combined cycles, and on board automobiles in the electric drive train and as electrical generators. Storage is guaranteed through high pressure gas, metal hydrides, or energy dense liquefied hydrogen. Hydrogen energy policy is technology politics!
- ... safe** because long term and unforeseeable damages are inexistent, since hydrogen energy is without toxicities or radioactivity, and the specific hydrogen risks are low;

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<sup>1</sup> ... it's HYtime; it's HYdrogen time

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since, on principle, there is no absolute safety in technical systems, nowhere and under no condition, hydrogen's specific safety risks have to be thoroughly taken care of. – The space launching industry, for the time being the only industrial branch which utilizes hydrogen energetically in large quantities for about almost half a century now, has never experienced an accident which was causally introduced by hydrogen

- ... worldwide traded in large quantities of some 50 million tonnes p.a. by the Merchant Gases Industry or by Big Oil; major users are the space and electronics industry, glass or food manufacturing, methanol or ammonia synthesis, electric generator cooling, and the refining industry (where hydrogen is captively utilized).
- ... ubiquitous since hydrogen energy perpetuates cleanly and securely the established world energy trade system; no continent or no nation is excluded as either hydrogen energy producers or hydrogen energy users
- ... enabling the “old” energies coal, oil, gas, in addition to the per se clean renewable energies, to play their role in a future environmentally and climatically clean sustainable energy world
- ... sustainable economically, environmentally and climatically, socially, and from a reversibility standpoint; energy non-reversibility is not sustainable.
- ... on the road because energy sustainability without hydrogen energy is irrational, and there are still many milestones ahead: energy sustainability is not a momentary value, rather than the road is the destination! Many hydrogen milestones aside the road lead into the Hydrogen Energy Economy.
- ... urgent because, generally, energy needs time, and hydrogen energy makes no difference. Decades, even half centuries, rather than years for the first market breakthrough in significant numbers or quantities are the appropriate time estimates. Consequently, it's HYtime to start the implementation of the Hydrogen Energy Economy and see it through.

**The quintessence:**

Never humans used only one form of energy, never a novel energy form fully replaced its predecessors, the ever growing energy demand of humankind

needed them all. After coal, oil, natural gas, and nuclear fission in the 18<sup>th</sup>, 19<sup>th</sup>, and 20<sup>th</sup> centuries, in addition to aggressive striving for energy and particularly exergy (the ability to provide technical work) efficiency as well as utilization of all sorts of renewable energies, the 21<sup>st</sup> century will be the century of hydrogen. Hydrogen is the so far final link in the anthropogenic energy development chain whose carbon content is continuously decreasing (less energy related carbon through de-carbonisation), and whose hydrogen content is increasing (more hydrogen through hydrogenation). The growing atomic hydrogen/carbon ratio H/C is under way:

Coal : oil : natural gas : hydrogen = <1 : 2 : 4 : ∞ .

Since the specific atomic weights of hydrogen and carbon are 1 and 12, respectively, the ongoing shifting process from the carbon rich/hydrogen poor hydrocarbon energy economy to the hydrogen rich/carbon poor hydrogen energy economy is accompanied by a continuous dematerialisation process; specifically, energy gets lighter and lighter by time. Already today, two of three atoms of worldwide utilized energy fuels are hydrogen atoms, the hydrogenation trend holds.

After the first solar civilisation which lasted well into the second half of the 18<sup>th</sup> century, after the 19<sup>th</sup> century which was the century of coal which, beginning in its second half, was complemented by mineral oil, natural gas, and, in the middle of the 20<sup>th</sup> century, by nuclear fission, the 21<sup>st</sup> century, after all we see, is going to become the century of energy efficiency, of all sorts of renewable energies, and hydrogen energy.

The “Era of Light” may be the appropriate energy label for that century, because

- energy efficiency makes more energy services from less weighty primary energy raw materials, renewable energies need no operational primary energy raw materials at all, and hydrogen is the lightest element in the Periodic Table of Elements; its ordinal number is 1.
- most renewable energies utilize directly or indirectly the light of the sun
- their utilization lightens the burden on environment and climate, and
- all three shed light on what will become the criterion for the 21<sup>st</sup> century of energy: Energy Sustainability.

... and keep in mind: energy compares nicely with a bike, if not pushed forward, it tumbles!