SOFT TRANSITION TO PLANETARY HYDROGEN ECONOMY – LOW PRICE FUELS AND ELECTRICITY

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Abstract

From 1981 the FDE (fossil derived energies, coal, oil, natural gas) consumption continue to increase and now, year 2018, the development of the Earth (wars included) is sustained for 85% by FDE consumed.
If the mean per capita FDE consumed/year remain constant (2.05 TEP/year per person) the probable time of total FDE exhaustion is year 2084. Then the 2030 energetic transition could be considered from now, to avoid the collapse of the global economy. This action requires:
1 - to give global dimension to the energetic world's perspectives
2 - to avoid to waste money
3 – to save strategic quantities of coal, from which carbonium is obtained (synthetic liquid fuels production)

The new planetary energetic economy could take into account:
a - how to find and to manage the necessary investments capitals
b - the security problems which emerge from the proliferation on the earth of energetic new systems
c - the time duration of economically recoverable energetic
d - the time lenght necessary to have the new energetic system 100% operative and related economy to manage its regime and renew time periods.

The probable FDE total exhaustion time is the year 2084.

THE HARD SOLAR PLANETARY PARK

This work has been written after consultation of the following documents:
1 – Life in a warmer earth – Possible climatic consequences of man made global warming, Author H. Flohn IIASA e.r. 1981
2 – Energy in a finite world, written by A. Mac Donald IIASA e.r. 1981
3 – I combustibili fossili, carbone, petrolio, gas naturale – Autore Eugenio Nardelli, Universale ETAS Editor, 1980
4 – The helios strategy – an erethical view of the potential role of the solar energy in the future of a small planet, Author J.M. Weingart IIASA e.r. 1981

This study referes to the arguments for a sustainable future mentioned by A. Mac Donald (number 2 of the reports consulted) namely, hydrogen sustained by hard solar exploitation economic perspectives.

In table 1 is the energetic scenario 2017-2090 in which the grow rate of energies consumed is proportional to the world's population grow rate.

Tab. 1 – Energetic scenario 2017-2090

(1)	(2)	(3)	(4)	(5)	(6)
2017	7	16.8	14.345	85	1235
2030	7.72	18.53	15.82	85	1047
2050	8.83	21.19	18.1	85	728
2070	9.94	23.85	20.37	85	364
2090	11.04	26.51	22.63	85	-46

Column 1 Time (y)
Column 2 World's population number x 10^9
Column 3 Total energies consumed x 10^9 TEP/year
Column 4 Total FDE consumed x 10^9 TEP/year
Column 5 Column 4/Column 3, %
Column 6 Total FDE reserves x 10^9 TEP

In the scenario, 2022-2122, of table 2 is shown the effect of soft synthetic liquid fuel penetration in the fuel market on the oil and coal reserves.

Tab. 2 – Oil and coal reserves and synthetic liquid fuels production

(1)	(2)	(3)	(4)	(5)	(6)	(7)
2022-2047	9750	750	17272	8.385	256	405
2047-2072	28500	1500	50488	24.51	172	230
2072-2097	47250	2250	87703	40.635	112	39
2097-2122	66000	3000	116919	56.76	76	-167

Column 1 Time (y)
Column 2 Synthetic fuel produced x 10^9 L
Column 3 Max production power x 10^9 L/year
Column 4 Hydrogen consumed x 10^9 NCM
Column 5 Coal consumed x 10^9 TEC

Column 6 Oil reserves x 10^9 TEP
Column 7 Coal reserves x 10^9 TEC

Exhaustion of oil reserves year 2175, of coal reserves before the year 2100. Then it seems necessary to save coal to continue to have carbonium for synthetic liquid fuels production.

In table 3 is shown the effect of coal saved for carbonium production

Tab. 3 – Strategic coal substitution by hydrogen

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2022-2047	9750	17272	403750	421022	8.385	531	256
2047-2072	28500	50488	403750	454238	24.51	490	173
2072-2097	47250	83703	403750	487453	40.635	430	113
2097-2122	66000	116919	403750	520669	56.76	376	76

Column 1 Time (y)
Column 2 Synthetic fuel produced x 10^9 L
Column 3 Hydrogen consumed for SLF production x 10^9 NCM
Column 4 Hydrogen which substitutes coal x 10^9 NCM
Column 5 Total hydrogen consumed x 10^9 NCM
Column 6 Coal consumed to produce carbonium x 10^9 TEC
Column 7 Coal reserves x 10^9 TEC
Column 8 Oil reserves x 10^9 TEP

Oil reserves exhaustion year 2175. Carbonium from coal can be obtained up to the year 2287.

The hydrogen consumed in the regime phase has to:

a) produce 5750 billion NCM/year of electrolitic hydrogen to sustain the liquid and gaseous planetary fuels consumptions
b) substitute 3 billion TEC/year of coal as heat
c) substitute 9245 billion KWhe/year coal thermoelectric with turboelectricity hydrogen fueled.

Total hydrogen to be produced 21232 billion NCM/year*

Electricity consumed to produce 1 NCM of electrolitic hydrogen stored at 70 atm, in caverns excavated in the area of each hydrogen farm, 4.93 KWhe/NCM.
Electricity to be produced 104674 billion KWhe/year, enhancement factor +5%, which takes into account the mean losses in the H.V. transmission lines; total electricity to be produced 109907 billion KWhe/year.

70% - 76935 x 10^9 billion KWhe/year wind planetary park, made of 5 MWep each unit Fig. 2
30% - 32972 x 10^9 billion KWhe/year light planetary park, made of 45.545 MWep photovoltaic ring convertors Fig. 3

* see Appendix

- WIND park – hypothesis:
the wind convertors are placed in sites of the earth where winds blow at mean speed 8-12 m/s for 3500 hours/year 16625000 KWhe/year is the mean electricity produced from each unit when a reducing factor 0.95 takes into account the efficiency of transformation to high electric voltage for transmission. Total number of wind convertors 4629950.
- LIGHT park – hypothesis:
the light convertors are placed in sites of the earth where on an orizontal one square meter surface 2000 KWhe/year are received. Then 91090000 KWhe/year are produced by one unit x 0.95 (efficiency to H.V. transformation) 8653500 KWhe/year per unit. Total number of light convertors 381207 units.
Wind power installed 23149750 MWep
Light power installed 17362072 MWep
Total power 40511822 MWep
Figure 1 - The Hydrogen Farm Module

8102 MWep wind – light convertors park/ unit H.M.	H.V. grid transformers to M.V. - medium voltage – M.L. low voltage electricity	Evaporator	Condenser	Distilled water storage	Basic drug volume
Electrolysis facilities	Pressurized oxygen storage	Pressurized hydrogen storage			

In fig.1 are shown the operative facilities of an hydrogen farm (H.F.). The H.F. is the smallest modular unit of the hydrogen producing system – sustained by hard solar. The H.F. are 5000 spread on the southern and northern emisphere of the earth. The H.F. captures the stochastic electricity, transferred by the planetary H.V. grid network, and transform it in a fuel on demand. The fuels hydrogen and oxygen can be transmitted, from H.F. to consumer areas, by pipes, railways, in pressurized containers, and in the sea by great tankers. In the H.F. there is a family of high power transformers, and a soft hard control system programmed to exploit at the best the stochastic captured electricity.

Material composition of the hydrogen planetary system, table 4.

Table 4 - Material composition of the PHS x 10^6 ton

	Material	Renew (y)	
Polycristal sylicon	129	25	(100% sylicates)
Glass	644	25	(100% sylicates)
Concrete	14163	300	(40% sylicates)
Aluminium	174		(100% rec)
Copper	3124		(100% rec)
Inox	275		(100% rec)
Iron	3689		(100% rec)
Bricks	5972	1500	

The sylicates consumed are 49.8 million ton/year, then the productivity of the hard solar system is 0.475 gram/KWhe.
On the first 120 km of the emerged earth's crust there are about 23 x 10^{24} gr of sylicates*
The 0.00025% of these reserves allow the hydrogen economy, here discussed, to go on the future for, at least, one million years. The surface of the earth involved, (marginal area), is 38 million hectares (0.25% of the emerged earth' surface), of these 3.3 million hectares not cultivable (90% of the area involved can be cultivated for food or bioenergy production).

* G.Bruni see references

The planetary economic strategy (PES)

The PES considers the decommission time lenght D and assumes 1/D as the rate of components production of the material recycling of renew defraction of the energetic system which has been already decommission. PES foresees, also, to sell the energy produced by the system during its construction, decommission, renew phases. 1/D for the hydrogen economy hard solar sustained is 0.04 and PES manages all the phases in such way to obtain the optimum profit.

In table 5 are the essentials of PES:

C means construction at a rate of 4%/year
D means decommission-renew of the 4% of the system whose construction has been completed in C

When the energetic system is 100% operative, PES continues to manage all the phases of decommission-renew. For the hydrogen-hard solar these phases refer to 4%/year of the all system which indefinitely continues.

Table 5 – Costs assumed

	C x 10^9 USD	D x 10^9 USD
Electric power	17470	17470
H.V. grid network	10	
Evaporator	1	
Condenser	245	
Distilled water storage	119	
Drug volume	1	
Electrolysis facilities	2381	2381
Pressurized gases storage	233	
Ammortization		39
Enterprize profit	192	192
Jobs assurance	192	192
TOTAL	**20845**	**20274**

Description	
Electric power	1.725 x 10^6 USD/MWep
H.V. electric grid lines	500000 USD/km
Electrolysis facilities	0.025 USD/NCM (ammortization 10 years)
Assistance	0.005 USD/NCM (NCM produced)
Jobs	20000 USD/year x person
Pressurized storage	64.595 x 10^9 USD/m^3
Oxygen price	0.12 USD/NCM
Concrete	130 USD/ton
Bricks	80 USD/ton
Iron	51.1 USD/ton
Steel	540 USD/ton
Inox steel	3710 USD/ton
Aluminum	3490 USD/ton
Copper	6900 USD/ton
Cave excavation	30 USD/m^3 (+8% to impermeabilize the hydrogen cavern)

Table 6 - The planetary economic strategy

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
25 C1	20845	69036	1242	751	345	146	0.2998
50 C2,D1	41119	201798	3632	1503	1609	1120	0.198
75 C3,D1,D2	61393	334590	6623	2254	1922	1847	0.178
100 C4,D1,D2, D3	81677	467352	8412	3006	2237	3067	0.168
125 D1,D2,D3, D4	81096	531048	9559	3757	2685	3147	0.147

Column 1 Time (y), phases
Column 2 Investment x 10^9 USD
Column 3 Hydrogen produced x 10^9 NCM
Column 4 Oxygen credit: 70% of the produced oxygen is dispersed in the atmosphere 30% is sold at 0.12 USD/NCM x 10^9 USD
Column 5 Added jobs cost x 10^9 USD
Column 6 Assistance to elecrolitic production-distribution (0.005 USD/NCM x 10^9 USD)
Column 7 Column 4 – Column 5 – Column 6 x 10^9 USD
Column 8 Industrial hydrogen cost USD/NCM

The effects of the planetary economic strategy

a) Hydrogen cost decreasing
b) Cost of the investment (83380 billion USD) payed by the hydrogen sold at the prices of Column 8 table 6

In table 7 the scenario 2017-2117 of the FDE marketing prices

Time (y)	Coal USD/TEC	Oil USD/TEP	Nat gas USD/TEP
2017	90	339	350
2022	138	521	538
2027	213	802	828
2032	328	1234	1275
2037	460	1731	1788
2042	645	2429	2508
2047	904	3407	3517
2052	1154	4348	4489
2057	1472	5549	5729
2062	1879	7078	7312
2067	2178	8205	8477
2072	2526	9512	9827
2077	2928	11027	11392
2082	3077	11589	11974
2087	3234	12180	12584

The grow of the prices (as a mean) is due to the higher cost to ammortize the investments to extract the residual earth's FDE reserves. The grow rate of the prices decrease because in the energy market appear competitors, which offer more convenient prices of fuel and electricity. The stability of the economic exchange market will depend from the stability or decreasing value of the energetic prices; then the time duration of the energetic recoverable economic reserves will be very important to give stable outlook of the global economy.

In table 8 are compared the prices of electricity produced by turbogas hydrogen fueled (1.4335 KWhe/NCM) and the thermoelecricity from coal (2560 KWhe/TEC)

Table 8 – Prices of electricity

(1)	(2)	(3)	(4)
25 C1	0.2998	0.21	0.21

50 C2,D1	0.198	0.138	0.95
75 C3,D1,D2	0.178	0.124	1.2
100 C4,D1,D2,D3	0.168	0.117	>1.2
125 D1,D2,D3,D4	0.147	0.102	>1.2

Column 1 Time (y), phases
Column 2 Industrial cost of hydrogen USD/NCM
Column 3 Industrial cost of turboelectricity Hydrogen fueled USD/KWhe
Column 4 Industrial cost of thermoelectric production from coal USD/KWhe

The scenario of table 8 demonstrates that the torboelectricity from hydrogen can be the more economic.
In table 9 are compared the prices of synthetic liquid fuels with the costs of the oil derived fuels.

Table 9 – Prices of liquid fuels

(1)	(2)	(3)	(4)	(5)
2022-2047	0.533	0.491	1.02	2.8
2027-2072	0.335	2.13	2.46	11.6
2072-2097	0.315	2.71	3.025	14.8
2097-2122	0.298	2.71	3.008	-
2122-2147	0.26	2.71	2.97	-

Column 1 Time (y)
Column 2 Cost of hydrogen consumed to produce 1 L of SLF USD/L
Column 3 Cost of coal consumed to produce 1 L of SLF USD/L
Column 4 Industrial cost of 1 L of synthetic liquid fuel USD/L
Column 5 Industrial cost of 1 L of oil derived fuel USD/L

Table 10 – The impact on the economy of the electricity and fuel prices

(1)	(2)	(3)	(4)	(5)	(6)
2022-2047	0.03737	0.14	0.051	0.035	0.035
2027-2072	0.02475	0.58	0.123	0.023	0.158
2072-2097	0.0222	0.74	0.151	0.0207	0.2
2097-2122	0.021	>0.74	0.15	0.0195	>0.2
2122-2147	0.01838	>0.74	0.148	0.017	>0.2

Column 1 Time (y)
Column 2 Hydrogen fueled car (8 km/NCM)
Column 3 Oil derived fueled hybrid car (20 km/L)
Column 4 Synthetic fuel fueled hybrid car (20 km/L)
Column 5 Turboelectricity from hydrogen fueled electric car (6 km/KWhe)
Column 6 Thermoelectricity from coal fueled electric car (6 km/KWhe)

From tabel 10 is evident the competitivity of electricity and fuels hydrogen, hard solar sustained.

Correction of the man-made global warming

The negative economic effects of the man-made global warming are so high that they have to be prevented (H. Flohn IIASA e.r. 1981)

The way in which the atmosphere accepts and rejects the pollutant i.r. reflectors is not well known; what is known is that

- the sea absorbs almost 40% of the carbon dioxide produced in eccess
- the vegetation adds carbon dioxide to the atmosphere because its surface is reduced by hard deforestation and by fire in the long period of draught
- the correction of the man-made global warming has to be performed in all the planet to have probability of local benefits
- interglacial periods of the earth have a time duration of 75 thousand years;
- at present the earth is the year 18000 from the end of the last glacial period

In table 11 are decorrections to man-made global warming which can be expected from the planetary hydrogen economy here discussed

Table 11 – Correction of man-made global warming

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2022-2047	54	120	0.0	174	198	228	52
2027-2072	42	120	0.0	164	187	215	54
2072-2097	30	120	0.0	150	171	117	58
2097-2122	18	_	0.0	18	20	24	95
2122-2147	12	_	0.0	12	14	16	97

Column 1 Time (y)
Column 2 Oil burned x 10^9 TEP
Column 3 Nat. Gas burned x 10^9 TEP
Column 4 Coal burned x 10^9 TEC (coal is substituted by hydrogen)
Column 5 Total FDE burned x 10^9 TEP
Column 6 Carbon dioxide in the atmosphere (Column 5 x 0.6 x 1.9) x 10^9 ton
Column 7 Effect of total pollutant i.r. reflector (Column 6 x 1.15) x 10^9 ton
Column 8 % of man-made global warming correction (Column 8 = 1-Column 7/(360x1.9x0.6x1.15); (360x1.9x0.6x1.15) is the total pollution produced without correction

The step from 58% to 95% (Column 8) is due to the 0 contribution from the natural gas almost exhausted and to the reduced residual FDE burned. We do not know how will be the planetary climatic situation in the next 50 years. We know that the man-made global warming can reach a physical condition which can not be corrected because it feeds itself, with, as a consequence, a planetary catastrophic geostorm; we do not know **when** and we try to prevent (H. Flohn IIASA e.r 1981). From this work a correction of man-made made global warming around 50% can be achieved in less than 25 years and, as can be verified from the scenario in table 11. In short is not a solution the "après moi le déluge" pronuncied by the French King Louis XV , better is to follow the suggestions of Prof. Flohn and to find an economic and safe proposal to contribute to prevent a catastrophic geostorm.

How stochastic electricity is transformed in fuel on demand (hydrogen)

The light-wind convertors are distributed in well suited areas of the earth' surface. The stochastic electricity produced is transmitted by the H.V. planetary grid array of which already now exist lines 3000 km long. 5000 hydrogen farms (H.F.), spread on the earth's surface, capture the stochastic electricity and perform the phases of figure 1. Water is pumped from the source, lake, river, sea, into the evaporator volume, made of brick material (long time duration, low thermal transmission coefficient) inside the evaporator volume (divided in ten cilindrical subvolumes)* is ohmic resistor which, allows, to transform the liquid water into steam at 100°C, (40 KW voltage and 3800 ampere for 6 hours).

*in the bottom of each subvolume is a window from which, when opened, are extracted the solid materials remained after the water evaporation

The condenser is the roof of the distilled water storage, made of inox material. The steem laps the back surface while a flow of fresh water, pumped in the roof surface from the source, allows to the steem to condense at 1100°C. The distilled water is stored in the volume of the distilled water storage (d.w.s.), (3434870 m^3). The volume, when it is full of water contain 100% of a year of consumptions stored. The hard-soft facilities of each H.F. exchange informations with meteo satellities and space aircraft observer of the earth' surface.
A transition phase has to be foreseen during which the distilled water storage is charged. When the d.w.s. is charged all the captured electricity is consumed to produce electrolitic hydrogen from water pumped from the drug volume. The gases produced by the water electrolysis have to be immediately stored (pressured volumes, 70 atm). To store the gases at high pressure in excavated caverns consumes about 0.2 $KWhe/m^3$ (5% of the electricity consumed to produce 1 NCM of hydrogen). When the incoming electricity is not sufficient for the water electrolysis and the contemporary pressurized storage, the hard soft control facility deviates th power to charge the d.w.s.
When the gases (hydrogen oxygen) are in the pressurized storage, the stochastic electricity is transformed in a gas on demand. The gases can be transferred from H.F. to the consumptions areas by pipes, railway transport of pressurized volumes (200-300 atm), by sea tanker.

Conclusions

In this paper has been demonstrated that the planetary hydrogen economy – hard solar sustained ca be economically convenient as option fo a stable future on the earth. This result can be achieved by accepting the planetary economic strategy which introduces innovative approaches on the production processes of the necessary energetic goods as well as in there use and management. The modular hydrogen farm is the standard unit which is multiplied on the earth: it captures, from the H.V. grid lines, the stochastic electricity, produced by the hard solar parks and transforms into fuels (electrolitic hydrogen and oxygen on demand). At present on the earth there exist several hard soalr parks whose produced stochastic electricity is transformed in electricity on demand by a smart electric grid which transports also other no stochastic electricity. But when long time duration energetic world's transition is considered this condition does not continue to exista and it becomes necessary to discover a way to transform stochastic electricity in an energetic consumable supply on demand (hydrogen plus oxygen gases). Not expensive hydrogen fuel can subsitute other polluting and exhaustible fuels in industrial processes where the requested flamed temperature is up 2600°C, in poducing electricity and fuels at very competitive prices, with benefits for the global economy and the global environment.