Soft Transition to Hydrogen Economy to sustain the development on the Earth: the planetary techno-economic strategy

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Summary

The nutricola index N.I. = economically exploitable discovered energy reserves, mean consumptions x year measures measures the time lenght duration of the energy reserves; high values of N.I. correspond to stable price of the energy produced (electricity, fuel). In this work the author presents the techno-economic analysis of planetary hydrogen economy, substitute of the present F.D.E. (Fossil Derived Energies economy), whose probable exhaustion date is around the year 2100. To substitute 85% of F.D.E., now consumed, to sustain the next future economy and to correct the climatic effects, that is 12 billion TEP/y, the necessary hydrogen volume is 47000 billion NCM/y. The electricity to produce the NCM electrolitic hydrogen is 231000 KWhe/y, derived by the proliferation on the earth of 45 million MWe of thermoelectric convertors, or 92 million MWep of light-wind solar energy convertors. To these have to be added all the facilities to transport and store the hydrogen produced. An **unexpected discover of this analysis** is that **silicates safe materials are the fuel consumed by light-wind convertors in a planetary proliferation**, being all the other material used 100% recyclable. The results of the analysis, whose confidence index is 80% are the following:

- renewable hydrogen economy has a time duration of 20 million centuries, the prices of the fuel decreasing under 0.2 USD / NCM
- the necessary investment to have the planetary hydrogen economy 100% operative is 229000 billion USD, but its cost is **0 USD** (the in-out balance presents a perennial positive cash surplus)
- the planetary hydrogen strategy (P.E.S.) requires 125 years (five consecutive periods 25 years each) to have 100% operative the hydrogen producing system.

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Foreword

At the present, the world's population is 7 billion H.B. (Human Beings), while the probable number, around the year 2050, will be 10 billion H.B. Then the energetic consumptions could grow up to 25 billion TEP/y (about 21.5 billion TEP/y of Fossil Derived Energies, F.D.E.), and the climatic effects will increase too. The picture of 2016 energy consumptions is

- Global energy consumed 16.6 billion TEP/y
- F.E.D. consumed 14.325 billion TEP/y
- Atomic 0.75 billion TEP/y
- Renewable (hydro, wind, ligth and others) 1.515 billion TEP/y

Proved and foreseen exploitable F.D.E. reserves at the year 2016

ENERGY	RESERVES x 10^9 TEP
Oil	350
NAT. GAS	365
COAL	1260
TOT.	1975
	To these, easily exploitable, (added)
Schists	21
Sands	22
Geological coal	760
	(total geo coal reserves 8000 billion TEP)

The reduction of the F.D.E. world's reserves is a function of global consumptions; 1215 billion TEP is assumed as probable exploitable value of F.D.E. at the year 2016, of which 715 billion TEP are the oil plus gas reserves while 500 are those of hard coal.

The future energy economy which the world is facing presents the following main problems:

1 – the huge quantity of wastes produced and their effect on the planet environment and the health of the whole biodiversity. These wastes can be not dangerous too (see forward)

2 – the fast depletion of F.D.E. and the strategies for their substitution

As to point 1, **a change in the structure of present energy consumptions, to respond to the problems of present and near future, it is virtually impossible, due to the rigidity of the F.D.E. consumption now in the world**. Therefore it seems appropriate to explore **the opportunities that carbon-dioxide free energetic solutions may offer to correct the climate changes and to provide long-term stability to the energy supply of human activities.** Climate changes in the globe are caused by astronomical phenomena associated with interglacial period that go on 75000 years, and in the last of which the earth is from 18000 years; in addition to this the increase of carbon-dioxide emissions (more than 25 billion tons/y)* due to the burning of 14.375 billion TEP/y of F.D.E.

As to point 2 **a planetary hydrogen economy (P.H.E.),** discussed in this paper, can substitute the F.D.E. world economy. **P.H.E. is a final energetic solution carbon-dioxide free**; which requires time to be 100% operative and a long duration of the reserves consumed to avoid instability on the fuel market price, and in the global economy.

The nutricola index

The nutricola is a jellyfish which renews its cells, when old, and continues to repeat a new life cycle. Nutricola is an immortal being. In the field of energy there are not reserves of infinite duration as it is the nutricola's life. However, deeply going in the analysis of the earth's reserves which can be exploited for very long time duration to substitute F.D.E. (by hydrogen planetary economy), it is possible to discover not expected properties of the **earth' silicates reserves used as a fuel**. Silicates reserves of the earth are concentrated in a band deep 120 km near the earth's crust. The reasonably exploitable reserves are enormous, and in this work are assumed 3% of the silicates recoverable in the band contained in the emerged earth's zones. Then **the high probable exploitable silicates reserves** are 1.06×10^{18} ton, at 2016 year.

Silicates have been consumed and are consumed for civil and industrial application of the old and modern world as silicates derived materials. Concrete contains 40% of silicates. The present world consumption can be valued around 450 million ton/y of silicates.

Silicates are also the fuel consumed by light-wind convertors of solar energy.

Light-wind convertors are made of 100% recyclable materials like iron, steel, aluminum, copper, silver, glass and silicates materials non recyclable, safe long-duration materials, consumed for construction and operative maintenance of the convertors.

* carbon-dioxide in the atmosphere 700 billion tons.

Wind power and sunlight technology have reached a guaranted level of reability also in long term use with amortization and 25 years substitution cycles of the energetic components.

A world hydrogen economy of long duration needs of

A – abundant reserves of energy to be consumed
B – proved convertors
C – a planetary economic strategy (P.E.S.) to manage the investments and to save money.

As to point C, **the planetary economic strategy (P.E.S.)** considers a family of energetic convertors and their decommission time D. **Then 1/D=R is the rate of construction of the total power delivered P**; this is the **transition phase T**, at the end of which the energetic system already built is 100% operative and begins the **regime phase RP**. In the regime phase the energetic family, 100% operative, delivers the maximum energy Em/y. **The rate R of decommission-renew** continues to be applied to the whole family of convertors up to the total exhaustion of the reserves of energy consumed, if it is convenient. As to **economy** P.E.S. foresees to sell the energy produced (fuel, electricity) also in the transition phase T; then the cost of the investement I (dollars) can be reduced over 90% of its value I or even to zero USD. By anticipating results, forward demonstrated in this work, the silicates consumed by the **Planetary Hydrogen Economy** are 80 million ton/y, 18% of the present civil industrial consumptions; by adding all the world silicates consumptions the **nutricola index N.I. = 2 billion years**. The choice to entrust the world on hydrogen economy and to solar energy is favoured by the N.I. high value from which **high stability of the market price of hydrogen fuel has to be foreseen**.
In Tab. 1 is shown the role of renewable hydrogen in a world economy based on it. **The F.D.E. to be saved is mainly coal**, now burned in concrete and syderurgic industrial facilities and to produce electricity. The coal subtracted to the combustion will be substituted by hydrogen fuel*, while the carbonium from coal will make to react with hydrogen gas to produce **mainly synthetic liquid fuels**. Synthetic liquid fuels production will be strategic in the next 30 years to substitute oil derived fuels.
With a world energy consumptions of 4.8 billion TEP/y for each of the energy consumed, oil, n.g., h.c. In the year 2021 (after 2016) the reserves are reduced to:

oil 326 billion TEP
n.g. 341 billion TEP
h.c. 476 billion TEP

In Table 1 are shown the effects of a durable hydrogen fuel introduced in the **planetary energetic economy**.

*as electricity and fuel

Tab. 1

Time (y)	Synthetic L.F.	Hydrogen gas	Oil saved x 10^9 TEP	Oil reserves	Coal consumed	Hydrogen fuel as	Coal reserves

	produced x 10^9 litres	consumed x 10^9 NCM		x 10^9 TEP	x 10^9 TEP	substitute x 10^9 NCM	x 10^9 TEP
2021-2046	31250	55395	53.125	259	23.8	66430	373
2046-2071	31250	55395	53.125	192	23.8	300800	331
2071-2096	31250	55395	53.125	126	23.8	536857	307.2
2096-2121	31250	55395	53.125	59	23.8	826492	282.4
2121-2146	31250	55395	53.125	-9	23.8	1005376	259.6
2146-2171	31250	55395			23.8	1116104	235.8

Oil reserves extinction 2141 year

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2418 31250 55395 extinction of h.c. reserves 1116104 -

The oil reserves are exhausted in the year 2141.

The substitution of coal consumptions, 3.848 billion TEP/y, with hydrogen reduces the coal consumption to 0.952 billion TEP/y used for L.S.F. production. The hard coal duration and L.S.F. production arrive to year 2418.

This long time production of L.S.F. will allow to emerge all the sectors in which is more convenient to continue to consume liquid, easily transportable, fuels and to organize their production (see forward).

The effects on the world economy by renewable hydrogen production are the following:
A – continuation of the industrial activities (3.848 billion TEP/y, depending now from coal) supported by hydrogen for an indefinite time lenght
B – production of 74299 billion KWhe/y (6000 from hydroelectricity) for an indefinite time lenght
C – continuation of L.S.F. production up to the year 2418 (exhaustion of H.C. reserves)
As to point C the introduction into the energy market of 760 billion TEP of geological coal allows to produce L.S.F. up to the year 3026.

The **extreme durability** of hydrogen economy on the world opens a perspective of a **great economic stability**.

Conversion hydrogen → TEP (2.6 x NCM of hydrogen gas)/10000

Column 1 Time, years
Column 2 Liquid synthetic fuel produced x 10^9 litres
Column 3 Hydrogen gas consumed in L.S.F. production process x 10^9 NCM
Column 4 Oil saved from refineries consumption x 10^9 TEP
Column 5 Oil reserves (effects of oil saved with L.S.F. production)
Column 6 Coal consumed in L.S.F. production process x 10^9 TEP
Column 7 Hydrogen gas as substitute of industrial coal consumptions x 10^9 NCM
Column 8 Coal reserves x 10^9 TEP

A renewable planetary hydrogen economy on the Earth – economic analysis

The innovative economic concept of amortization, introduced by P.E.S., allows profits cashed from energy sales that are produced from an already functioning RES (Renewable Energy System), thereby reducing temporary debts to sustainable amounts.

This type of amortization is compulsory considering global financial projects.

Now apply the economic strategy (P.E.S.) with programmed substitution of dwindling energy stocks and replace it with a planetary RES (using wind power and sunlight from any location on the earth) that can produce up to 15 billion TEP per year to supply energy at convenient prices and for a long time length. Assuming that 1500000 US$/MWep, i.e. the cost prior to the construction (industry production), x 1.15 (transport and delivery costs), for a total of 1725000 US$/MWep.

To this have to be added the costs for setting up and managing the whole hydrogen producing system, the energy transport and storage, workers' insurance, companies' profits. These are indicative prices (and costs) for a global level market for the structured set up of large systems that can survive for hundreds and thousands of centuries to come, with "continuous periodic renewal" (in the same site where they have been built up). Global production of necessary electricity (via water electrolysis) to obtain the equivalent hydrogen (NCM / year) of 12.176 billion TEP/y**.

** Around 85% of the 2016 F.D.E. planetary consumptions

- Hydrogen equivalent to 12.176 billion TEP 46831 billion NCM H_2
- Water electrolysis, total consumption, 4.93 KWhe / NCM H_2
- Electricity for production 231000 billion KWhe / year, see Fig. 1

Therefore, electricity could be increased up to 231000 billion KWhe/year using a system that produces electricity:

- 60% **wind power** in areas of the earth where winds blow for a time length of 3500 hours a year (as a mean) at an average speed of 8-12 metres per second.

- 40% **sunlight** in areas where the total solar light on the earth' surface is 2000 KWh/m^2 per year, areas, around the world, where is also possible to exploit 1750 KWh/m^2 per year of **direct light beam**.

Therefore

- **wind power** 138600 billion KWhe / year (60%) obtained by installing **wind convertors** (Fig. 2) which work for 3500 hours a year at an **average power** of 4.5 MWep each (14962500 KWhe / year per unit, when 95% is the mean efficiency for H.V. electricity transmission from the wind park convertors to the nearest hydrogen farm). Everywhere it is possible to find constant and strong winds.

- **number of wind convertors** 9263150 units

- **wind peak power** 41648175 MWep

- **sunlight** 92400 billion KWhe / year obtained by installing:

central receivers with mirror field convertors (Fig. 2), 23100 billion KWhe / year (10%) which work for 1750 hours a year at an average power of 54.524 MWep each (90646150 KWhe / year per unit, 95% electricity transmission mean efficiency included). Promise high conversion efficiencies.

number of central receivers convertors 254837

central receiver peak power 13894732 MWep

photovoltaic ring convertors (Fig. 2), 69300 billion KWhe / year (30%) which work for 2000 hours a year at an average power of 54.524 MWep each (103595600 KWhe / year per unit, 95% electricity transmission mean efficiency included). They convert the total light.

number of photovoltaic ring convertors 668947

photovoltaic ring convertors peak power 36473684 MWep

Total working power 92016596 MWep.

Carbondioxide emissions reductions

The planetary economic strategy (P.E.S.) foresees 5 time succesive periods, each one of 25 years time length, during which a growing quantity of F.D.E. is substituted by hydrogen, while the RES is built 4% / year. At the year 125 hydrogen substitutes 12.176 billion TEP/y and the RES, full operative, "continues" to produce hydrogen and to be renewed 4% / year.

In Tab. 2 is shown the produced correction of greenhouse effect from F.D.E. consumptions.

Tab. 2 – **Derived fossil energy substituted and reduction of carbon dioxide emissions**

RES – Time (year) and phases	NCM GAS x 10^9	TEP-S x 10^9 *	CO_2 x 10^9 tons	%
25 C1	121825	40	76	10
50 D1-C2	356165	116	220	30
75 D1,D2-C3	592211	196	363	50
100 D1,D2,D3-C4	826496	269	511	71
125 D1,D2,D3,D4-C5	1060772	344	654	91
150 D1,D2,D3,D4,D5	1171399	**380**	**722**	**100**

***** TEP-S. TEP substituted (the energy saved from present oxygen industrial production has also been considered, + 25%).

Column 1: time (years), decommission (D), commission (C), phases going on
Column 2: total gas produced by electrolysis (Hydrogen) already in the Halfway Point and in the pressurized Storage (Figure 1)
Column 3: the fossil derived energies not consumed
Column 4: the reduction of the carbon dioxide added to the atmosphere by F.D.E. consumed (Column 3 x 1.9)
Column 5: % of CO_2 reduction

The RES is equivalent to an added planetary forest because of the volume of Oxygen produced x year (around 20000 billion NCM / year, x 2.0 the Oxygen from the chlorophyll process by the Amazon forest; the Oxygen produced by RES and not consumed, is dispersed in the atmosphere).

RES – Hydrogen producer, Materials and energy consumed

Global RES is made up of:

- Mainly recycled material (sales, towers, heaters, directional mirrors, ...), which is substituted at 25 year intervals.
- Non recyclable material which is substituted at 25 year intervals (Photovoltaic silicon wafer cells, used elements from the electrolysis plants, glass not recoverable).

- Mainly recycled material, which is substituted at 150-250 year intervals (gas pipes, valves, iron pilons, electrical lines, transformers, ceramic material).
- Mainly non-recyclable material (concrete derived) that make up the structure of the Hydrogen producing system (substitution strategy 300 years), electric and pressurized gas energy storage (quarries and galleries excavation, greater than 1000 years) that have a long-term substitution strategy.

Tab. 3 – **RES, 100% performant, materials composition**

MATERIAL	QUANTITY x 10^6 tons	SPECIES	SUBSTITUTION, YEAR
Polycryst. Syl.	273	Not recyclable	25
Glass	1197	70% Recyclable	25
Silicates derived material*	41000	Not recyclable	300
Copper	2700	100% Recyclable	150
Aluminum	1050	100% Recyclable	25
Iron	36438	100% Recyclable	150
Steel	7400	100% Recyclable	150
Silver	156	100% Recyclable	25

The RES (electricity, gases producer) total weight is 90214 x 10^6 tons, 53% materials 100% recyclable, 47% silicates derived materials.

*silicates contained in materials (40% weight)

Tab. 4 – **RES, 100% performant, materials consumed-recycled x year**

MATERIAL	QUANTITY x 10^6 ton/y	Hydrogen consumed in furnaces (50% eff.) x 10^6 NCM
Polycryst. Syl.	11	3891

Glass	48	16937
Concrete	55	19456
Copper	27	1060
Aluminum	42	3076
Iron	243	9955
Steel	49	28663
Silver	6.2	120

Total Hydrogen consumed in furnaces to sustain RES renew phases is 83265 million NCM per year, that is the 0.18% of the gas produced per year by RES (100% performant, regime phase).
Total silicates consumed 80 million ton/y
RES performance 231/80 = 2.9 KWhe / gr
RES max time length duration 1.06 x 10^{24} / 80 x 10^{12} = 13.25 billion years
Total world' silicates consumed 450000 billion gram / year
Total RES silicates consumed (added) 80000 billion gram / year
Total consumed silicates 530000 billion gram / year
Probable effective RES time length duration = 2 billion years

The RES 100% performant **absorbs from the source (river, lake, sea) 37821 million cubic meters of water / year**, which **return water** in the Hydrogen combustion in air. Total **surface cover** is equal to **0.6%** of the emerged earth surface. 80% of these areas could be also used for agrofood and angrofuel cultivations.

RES – catastrophic vulcan explosion

More or less every 500 years it happens on the earth a catastrophic vulcan explosion and a grey cloud covers the earth' sky until after about six months the winds blow up the clouds. As consequence of these events the electricity produced by light convertors is reduced (30% pv, 100% concentrating convertors) and also the winds can be modified of a ±10% . To overcome this problem it is necessary to built a thermoelectric park consuming solid fuels which is in standby, (or devoted to other uses) for about five centuries and has to work for six months. To prepare the solid fuel will be cultivated the areas of the light and wind convertors with energetic biomasses (*Faboidae* sp, *Spartium junceum*) from which derivering coal stored waiting the event. The numbers: the electricity to be produced is 28875 billion KWhe, 7.22 billion TEP every 50 years. With a biomass productivity of 3.3 TEP x ha x year and an efficiency of 50% in producing coal from biomasses, are to be cultivated 437 million hectares of the 3325 million at disposal. All this to store coal which can sustain the catastrophic event every 50 years. The power of the thermoelectric conversion family is 11550000 MWhe.

RES – Financing the investments

The investment is made of 5 consecutive phases each of 25 years time length. On each phase, 20% of the whole system is built, while section-sections already built are 100% operative and renewed 4% year in the fraction with substitution time 25 years. The balance to interpret Table 5 are C and D, C (construction), D (decommission, renew); they make reference to a time period of 25 years. After year 126 only five balances D.

C
- electric section construction, management, the necessary H.V. grid construction, mainteinance, repair, thermoelectric convertors (catastrophic event), construction, management 34703 billion USD
- electrolysis facilities, construction, mainteinance, management, repair, water purifier, evaporator, condenser, liquid storage, pressurized storage, construction, management 8092 billion USD
- hydrogen consumed, materials, workers insurance, enterprise profit 2959 billion USD
Total C balance 45754 billion USD

D
- electric session decommission – renew, management, 32610 billion USD
- electrolysis facilities, decommission – renew, 5875 billion USD
- ammortization of investments with substitution time greater than 150 years 462 billion USD
- materials, energy consumed, workers insurance, enterprise profit 2650 billion USD
Total D balance 41601 billion USD

In C and D the following costs have been assumed:
- concrete 130 USD/ton
- brick and other concrete derived material 104 USD/ton
- quarries and galleries excavation 30 USD/cubic meter
- jobs 24000 USD/year
- workers insurance 32 billion USD/year
- enterprise profit 50 billion USD/year

In Tab. 5 below there are the essential elements that are key to this economic strategy (P.E.S.).

Tab. 5 – **RES - Planetary economic strategy (P.E.S.)**

RES time years and phases	Out 1	Electrolitic Hydrogen production	Income 1	Incom e 2	Out 2 x 10^9	Net Incom	Fin. support x 10^9	Indust. cost

		x 10^9 NCM	x 10^9 US$	x 10^9 US$	US$	e x 10^9 US$	US$	US$ / NMc
25 C1	45754	121285	30321	2426	2426	30321	15423	0.25
50 D1-C2	87355	356165	89041	7123	7123	89041	- 1688	0.25
75 D1,D2-C3	128956	592211	136208	11844	11844	136208	- 7252	0.23
100 D1,D2,D3 -C4	170557	826490	190093	16530	16530	190093	- 19576	0.23
125 D1,D2,D3 ,D4-C5	212158	1060771	222762	21215	21215	222762	- 10604	0.21
150 D1,D2,D3 ,D4,D5	208005	1171399	234279	23500	23500	234279	- 26269	0.2
175 D1,D2,D3 ,D4,D5	208005	1171399	234279	23500	23500	234279	- 26269	0.2
200 D1,D2,D3 ,D4,D5	208005	1171399	234279	23500	23500	234279	- 26269	0.2

Column 1: Time, years and phases
Column 2: Out 1, Investment to built up and to renew RES
Column 3: Electrolitic Hydrogen production x 10^9 NCM (already in the pressurized buffers)
Column 4: Income 1 (Column 3 x Column 9)
Column 5: Income 2 from oxygen credit
Column 6: Out 2, expenses to manage the production and distribution of Hydrogen-Oxygen gases
Column 7: Net Income
Column 8: Financial support – negative values correspond to cash surplus in the In – Out RES economic balance
Column 9: Price of the Hydrogen gas

From Tab. 5 it follows that RES can be built up also without require the stock exchange financial market contribution.

Indeed the discount of the cash surplus in the in-out balance (operation guaranteed by the very high value of N.I.), can allow to have the amount necessary to have each year in the first 25 years of the RES construction, a mean of 617 billion US$ / year.

N.I. and P.S.E. allow to make an investment of 229000 billion US$ with **0 US$** of its cost. The cash surplus in Tab. 5 is a sum free from ordinary expenses, by following P.E.S. the whole system is **renewed 4% / year at indefinite time length*** and produces 12.176 billion TEP/y of equivalent energy; when this value is summed to 1.5 billion TEP/y, contribution of hydroelectric production, it gives 13.676 billion TEP/year of renewable energy for the world development.

How RES functions
RES can be made of 2500 Hydrogen farms, scattered on the surface of the earth in such way to optimize the mean distances from the parks producing electricity and the points where the hydrogen gas and liquid fuels are produced and delivered to consumptions.

A planetary software-hardware control system regulates the distribution of the aivalable electricity intensity to the RES hydrogen-oxygen producing facilities. The electricity is easily stored in the process of hydrogen-oxygen syntethic fuel production. The phases of the water pumped into RES conversion, storage facilities from the source (rivers, lakes, sea) are:

RES 100% operative

- filter – evaporator – condenser 1036 million cubic meters (water)

- liquid storage 1036 million cubic meters (water)

- electrolysis facilities, electrolitic basic mixture, 104 million cubic meters (water, gases)

- high pressure Hydrogen gas storage 152 billion cubic meters (gas)

- high pressure Oxygen gas storage 51 billion cubic meters (gas)

From the solar energy storage the planet receives (from the year 126) and for long duration 255 million EPB/day (Equivalent Petroleum Barrel) to be consumed.

RES electricity consumption
- Filter 12.867 billion KWhe /year

- Evaporator – condenser 31637 billion KWhe /year

- Gas compression in storage volume (hydrogen-oxygen) 11033 billion KWhe /year

- Water electrolysis (hydrogen and oxygen gases production) 187324 billion KWhe /year

- Electric grid network losses 993 billion KWhe /year

Total electricity produced and consumed 231000 billion KWhe /year

*In all the parts with substitution time 25 years

Conclusions

The planetary hydrogen system is made of two main parts:
the system to produce the necessary electricity, the electrolytic hydrogen-oxygen gases producers and storage (the system contains also the industrial facilities to produce synthetic liquid fuels located in several hydrogen and synthetic liquid fuels farms). The analysis discussed in this work present an hydrogen producing system which can survive for thousand of centuries (up 20 million centuries), all this obtainable by following P.E.S.

(Planetary Economic Strategy) and N.I. (Nutricola Index), and by choosing the most durable fuel and its proved convertors.

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