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The History Could Repeat Itself: Hydrogen-Oxygen Fuel Cell is the 'Game Changer'

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2019: the 50th anniversary of the moon landings

- Saturday 20 July 2019 marked the ***50th anniversary of the moon landings***, and while most of us are very familiar with the iconic scenes of this ***'giant leap for mankind'***, many of us are completely unaware that ***the hydrogen-oxygen fuel cell invention made Neil Armstrong's 'small step' possible.***
- ***"Without you, we would not have gotten to the moon"*** said President Richard Nixon to Francis Thomas Bacon, referring to Bacon's invention of the first practical hydrogen-oxygen fuel cell.
- The Bacon fuel cell was perfect for powering NASA's spacecraft: it was lighter and much less bulky than batteries of the time, it was more efficient than 1960's solar panels, and hydrogen and oxygen were already going to be on board the ship for use as rocket fuel. What's more, the only waste product from the reaction was water – needed on Apollo 11 for the astronauts to drink.

Ph. Valentino Romeri - 2016

Source: University of Cambridge, Dept. of Chemical Engineering and Biotechnology, 2019, E. Hall: *"Powering Apollo 11: the fuel cell that took us to the moon"* https://www.ceb.cam.ac.uk/news/powering-apollo-11-fuel-cell-took-us-moon

'Hydrogen is today enjoying unprecedented momentum'

- **During last 50 years a tremendous technological progress are made** in all fields, **also in the field of hydrogen-oxygen fuel cells**.
- Hydrogen has seen several waves of interest in recent history, none of which fully translated into rising, sustainable investment.
- For long time hydrogen energy vector and fuel cells technologies seem to be a Cinderella low-carbon solution in energy, transport and climate change debates but recently something happened. As I pointed out in my 2018 ***"Consideration about Hydrogen and Fuel Cells in the Paris Agreement 1.5° C Perspective"***, in recent years **this low-carbon solution has made a strong comeback in energy portfolio options and it is considered as one of possible 'game changer'.**
- This fact was confirmed in 2019. **In June** at the **Japan's G20** and the publication of the **IEA** report ***"The Future of Hydrogen".*** According to Fatih Birol words: *"**Hydrogen is today enjoying unprecedented momentum.** The world should not miss this unique chance to make hydrogen an important part of our clean and secure energy future"*. **In September** in the **IRENA** report ***"Hydrogen: a Renewable Energy Perspective",*** prepared for the **2nd Hydrogen Energy Ministerial Meeting,** according to which ***"Hydrogen has emerged as an important part of the clean energy mix needed to ensure a sustainable future".***

Sources: M.V. Romeri, 2018: *"Consideration about Hydrogen and Fuel Cells in the Paris Agreement 1.5°C Perspective"*, http://www.aieeconference2018milan.eu/documents/AIEE_SYMPOSIUM_2018_proceedings.pdf IEA, 2019: "*The Future of Hydrogen*", https://www.iea.org/hydrogen2019/ . IEA, 2019 F. Birol : "*Foreword to 'The Future of Hydrogen'*", https://www.iea.org/hydrogen2019/ . G20 Osaka, 2019: *"G20 Osaka Leaders' Declaration"* , https://g20.org/pdf/documents/en/FINAL_G20_Osaka_Leaders_Declaration.pdf . IRENA, 2019, *"Hydrogen: A renewable energy perspective",* https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Hydrogen_2019.pdf. METI, 2019, *"METI Hosts Three Conferences: Second Hydrogen Energy Ministerial Meeting,.."* , https://www.meti.go.jp/english/press/2019/0927_002.html.

Considering H_2FCPowertrain as a Power Generation Plant

- From longtime I underlined the possible relevant implication of Hydrogen and Fuel Cell use in stationary and transport applications and, in recent years I presented different works in which I argued that it's time to consider Fuel Cell Vehicle (FCV) as a relevant possible low-carbon solution in energy debate.
- The electricity produced by a Hydrogen Fuel Cell can be used both for stationary and transport application and the traditional model to link transport to energy sector is the Vehicle-to-Grid (V2G) approach. I think that it is time to consider this link not only in a V2G approach but in another perspective, more direct, relevant and disruptive.
- **The Hydrogen Fuel Cell Powertrain** (H_2FCPowertrain) **or,** in other words, **the propulsion system of a FCV, is a small power generation plant** (typically 100 kW, or 80kW$_{net}$).
- **In the coming years the high volume associated with the possible FCVs mass production will permit to reduce dramatically the FC system manufacturing costs, in order to be competitive with gasoline in hybrid-electric vehicles. In a mass production perspective, H_2FCPowertrain will be so cost competitive to be useful adopted also for stationary power generation application, also in LCOE terms.**
- **In this perspective it will be possible to consider the H_2FCPowertrain as a power generation plant.**

Considering H_2FCPowertrain as a Power Generation Plant LCOE – *The U.S. Context: EIA Data 2014–2019*

The U.S. LCOE of New Generation Resources from the EIA Annual Energy Outlook 2014-2017 *(Plants Entering Service in 2022-2023)*

Plant Type	2014 n.s. Total LCOE (USD/MWh)	Overnight Cost in 2014 (USD/kW 2013)	2015 Capacity Factor (%)	2015 n.s. Total LCOE (USD/MWh)	Overnight Cost in 2015 (USD/kW 2014)	2016 Capacity Factor (%)	2016 n.s. Total LCOE (USD/MWh)	Overnight Cost in 2016 (USD/kW 2016)	2017 Capacity Factor (%)	2017 n.s. Total LCOE (USD/MWh)	Overnight Cost in 2017 (USD/kW 2017)	2018 Capacity Factor (%)	2018 n.s. Total LCOE (USD/MWh)	Overnight Cost in 2018 (USD/kW 2018)	2019 Capacity Factor (%)	2019 n.s. Total LCOE (USD/MWh)
Conventional Coal	**95,7**	2726	85	**95,1**												
Advanced Coal IGCC	**115,9**	3483	85	**115,7**												
Advanced Coal IGCC with CCS	**147,4**	5891	85	**144,4**	5098	85	**139,5**	4586-5072	85	**123-140**	4641-5132	85	**119-130**	4713-5212	85	**98,6-104**
Conventional Gas Combined Cycle	**66,3**	869	87	**75,2**	956	87	**58,1**	923	87	**57,3**	935	87	**50,1**	952	87	**46,3**
Advanced Gas Combined Cycle	**64,4**	942	87	**72,6**	1080	87	**57,2**	1013	87	**56,5**	1026	87	**49,0**	736	87	**41,2**
Advanced Gas Combined Cycle with CCS	**91,3**	1845	87	**100,2**	2132	87	**84,8**	1917	87	**82,4**	1936	87	**74,9**	1963	87	**67,5**
Conventional Combustion Gas Turbine	**128,4**	922	30	**141,5**	922	30	**110,8**	1040	30	**109,4**	1054	30	**98,7**	1072	30	**89,3**
Advanced Combustion Gas Turbine	**103,7**	639	30	**113,5**	664	30	**94,7**	640	30	**94,7**	648	30	**85,1**	658	30	**77,7**
Advanced Nuclear	**96,1**	4646	90	**95,2**	6108	90	**102,8**	5091	90	**99,1**	5148	90	**92,6**	5224	90	**77,5**
Geothermal	47,8	2331	92	47,8	2331	91	45,0	2331	91	46,5	2615	90	44,6	2654	90	**41,0**
Biomass	**102,6**	3399	83	**100,5**	3498	83	**96,1**	3540	83	**102,4**	3584	83	**95,3**	3642	83	**92,2**
Fuel Cells		*6042*			*7181*			*6252*			*6192*			*6250*		
Wind	**80,3**	1850	36	**73,6**	1536	40	**64,5**	1576	39	**63,7**	1548	41	**59,1**	1518	41	**55,9**
Wind - Offshore	**204,0**	4476	38	**196,9**	4605	45	**158,1**	4648	45	**157,4**	4694	45	**138,0**	4758	45	**130,4**
Solar PV	**130,0**	3787	25	**125,3**	2362	25	**84,7**	2169	24	**85,0**	1763-2004	29	**63,2**	1698-1876	29	**60,0**
Solar Thermal	243,1	3123	20	239,7	3895	20	235,9	3908	20	242,0	3952	25	165,1	4011	25	157,1
Hydro	**84,5**	2651	54	**83,5**	2191	58	**67,8**	2220	59	**66,2**	2634	64	**61,7**	2680	75	39,1

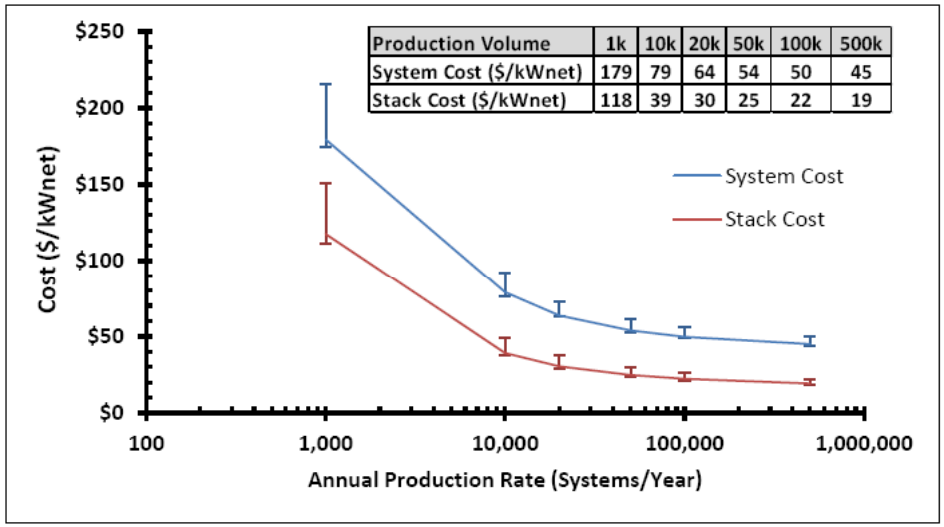
- In the mid 70's the Energy Information Administration (EIA) began publishing the *Annual Energy Outlook* (AEO) in which, annually, presents a forecast and analysis of U.S. energy supply, demand, and prices.
- Since 1996 AEO considers and realizes forecast about Overnight costs and LCOE. Fuel Cells technologies were mentioned and included in EIA documents since 1994, but EIA never provided data about the Fuel Cells LCOE. From 2010 the LCOE data for Central Production Power Plant are published in a separated document *Levelized Cost of New Generation Resources from the Annual Energy Outlook* and revised annually.
- In 2014 EIA introduced the new concept of "Levelized" Avoided Cost of Electricity (LACE) that provides an estimation of the value of build the new capacity. by considering the avoided cost, a measure of what it would cost the grid to generate the electricity that would be displaced by a new generation project . Estimating avoided costs is more complex than estimating levelized costs because it requires information about how the system would operate without the new option being considered. I don't take in consideration the LACE data .

n.s. *no subsidy*

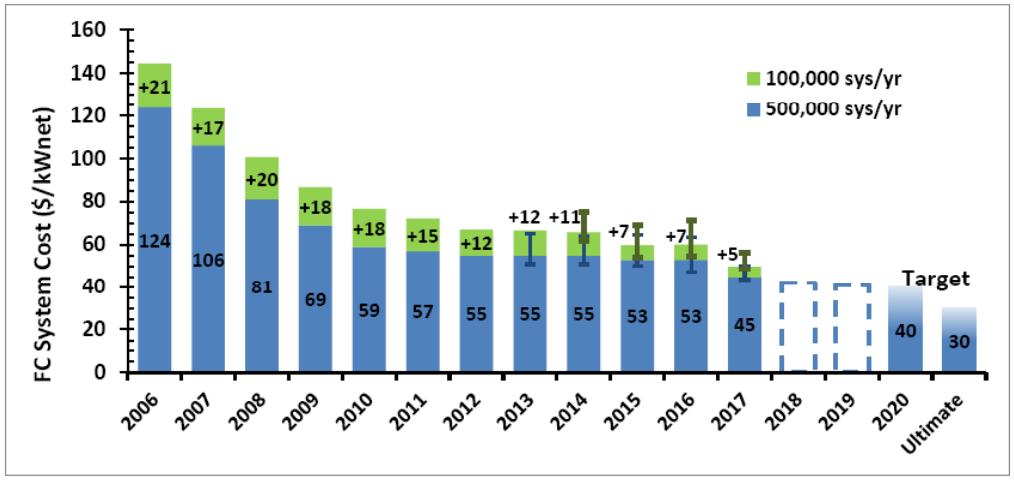
Sources: EIA, 2019: "*Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2019*", https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf and "*Assumptions to the AEO 2019, Electricity Market Module*", https://www.eia.gov/outlooks/aeo/assumptions/pdf/electricity.pdf.

Considering H_2FCPowertrain as a Power Generation Plant
The U.S. Context – *DOE Data & Assumptions* (1/2)

- **Current Status (2017) - 80-kW$_{net}$ PEM FC System**: Overnight cost, 45 USD/kW (at 500k units/year; 50 USD/kW at 100k units/year; 179 USD/kW 1k units/year); 52% System Efficiency; Lifetime, 4100 hours. H_2 cost: 5 UDS/kg-GGE (based on natural gas steam reforming, high volume projection; **including: production, delivery & dispensing**).



- **2020 DOE technical targets**: Overnight cost, 40 USD/kW (at 500k units/year); 60% System Efficiency; Lifetime, 8000 hours *(in 2014, 5000 hours)*; H_2 cost, 4 UDS/GGE (same assumptions of current status).



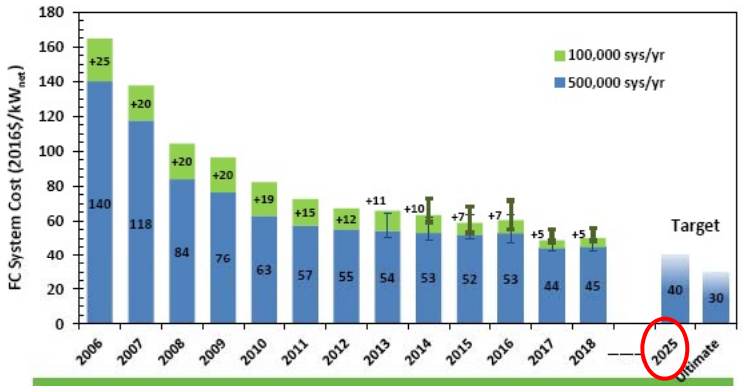
Sources: DOE, 2017, "*Hydrogen and Fuel Cells Program Record, Fuel Cell System Cost – 2017*" https://www.hydrogen.energy.gov/pdfs/17007_fuel_cell_system_cost_2017.pdf from M.V. Romeri, 2018, (cit.).

Considering H_2FCPowertrain as a Power Generation Plant
The U.S. Context – *DOE Data & Assumptions* (2/2)

- **Current Status (2018)**
- **DOE technical targets (2025 new vs. 2020 previous)**
- **New: Durability-Adjusted Cost**

Fuel Cell Cost Status

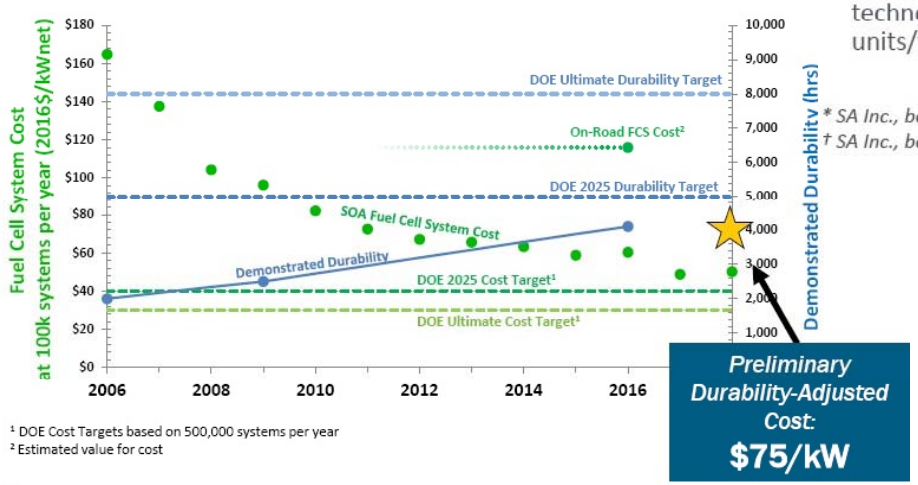
- **$50/kW*** for 100,000 units/year
- **$45/kW*** for 500,000 units/year
- **$181/kW*** for 1,000 units/year
- **$210/kW†** for currently commercialized on-road technology at 1,000 units/year



67% cost reduction since 2006

Cost analysis is not adjusted to account for durability

** SA Inc., bottom-up analysis of model system manufacturing cost, high volume manufacturing with next-gen lab technology*
† SA Inc., bottom-up analysis of model system based on commercially available FCEVs



¹ DOE Cost Targets based on 500,000 systems per year
² Estimated value for cost

Coming soon: combined durability-system cost metric for state of the art light-duty vehicles

SA Inc., bottom-up analysis of model system manufacturing cost, high volume manufacturing with next-gen lab technology

Fuel Cell Targets and Status

Application	Power (kW)	Cost ($/kW)	Durability (h)	Performance
Light-duty vehicles	80	30 75* 120*	8,000 5,000 4,100	70% efficiency, ≤0.125 mg_{PGM}/cm^2 ~0.35 mg_{PGM}/cm^2

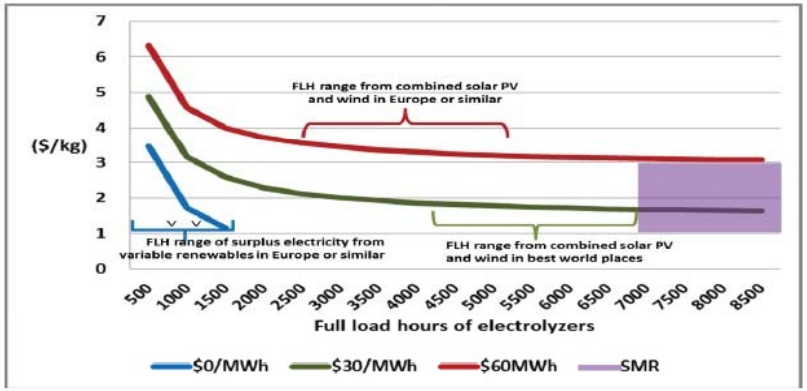
Green: target; black: lab-demonstrated tech; blue: on-road/installed tech
*Projected system cost for 100,000 units/year

Sources: DOE, 2019 April, D. Papageorgopoulos: *"Fuel Cell R&D Overview"*, www.hydrogen.energy.gov/pdfs/review19/plenary_fuel_cell_papageorgopoulos_2019.pdf .
DOE, 2019 May, S. Satyapal: *"Hydrogen and Fuel Cells Enabled through the U.S. Department of Energy"*, https://www.energy.gov/sites/prod/files/2019/06/f63/fcto-satyapal-overview-for-ecs-meeting-2019-05-27.pdf.

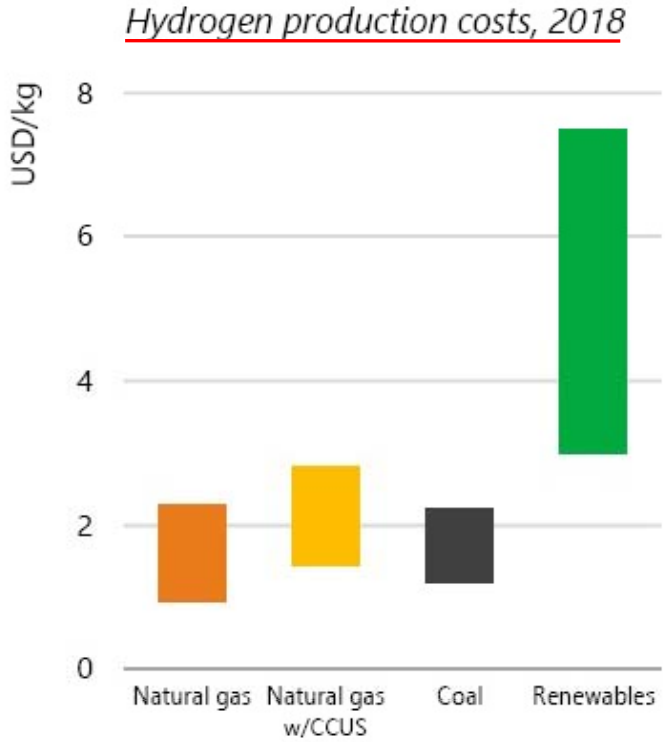
Considering H_2FCPowertrain as a Power Generation Plant
Hydrogen Production Cost – *IEA Data & Assumptions*

According to **IEA** (2017): *"Thanks to the recent cost reductions of solar and wind technologies, ammonia production in large-scale plants based on electrolysis of water can compete with ammonia production based on natural gas, in areas with world-best combined solar and wind resources"* and *"similar H_2 prices could be reached in countries with lower-quality renewable resources* ***if 'surplus' electricity is considered free"***.

Cost of hydrogen from electrolysers at USD 450/kW Capex for different electricity costs and load factors.



Assumptions: Capex of electrolysers $ 450/kW (NEL 2017), WACC 7%, lifetime 30 years, efficiency 70% (IEA 2015); cost of hydrogen from SMR $ 1 to 3/kg H_2.depending on natural gas prices.



Sources: IEA, 2017, C. Philibert: *"Producing ammonia and fertilizers: new opportunities from renewable"*, https://www.iea.org/media/news/2017/Fertilizer_manufacturing_Renewables_01102017.pdf .
IEA, 2019 November, M. Wörsdörfer: *"The Future of Hydrogen"*, https://www.fch.europa.eu/sites/default/files/4%20-%20Session%20IV%20-%20Woersdoerfer%20%28ID%207452326%29.pdf .

Considering H_2FCPowertrain as a Power Generation Plant
The H_2FCPowertrain LCOE – *DOE & IEA Data & Assumptions*

- **In 2018 combining DOE (2017) and IEA (2017) data and assumptions we found these 2020 H_2FCPowertrain LCOE results (at 500k FCV/year).**

H_2FC Powertrain Levelised Cost of Electricity (USD/MWh)								
Efficiency	LIFE Hours	IEA Hydrogen Cost USD/kg-GGE^	Capital Overnight Cost USD/kW	Levelized Capital Cost LCC USD/MWh	Others (Assumed Equal to 10% LCC)	Fuel Cost USD/MWh	LCOE USD/MWh	ASSUMPTIONS
60%	8000	4,0	40,0	5,0	0,5	200,0	**205,5**	2020 DOE Targets (2017) & H_2 IEA (2017)
60%	8000	3,0	40,0	5,0	0,5	150,0	**155,5**	2020 DOE Targets (2017) & H_2 IEA (2017)
60%	8000	2,0	40,0	5,0	0,5	100,0	**105,5**	2020 DOE Targets (2017) & H_2 IEA (2017)
60%	8000	1,0	40,0	5,0	0,5	50,0	**55,5**	2020 DOE Targets (2017) & H_2 IEA (2017)

^ Production costs: H_2 from natural gas steam reforming and H_2 from electrolizers (for different electricity costs and load factors)

- **Today, combining DOE (2019) and IEA (2017-2018) data and assumptions we found these new 2025 H_2FCPowertrain LCOE results (at 100k FCV/year).**

H_2FC Powertrain Levelised Cost of Electricity (USD/MWh)								
Efficiency	LIFE Hours	IEA Hydrogen Cost USD/kg-GGE^	Capital Overnight Cost USD/kW	Levelized Capital Cost LCC USD/MWh	O&M + Others (Assumed Equal to 10% LCC) USD/MWh	Fuel Cost USD/MWh	LCOE USD/MWh	ASSUMPTIONS
60%	5000	4,0	75,0	15,0	1,5	200,0	**216,5**	2025 DOE Targets (2019) & H_2 IEA (2017-2018)
60%	5000	3,0	75,0	15,0	1,5	150,0	**166,5**	2025 DOE Targets (2019) & H_2 IEA (2017-2018)
60%	5000	2,0	75,0	15,0	1,5	100,0	**116,5**	2025 DOE Targets (2019) & H_2 IEA (2017-2018)
60%	5000	1,0	75,0	15,0	1,5	50,0	**66,5**	2025 DOE Targets (2019) & H_2 IEA (2017-2018)

^ Production costs: H_2 from natural gas steam reforming and H_2 from electrolizers (for different electricity costs and load factors)

- **The 2025 H_2FCPowertrain LCOE value-range would be 66,5-216,5 USD/MWh and, in favorable conditions of H_2 production costs, H_2FCPowertrain seems to be useful to be adopted also for stationary power generation application.**

Considering H_2FCPowertrain as a Power Generation Plant
Possible Long-Term Effects in the Power Generation Sector

- As I underlined in my 2018 ***"Consideration about Hydrogen and Fuel Cells in the Paris Agreement 1.5° C Perspective":***
- **Thanks to the introduction and use of H_2FCPowertrains as power plants,** considering the low level of **Overnight Cost, it seem to be possible to think that the present capital intensive profile of the Power Generation Sector could change gradually.**
- In terms of plant **Lifetime**, the H_2FCPowertrain appears poor (also considering the DOE target of 8000 hours lifetime) if compared either to the other generation technologies or to the U.S. DOE CHP target (80000 hours). But, in a long term investment perspective, it is possible to foresee a planned replacement of the H_2FCPowertrain stack at the end of each lifetime at a cost that is estimated around 42% of the whole system (and this, without taking into account the value of recoverable Platinum from the exhaust stack).
- **Thanks to the introduction and use of H_2FCPowertrains as power plants it seem to be possible also to think that the present long-term investment profile of the Power Generation Sector could change gradually.**

Source: M.V. Romeri, 2018, (cit.).

From 'Paris Agreement 1.5°C Perspective' (IPCC SR15) to 'Climate Emergency' (Highlighted by Greta Thunberg)

The 'Paris Agreement 1.5°C Perspective' is stated by Article 2 and the first assessment of his global implications was published in 2018 by IPCC with the *Special Report on 'Global Warming of 1.5ºC' (SR15)*.

Main difference between *'below 2°C'* and *'1.5°C'* perspectives are the timelines. Simplifying data, according to IPCC *SR15* in order to limit global warming to *'1.5°C'* CO_2 emissions need to decline by about 45% by 2030, reaching net zero around 2050. For limiting global warming to *'below 2°C'* CO_2 emissions are projected to decline by about 25% by 2030, and reach net zero around 2070.

"Limiting warming to 1.5°C is possible *within the laws of chemistry and physics* ***but doing so would require unprecedented changes"*** and, for this reason "***the next few years are probably the most important in our history"***.

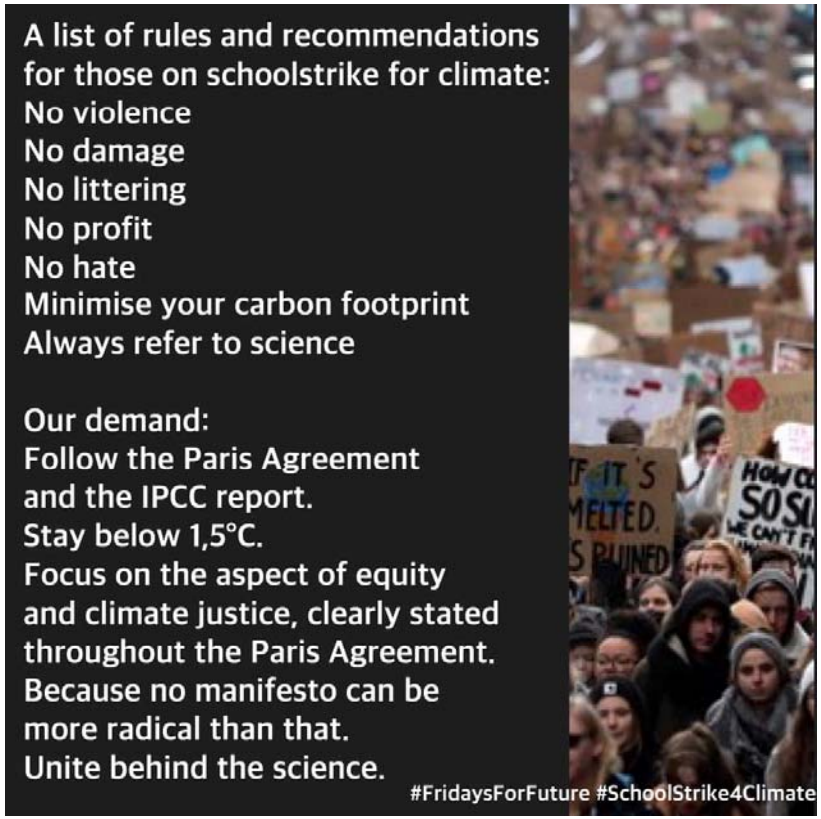
The 'climate emergency' was highlighted in 2019 by Greta Thunberg and it is clearly described also in her speech, in Sept., at the **U.N. Climate Action Summit**:

"To have a 67% chance of staying below a 1.5°C temperature rise the world had 420 gigatons of CO_2 left to emit back on Jan. 1st, 2018. Today that figure is already down to less than 350 gigatons. (…) With today's emissions levels, that remaining CO_2 budget will be entirely gone within less than 8 1/2 years. (…)
There will not be any solutions or plans presented in line with these figures here today, because these numbers are too uncomfortable."

Sources: IPCC, 2018: "*Global Warming of 1.5 ºC, IPCC Special Report*" https://www.ipcc.ch/sr15/ . M.V. Romeri, 2018, (cit.).
U.N. Climate Action Summit, 2019: *"Greta Tunberg speech"*, http://webtv.un.org/search/part-1-climate-action-summit-2019/6089117286001#t=20m35s

Three Icons of 2019 (1/3)
Greta Thunberg

During 2019 **Greta Thunberg** has had the ability to attract attention, raise awareness and create a new conscience in millions of young people, and in their parents, against the challenge of climate change and the *'climate emergency'*.



Change is coming, whether you like it or not.

Sources: Greta Thunberg, 2019 March, *"A List of Rules and Recommendations"*, https://www.facebook.com/gretathunbergsweden/photos/a.733630957004727/785816985119457 .
U.N. Climate Action Summit, 2019: *"Greta Tunberg speech"* (Cit.).

Three Icons of 2019 (2/3)
Holy Father Francis

According to the **Holy Father Francis** message to the participant to **UNFCCC COP25**:
"In 2015, the COP 21 adopted the Paris Agreement, the implementation of which 'will require concerted commitment and generous dedication by each one'. Its rapid entry into force, in less than a year, showed a growing awareness of ***the importance and need to 'work together in building our common home'.*** *(…)* ***But current commitments*** *made by States to mitigate and adapt to climate change* ***are far from those actually needed to achieve the goals*** *(…).* ***Numerous studies tell us that it is still possible to limit global warming.*** *To do this we need a clear, far-sighted and strong political will, set on pursuing a new course that aims at refocusing financial and economic investments toward those areas that truly safeguard the conditions of a life worthy of humanity on a 'healthy' planet for today and tomorrow.* ***All this calls us to reflect conscientiously on the significance of our consumption and production models*** *and on the processes of education and awareness to make them consistent with human dignity. We are facing a* ***'challenge of civilization'*** *in favour of the common good and of a change of perspective that places this same dignity at the centre of our action, which is clearly expressed in the 'human face' of climate emergencies.* ***There remains a window of opportunity, but we must not allow it to close.***

Next year event *"Economy of Francesco"* will reflect around these challenges and, in the words of Holy Father Francis, ***"will help bring us together and allow us to meet one another and eventually enter into a 'covenant' to change today's economy and to give a soul to the economy of tomorrow".***

Sources: Holy Father Francis, 2019: *"Message of the Holy Father Francis to the Participants in the United Nation Framework Convention on Climate Change"* , http://w2.vatican.va/content/francesco/en/messages/pont-messages/2019/documents/papa-francesco_20191201_messaggio-carolina-schmidt.html . Holy Father Francis, 2019: "*Letter Sent by the Holy Father for the Event 'ECONOMY OF FRANCESCO'"*, http://w2.vatican.va/content/francesco/en/letters/2019/documents/papa-francesco_20190501_giovani-imprenditori.html .

Three Icons of 2019 (3/3)
Ursula von der Leyen

In July the new European Commission President **Ursula von der Leyen** **statement gives a new prospective for EU:**"

Our most pressing challenge is keeping our planet healthy. This is the greatest responsibility and opportunity of our times. I want Europe to become the first climate-neutral continent in the world by 2050. *To make this happen, we must take bold steps together. Our current goal of reducing our emissions by 40% by 2030 is not enough. We must go further. We must strive for more. A two-step approach is needed to reduce CO_2 emissions by 2030 by 50%, if not 55%.*

The European Union will lead international negotiations to increase the level of ambition of other major economies by 2021 because, to achieve real impact, not only do we have to be ambitious at home – we have to do that, yes – but the world also has to move together. *To make this happen, I will put forward a* ***Green Deal for Europe*** *in my first 100 days in office.*

I will put forward the first ever European Climate Law, which will set the 2050 target in law. This increase in ambition will need investment on a major scale. *Public money will not be enough. I will propose a Sustainable Europe Investment Plan and turn parts of the European Investment Bank into a Climate Bank. This will unlock EUR 1 trillion of investment over the next decade.* ***It means change****."*

Ursula von der Leyen presented today the *'European Green Deal'* and tomorrow it will be discuss at the European Council.

Sources: Ursula von der Leyen, 2019 July, *"Opening Statement in the European Parliament Plenary Session Ursula von der Leyen Candidate for President of the European Commission"* https://ec.europa.eu/commission/presscorner/api/files/attachment/857948/Opening%20Statement%20Ursula%20von%20der%20Leyen.pdf.pdf
European Commission, 2019 December, *"A European Green Deal - Striving to be the first climate-neutral continent"* https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

The History Could Repeat Itself:
Hydrogen-Oxygen Fuel Cell is the 'Game Changer'

Frans Timmermans, first EC Vice-President, said on 21 Nov. at 2019 Fuel Cells and Hydrogen Joint Undertaking Stakeholder Forum: ***"The green energy transition is not an option but a necessity. I see a pivotal role for clean hydrogen... it is an area where Europe is still leading.*** *(…) The most important thing is that you help us to find ways to make relatively quick successes to show people that it works".*

This analysis confirmed, in LCOE terms, the economic advantage *'to consider an H_2FCPowertrain as power generation plant'* and explained related possible long-term effects in power generation, but this option has still not been considered in the energy debate.

According to IPCC SR15 in the next few years it will be necessary to start unprecedented changes and to speed up CO_2 emissions reduction. For these reasons **next few years are probably the most important in our history.** So, other detailed analyses seem to be needed in order to well understand the relevance of hydrogen and fuel cells in '*1.5°C'* perspective and to suitably assess all the economic, financial an geopolitical implications.

The history could repeat itself. In 1969 the hydrogen-oxygen fuel cell invention made Neil Armstrong's *'small step'* possible. Today, the *'state of the art'* hydrogen-oxygen fuel cells seems to be able to be, in next future, the *'game changer'* against the *'climate emergency'*, to play a relevant role in the *'economy of tomorrow'* and maybe to be a new *'giant leap for mankind'*.

Sources: FCH JU, 2019, "Hydrogen is ready to forge a zero-emission economy, FCH JU Stakeholders Forum confirms", https://www.fch.europa.eu/sites/default/files/Forum_PRESS%20RELEASE_21112019.pdf

Thank you for your attention

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