HYDROGEN FUEL CELL POWERTRAIN LEVELIZED COST OF ELECTRICITY

Mario Valentino Romeri

Independent Consultant, Italy, Valentino.Romeri@Alice.it

Overnight Costs and Levelized Costs of Generating Electricity

Investment costs are probably the most important element in any investment decision. They vary greatly from technology to technology, from time to time and from country to country. **Overnight cost** is a common unit of measure of power investments. Overnight cost is the cost of a construction project if no interest was incurred during construction, as if the project was completed "overnight." **The unit of measure typically used for Overnight cost is USD/kW**.

The notion of **Levelized Costs of Generating Electricity (LCOE)** is a handy tool for comparing the unit costs of different power generation technologies. The **LCOE approach is a financial model used for the analysis of generation costs.** Focus of estimated average LCOE is the entire operating life of the power plants for a given technology. **The unit of measure typically used for LCOE is USD/MWh**.

In LCOE financial model, different cost components are taken into account: capital costs, fuel costs, operations and maintenance costs (O&M). These costs are an average over the life of a project and for a specific technology, based on a specific and particular set of assumptions. The costs cash-flow is discounted to the present (date of commissioning) using assumed specific discount rates. The resultant LCOE values, one for each generation option, are the main driver for choice technology.

Currently, with different frequency, public and private institution released analyses[1] regarding present and future LCOE generation focused on broad or specific power generation technologies. Each of these LCOE analyses adopts little difference with regard to definition (*i.e.* elements included in formula) and assumptions adopted (as: year of reference, discount rate, currency, geographic area, cost of fuel and so on). Analyzing these studies a wide dispersion of data is evident and there is no technology that has a clear overall advantage globally or regionally. Results are particularly sensitive to fuel and electricity price assumptions and discount rate level is another key element. Results vary from analysis to analysis, from time to time, from country to country, and even within the same region, there are significant variations in the cost for the same technologies.

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1 - See, among other:

Committee on America's Energy Future; National Academy of Sciences; National Academy of Engineering; National Research Council 2009: *"America's Energy Future: Technology and Transformation"* The National Academies Press Washington, DC, USA < http://www.nap.edu/catalog.php?record_id=12710 >.

Electric Power Research Institute (EPRI), 2009: "*Program on Technology Innovation: Integrated Generation Technology Options*" EPRI, Palo Alto, CA, USA < http://my.epri.com/portal/server.pt?space=CommunityPage&cached=true&parentname=ObjMgr&parentid=2&control=SetCommunity&CommunityID=404&RaiseDocID=000000000001019539&RaiseDocType=Abstract_id >.

European Commission (EC), 2008: *"Energy Sources, Production Costs and Performance of Technologies for Power Generation, Heating and Transport"*, European Commission SEC(2008)2872, Brussels, Belgium 13 November 2008, < http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SEC:2008:2872:FIN:EN:PDF >.

Google.org, 2011: *"The Impact of Clean Energy Innovation: Examining the Impact of Clean Energy Innovation on the United States Energy System and Economy"*, Google.org, USA < http://www.google.org/energyinnovation/The_Impact_of_Clean_Energy_Innovation.pdf >.

IPCC, 2011: *"IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation"* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA < http://srren.ipcc-wg3.de/report/IPCC_SRREN_Full_Report >.

Lazard Ltd, 2008, 2009 and 2010: *"Levelized Cost of Energy Analysis"* Lazard Ltd, New York, NY, USA.

Organization for Economic Co-operation and Development (OECD) / International Energy Agency (IEA) – Nuclear Energy Agency (NEA), 2010: *"Projected Costs of Generating Electricity"* 2010 Edition, Paris, France < http://www.iea.org/w/bookshop/add.aspx?id=403 >.

U.S. Energy Information Administration (EIA), 2010 and 2011: "*Levelized Cost of New Generation Resources from the Annual Energy Outlook"* EIA Washington, DC, USA (See infra).

World Economic Forum (WEF) in collaboration with Bloomberg New Energy Finance, 2009, 2010 and 2011: "Green Investing" World Economic Forum USA Inc. New York, NY, USA. 2009 *"Green Investing: Towards a Clean Energy Infrastructure"* < http://www3.weforum.org/docs/WEF_IV_GreenInvesting_Report_2009.pdf >; *"Green Investing 2010: Policy Mechanisms to Bridge the Financing Gap"* < http://www3.weforum.org/docs/WEF_IV_GreenInvesting_Report_2010.pdf > and "*The Green Investing 2011: Reducing the Cost of Financing"* < http://www3.weforum.org/docs/WEF_IV_GreenInvesting_Report_2011.pdf >.

Fuel Cells and Hydrogen

A Fuel Cell is a device that uses a fuel and oxygen to create electricity by an electrochemical process, without combustion. A single Fuel Cell[2] consists of an electrolyte and two electrodes (anode and cathode). Fuel Cells are classified primarily by the kind of electrolyte they employ: **Phosphoric Acid Fuel Cells (PAFC), Alkaline Fuel Cells (AFCs), Molten Carbonate Fuel Cells (MCFCs), Solid Oxide Fuel Cells (SOFCs), Direct Methanol Fuel Cells (DMFCs) and Polymer Electrolyte Membrane (PEM) Fuel Cells** (also called Proton Exchange Membrane Fuel Cells). PEM Fuel Cells use hydrogen as fuel and have emissions only of water.

Today Fuel Cells are present in a wide range of prototype and products: portable applications, micro CHP system, recreation products, vehicles, niche and professional application, military items.

In presence of such a wide context of application, I chose to consider in my analysis the Hydrogen Fuel Cell (PEM) Powertrain (H2FC Powertrain) as "Power Generation Plant" because, if the current U.S. Hydrogen and Fuel Cell Vehicle Program is able to meet all the 2015 technological targets, in the subsequent year, the high volume associated with the H2FC vehicles mass production (up to 500.000 units sold per year) will permit to reduce dramatically the Fuel Cell system manufacturing costs, in order to be competitive with current gasoline ICE systems.

The Vehicle-to-Grid Concept

Every day more than 90% of vehicles are parked, even during peak traffic hours. In this situation the vehicle power generation system H2FC powertrain, if properly equipped, could become a new power generation source, supplying electricity to homes and to the grid like a new type of distributed generation: **Vehicle-to-Grid** (V2G).

Academics, public and private operators well know the V2G concept[3]. V2G could be realized indifferently with Electric Vehicles and Fuel Cell Vehicles (FCV), but only in the case of FCV we are in presence of a real new power generation capacity GHG emission free: the H2FC powertrains[4]. FCV in a V2G mode may profitably provide power to the grid when they are parked and connected to an electrical outlet. In this perspective, literature analyzed also the economic aspects[5]. FCV have significant potential revenue streams from V2G, on peak power production, but it is possible to obtain higher return offering a series of high-value ancillary services to the grid.

This Study

If FCV, properly equipped and parked in V2G mode, become a new power generation source supplying electricity to homes and to the grid, it could be useful to begin to analyze the H2FC powertrain relevance in the power generation sector. But, in my opinion, in the mass production perspective (above mentioned) H2FC Powertrain will be so cost competitive to be useful adopted also for stationary power generation application.

In my *"Considering Hydrogen Fuel Cells Powertrain as Power Generation Plant"*[6] (EVS25, Shenzhen, China 2010), I considered first the H2FC Powertrain as "Power Generation Plant"[7]. In this study I have updated the analysis with focus on the U.S. context and I have used only the LCOE data released by the **U.S. Energy Information Administration (EIA)**.

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2 - For detail see: < http://www1.eere.energy.gov/hydrogenandfuelcells/fuelcells/basics.html > and < http://www1.eere.energy.gov/hydrogenandfuelcells/fuelcells/fc_types.html >.

3 - The concept of 'Vehicle-to-Grid' was first proposed in 1997 by W. Kempton "*Electric vehicles as a new power source for electric utilities"*, Transportation Research Part D 2 (3), 1997, p157–175 < http://www.udel.edu/V2G/docs/Kempton-Letendre-97.pdf >; Interesting documents to see are: "*Vehicle-to-Grid Power: Battery, Hybrid, and Fuel Cell Vehicles as Resources for Distributed Electric Power in California"*, 2001, Institute of Transportation Studies, University of California, Davis, CA, USA < http://pubs.its.ucdavis.edu/publication_detail.php?id=360 > and W. Kempton, J. Tomić *"Vehicle to Grid Implementation: from stabilizing the grid to supporting large-scale renewable energy"*, 2005, Journal of Power Sources Volume 144 < http://www.spinnovation.com/sn/Articles_on_V2G/Vehicle-to-grid_power_implementation_From_stabilizing_the.pdf >.

4 - In fact, in the case of Plug-In Hybrid Electric Vehicles or Electric Vehicles, we are only in presence of a new, and useful, energy storage capacity.

5 - See: T. Lipman, J. Edwards, D. Kammen, *"Economic Implications of Net Metering for Stationary and Motor Vehicle Fuel Cell Systems in California"*, 2002 < http://www.ucei.berkeley.edu/PDF/pwp092.pdf > and W. Kempton, J. Tomić, *"Vehicle-to-grid power fundamentals: Calculating capacity and net revenue"*, Journal of Power Sources, Volume 144, 2005 < http://www.spinnovation.com/sn/Articles_on_V2G/Vehicle-to-grid_power_fundamentals_Calculating_capacity.pdf >.

6 - M. V. Romeri *"Considering Hydrogen Fuel Cells Powertrain as Power Generation Plant",* World Electric Vehicles Symposium EVS25 "Sustainable Mobility Revolution". Shenzhen, China 2010, proceeding < http://www.evs25.org/event/2009ddc-en/index.html >.

7 - My EVS25 study was updated in *"Possible Hydrogen Fuel Cell Vehicles Powertrain Roles in the Copenhagen Accord Perspective" 2011* Fuel Cell & Hydrogen Energy Conference organized by Fuel Cell & Hydrogen Energy Association. Washington DC Area, USA.

The EIA Data

In the mid 70's EIA began publishing the "*Annual Energy Outlook*" (AEO)[8] in which, annually, presents a forecast and analysis of U.S. energy supply, demand, and prices.

Since 1996 AEO considers and realizes forecast about the **Overnight costs**[9] and the **Levelized Costs**[10] of Electricity. In January 2010 the LCOE data[11] for Central Production Power Plant are published in a separated document: *"2016 Levelized Cost of New Generation Resources from the Annual Energy Outlook 2010"*[12]. LCOE data are revisited in *"Levelized Cost of New Generation Resources in the Annual Energy Outlook 2011"* in December 2010[13] (based on the AEO Early Release) and in April 2011[14]. **Table 1** is the re-elaboration of EIA Overnight cost and LCOE data (national averages).

Table 1 - 2016 Levelized Cost of New Generation Resources from the Annual Energy Outlook 2010 and 2011 (EIA, Jan. 2010 and Apr. 2011)

US			LCOE 2010 (USD/MWh)					LCOE 2011 (USD/MWh)		
Plant Type	Plant Size (MW 2009)	Final Overnight Cost (USD/kW 2009)	Levelized Capital Costs	O&M + Other + Fuel Cost (USD/MWh)	Total System Levelized Cost	Plant Size (MW 2010)	Final Overnight Cost (USD/kW 2010)	Levelized Capital Costs	O&M + Other + Fuel Cost (USD/MWh)	Total System Levelized Cost
Conventional Coal	600	2223	69.2	31.3	**100.5**	1300	2809	65.5	29.6	**95.1**
Advanced Coal	550	2569	81.2	29.3	**110.5**	1200	3182	74.7	35.0	**109.7**
Advanced Coal with CCS	380	3776	92.6	36.6	**129.2**	520	5287	92.9	43.7	**136.5**
Conventional Gas Combined Cycle	250	984	22.9	60.2	**83.1**	540	967	17.5	47.7	**65.1**
Advanced Gas Combined Cycle	400	968	22.4	56.9	**79.3**	400	991	17.9	44.3	**62.2**
Advanced Gas Combined Cycle with CCS	400	1932	43.8	69.5	**113.3**	340	2036	34.7	53.7	**88.4**
Conventional Combustion Gas Turbine	160	685	41.1	98.4	**139.5**	85	961	45.8	77.1	**123.0**
Advanced Combustion Gas Turbine	230	648	38.5	84.9	**123.4**	210	658	31.7	70.3	**102.1**
Advanced Nuclear	1350	3820	94.9	24.1	**119.0**	2236	5275	90.2	23.8	**114.0**
Fuel Cells	10	5478				10	6752			
Wind	50	1966	130.5	18.8	**149.3**	100	2409	83.3	12.9	**96.1**
Wind - Offshore	100	3937	159.9	31.2	**191.1**	400	6056	209.7	34.0	**243.7**
Solar PV	5	6171	376.8	19.4	**396.2**	150	4697	194.9	16.1	**211.0**
Solar Thermal	100	5132	224.4	32.2	**256.6**	100	4636	259.8	52.4	**312.2**
Geothermal	50	1749	88.0	27.7	**115.7**	50	2482	77.4	22.4	**99.8**
Biomass	80	3849	73.3	37.8	**111.1**	50	3724	55.4	57.3	**112.6**
Hydro	500	2291	103.7	16.3	**120.0**	500	2221	78.5	12.0	**90.5**

Fuel Cells technologies were mentioned and included in EIA documents since 1994.

For **Central Production Power Plant** EIA data are relatively clear to understand, in fact:

- Since 1996, annually, in the *"Assumptions to the Annual Energy Outlook"* (AAEO), the Table *"New Central Station Electricity Generating Technologies"*[15] includes Fuel Cell forecast **overnight costs** related to a 10 MW Facility (only in 1998 edition Fuel Cells are defined as Molten Carbonate Fuel Cell, MCFC) and the Table "*Capacity Types Represented in the Electricity Market Module"*[16] included MCFC. **Table 2** summarizes the Fuel Cell Total Overnight cost presented in the above mentioned AAEO reports.

8 - EIA, *"Annual Energy Outlook 2011"* (AEO2011) < http://www.eia.doe.gov/forecasts/aeo/index.cfm >; AEO Archive < http://www.eia.gov/oiaf/archive.html >.

9 - Overnight costs are in *Table 8.2 "Cost and performance characteristics of new central station electricity generating technologies" (Electricity Generating Technologies),* EIA, *"Assumptions to the Annual Energy Outlook 2011"* (AAEO), < http://www.eia.gov/forecasts/aeo/assumptions/index.cfm > or < http://www.eia.gov/forecasts/aeo/assumptions/pdf/0554(2011).pdf >; AAEO Archive < http://www.eia.gov/oiaf/archive.html >. This Table is included in all the AAEO yearly editions (with various numbers).

10 - Levelized costs are presented in different parts, figures and footnotes of each annual AEO edition (with exclusion of year 1999, 2000 and 2001). In particular many AEO footnotes refer to specific National Energy Modeling System runs. EIA, *Annual Energy Outlook, Cit.*

11 - Referred to December 2009.

12 - EIA "*2016 Levelized Cost of New Generation Resources from the Annual Energy Outlook 2010",* January 2010, < http://www.eia.gov/oiaf/archive/aeo10/electricity_generation.html > or < http://www.eia.gov/oiaf/archive/aeo10/pdf/2016levelized_costs_aeo2010.pdf >.

13 - EIA *"Levelized Cost of New Generation Resources in the Annual Energy Outlook 2011", December 2010,* < http://www.eia.doe.gov/oiaf/aeo/electricity_generation.html > or < http://www.eia.doe.gov/oiaf/aeo/pdf/2016levelized_costs_aeo2011.pdf >

14 - EIA *"Levelized Cost of New Generation Resources in the Annual Energy Outlook 2011",* April 2011 version, based on the AEO 2011, < http://www.eia.gov/forecasts/aeo/electricity_generation.cfm > Accessed 25 August 2011.

15 - EIA AAEO Archive, cit. In AAEO 2011 (cit.) Table 8.2 (Fuel Cells).

16 - EIA AAEO Archive, cit. In AAEO 2011 (cit.) Table 8.1 (Molten Carbonate Fuel Cell).

Table 2 - Fuel Cells AAEO Central Production Plant Historical Total Overnight Cost (USD/kW Nominal, Unadjusted)																
	1996	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Fuel Cells	**1071**	**2247**	**2189**	**2146**	**2163**	**2041**	**2091**	**2137**	**2162**	**4250**	**4374**	**4520**	**5374**	**5360**	**5478**	**6752**
Plant Available in	*2000*	*2003*	*2003*	*2001*	*2001*	*2004*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*
USD (year)	*1987*	*1995*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*2009*
Reference	*T. 28*	*T. 33*	*T. 37*	*T. 37*	*T. 37*	*T. 43*	*T. 38*	*T. 40*	*T. 38*	*T. 38*	*T. 38*	*T. 39*	*T. 38*	*T. 8.2*	*T. 8.2*	*T. 8.2*

- In *"2016 Levelized Cost of New Generation Resources from the Annual Energy Outlook 2010"*[17] Fuel Cells are not included in the final Table published in the web but is considered in the AAEO[18] Tables and spreadsheet[19].
- In November 2010, the document *"Updated Capital Cost Estimates for Electricity Generation Plants"*[20] provides a summary of the current cost estimates for utility-scale electric generating plants. A Fuel Cell Facility[21] is considered and it utilizes multiple Phosphoric Acid Fuel Cell (PAFC) units.
- In *"Levelized Cost of New Generation Resources in the Annual Energy Outlook 2011" (*Dec. 2010[22] and Apr. 2011[23] versions) Fuel Cells are not included in the final Table published in the web but are considered in the AAEO[24] Tables.

For **Distributed Generation** EIA data are more complex to understand, because it is not possible to consult on the web many of the data sources mentioned[25]:
- From 2001 AAEO includes **Installed Capital cost** forecast for Distributed Generation selected technologies for residential[26] and commercial[27] subjects and takes in consideration also the Fuel Cells technologies[28].

Hydrogen Fuel Cell Powertrain LCOE

In order to calculate the H2FC Powertrain specific LCOE I need some H2FC Powertrain data: the system cost and efficiency, the expected system lifetime, the fuel cost (*i.e.* the H2 cost).

Current Status 2009 – 2010 (DOE[29] public data, based on projected high volume production): Overnight cost 51 USD/kW; 53%-59% System Efficiency; Lifetime 2500 - 2521 hours; and 3 UDS/GGE H2 cost (based on natural gas steam reforming).

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17 - EIA "*2016 Levelized Cost of New Generation Resources from the Annual Energy Outlook 2010"*, January 2010, Cit.
18 - In AAEO 2010 see Table 8.1 (Molten Carbonate Fuel Cell) and 8.2 (Fuel Cells) < http://www.eia.gov/oiaf/aeo/assumption/pdf/0554(2010).pdf >.
19 - EIA *"Generation costs & characteristics"* (Fuel Cells) < http://www.eia.gov/oiaf/aeo/excel/aeo2010%20tab8%202.xls >.
20 - EIA *"Updated Capital Cost Estimates for Electricity Generation Plants"*, November 2010 < http://205.254.135.24/oiaf/beck_plantcosts/pdf/updatedplantcosts.pdf >. EIA motivated the study in this way: "*The current and projected future costs of energy-related capital projects, including but not limited to new electric generating plants, have been subject to considerable change in recent years. EIA updates its cost and performance assumptions annually, as part of the development cycle for the Annual Energy Outlook (AEO). For the AEO2011 cycle, EIA commissioned an external consultant to develop current cost estimates for utility-scale electric generating plants".*
21 - EIA *"Updated Capital Cost Estimates for Electricity Generation Plants"*, November 2010, cit. Chapter 15. Phosphoric Acid Fuel Cell units with a power output of 400 kW, total Plant output of 10 MW.
22 - EIA *"Levelized Cost of New Generation Resources in the Annual Energy Outlook 2011"*, December 2010, cit.
23 - EIA *"Levelized Cost of New Generation Resources in the Annual Energy Outlook 2011"*, April 2011, cit.
24 - In AAEO 2011 (cit.) see Table 8.1 (Molten Carbonate Fuel Cell) and 8.2 (Fuel Cells).
25 - It is impossible to understand at what type of fuel cells AAEO refers because it was not possible to consult on the web these mentioned sources: for Residential Distributed Generation *"Commercial and Industrial CHP Technology Cost and Performance Data Analysis for EIA"* SENTECH Incorporated, 2010 (AAEO 2011) and *"Installed Costs for Small CHP Systems - Estimates and Projections"*, Discovery Insights LLC, 2005 (AAEO 2010); for Commercial Distributed Generation *"Commercial and Industrial CHP Technology Cost and Performance Data Analysis for EIA"* SENTECH Inc., and SAIC Inc., 2010 (AAEO 2011) and "*Commercial and Industrial CHP Technology Cost and Performance Data Analysis for EIA's NEMS"*, Decision Analysis Corporation and Discovery Insights LLC 2006 (AAEO 2010).
26 - EIA AAEO Archive, cit. In AAEO 2011 (cit.) Table 4.3 *"Capital cost and performance parameters of selected residential distributed generation technologies"*, with reference to a 10 kW Fuel Cell.
27 - EIA AAEO Archive, cit. In AAEO 2011 (cit.) Table 5.3 *"Capital cost and performance parameters of selected commercial distributed generation technologies"*, with reference to a 200 kW Fuel Cell.
28 - Only in AAEO 2004 and 2005 the Fuel Cell for Residential Distributed Generation are referred to a 10 kW PEM Fuel Cell. See Table 9 < http://www.eia.gov/oiaf/archive/aeo04/assumption/pdf/0554(2004).pdf > and < http://www.eia.gov/oiaf/archive/aeo05/assumption/pdf/0554(2005).pdf >. An updated and interesting reference of three different Fuel Cell technologies for CHP stationary systems is: NREL *"1–10 kW Stationary Combined Heat and Power Systems Status and Technical Potential - Independent Review"*, November 2010 < http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/48265.pdf >.
29 - S. Satyapal *"Hydrogen and Fuel Cell Technologies Update" Fuel Cells & Hydrogen Joint Undertaking Stakeholders General Assembly November 2010, Brussels* < http://ec.europa.eu/research/fch/pdf/sunita_satyapal.pdf#view=fit&pagemode=none >, p. 5-7.
K. Wipke *"Controlled Hydrogen Fleet and Infrastructure Analysis"*, US DOE NREL, Annual Merit Review, Washington, 2010, < http://www.hydrogen.energy.gov/pdfs/review10/tv001_wipke_2010_o_web.pdf >, p. 13 and 25.

Table 3 summarizes the DOE[30] Projected Transportation Fuel Cell System Cost.

Table 3 - DOE Projected Transportation Fuel Cell System Cost (USD/kW Nominal, Unadjusted)^						
	2002	2006	2007	2008	2009	2010
Fuel Cell System Cost	275	108	94	73	61	51
Of which: Stack		65				25
Of which: Balance of Plant		43				26

^ Projected to high volume (500,000 units per year)

2015 DOE technical targets (based on the same assumption): Overnight cost 30 USD/kW; 60% System Efficiency; Lifetime 5000 hours; and H2 cost 2 – 4 UDS/GGE[31].

Thanks to the fact that expected system life is shorter than one year (also in 2015) it is not necessary to consider any financial aspect. Also, in a conservative perspective, I do not take in consideration the possibility to recover the heat co-produced during the electricity generation (like in a CHP power plant).

Based on the above mentioned assumption the LCOE H2FC Powertrain range value is today 175 -192 USD/MWh and 107-207 USD/MWh for 2015. Table 4 shows these results.

Table 4 - H2FC Powertrain LCOE (USD)							
H2FC Powertrain Efficiency	H2FC Powertrain Hours LIFE	Hydrogen Cost USD/GGE°	Capital Overnight Cost (USD/kW)^	Levelized Capital Cost LCC (USD/MWh)	O&M + Other + Fuel Cost (USD/MWh)	Levelized Cost (USD/MWh)	
53%	2500	3	51	20	172	192	DOE Current status
59%	2500	3	51	20	155	175	DOE Current status
53%	2521	3	51	20	172	192	DOE Current status
59%	2521	3	51	20	155	175	DOE Current status
60%	5000	4	30	6	201	207	2015 DOE Targets
60%	5000	3	30	6	151	157	2015 DOE Targets
60%	5000	2	30	6	101	107	2015 DOE Targets

^ Projected, high-volume manufacturing cost of automotive H2FC systems
° Distributed Natural Gas Reforming (station capacities of 1500 kg/day, with 500 stations built per year)

Conclusions

If the current U.S. Hydrogen and Fuel Cell Vehicle Program is able to meet all the 2015 technological targets the high volume associated with the H2FC vehicles mass production will permit to reduce dramatically the Fuel Cell system manufacturing costs and the H2FC Powertrain will be so cost competitive to be useful adopted also for stationary power generation application.

Using the 2015 DOE H2FC Powertrain data target the LCOE would be in a range of USD 107-207 for MWh and, in the U.S. context, for the lower value of this range it appears competitive with many of the power generation technologies considered.

Observing these H2FC Powertrain data, it will be necessary to think the Hydrogen FCV link to energy sector considering also the possibility to utilize the H2FC Powertrain as a Power Generation Plant, smart grid connected, with relevant and positive consequences for a rapid development of these low-carbon technologies.

US DOE *"The Department of Energy Hydrogen and Fuel Cells Program Plan"* (2010 Draft) < http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/program_plan2010.pdf >, p. 33 and 41.
Other references and assumptions in M. V. Romeri *"Considering Hydrogen Fuel Cells Powertrain as Power Generation Plant"*, World Electric Vehicles Symposium EVS25 "Sustainable Mobility Revolution". Shenzhen, China 2010, Cit.
30 - S. Satyapal "*Hydrogen and Fuel Cell Technologies Update"* November 2010, cit. p. 6.
31 - Using the EIA "*The Impact of Increased Use of Hydrogen on Petroleum Consumption and Carbon Dioxide Emissions"* H2 production costs (after a check of row material 2008 price assumption coherence with current price) the low value of this range could be reduced from 2.0 USD/GGE (see Table 2.1 Estimated Hydrogen Production Costs).