TIP/IEA ENERGY INNOVATION CASE STUDY ON FUEL CELL TECHNOLOGY: Italy

(O.Tampone, A.Iacobazzi**)*

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ABSRACT:
This report has been prepared in order to describe how innovation is produced and transferred in Italian fuel cell energy sector. It deals with a short description on what is Italy's energy demand and the reasons for using fuel cells. After some short account about the different fuel cell technologies, market situation and operators are examined, followed by a description of governmental policies and an analysis of Italian situation in R&D. The last part is essentially devoted to discuss the answers given to specific questionnaires by public and private operators in fuel cell sector. The study has been carried out on the basis of the guidelines produced following the Focus Group meeting of March 27th 2003.

ENEA - Italian Board for New Technologies, Energy and Environment – Scientific Unit Renewable Sources and Innovative Energy Cycles
*** ENEA - Italian Board for New Technologies, Energy and Environment – Hydrogen and Fuel Cells Project*

CR Casaccia
Via Anguillarese,301
00060 Roma Italy

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ENERGY SITUATION IN ITALY

1. In Italy in the short and medium term fossil fuels will continue to play a fundamental role for electric energy generation and for transportation. In particular, in the last ten years the biggest development has been registered in the utilization of natural gas, this becoming the second source after oil to cover national energy demand. Natural gas has experienced an increase from 39,1 Mtep in 1990 up to 58,1 Mtep in 2000.

2. Italy needs approximately 190 Mtep per year, this being covered by oil for 49%, natural gas for 31%, by coal and similar sources for 75% and by primary electric energy for the remaining part. In particular in the last two or three years the value of Italian energy deficit has almost doubled, passing from approximately 13000 millions euros in 1999 up to 28000 millions euro in 2002. These are absolute values depending on the trend of the prices of crude oil, while as a percentage actually there has been a reduction of about 10% in oil import. Moreover, there has been a further increase of turning to natural gas in comparison to oil. This mix leads to a strong dependence from abroad in energy field, expressed in a import value of approximately 85% of the needed energy amount, whether not larger.

3. On the other hand, Italy has signed the Kyoto protocol and subsequently must reduce, within 2008-2012, its CO_2 and other greenhouse gases emissions of 6,5 % with respect to the values of 1990 (555 millions of equivalent tons). Considering the estimated emission value for 2012 (612 millions of equivalent tons), this means a reduction of about 103 millions of CO_2 equivalent tons.

4. To reach such an objective of emission reduction Italy acts through the promotion of energy efficiency in all sectors, the development of renewable sources to produce electric energy, and of innovative technologies for emission reduction, protection and extension of forests to have carbon adsorption , together with the adoption of fiscal instruments aimed at discourage greenhouse gas emissions.

5. A special resolution of the Interdepartmental Committee for Economic Planning states the actions to be undertaken and the actuation timetable of the different interventions.

6. This commitment is very strict and to reach fixed goals in the short-medium term it is absolutely mandatory to choose and adopt new technologies in energy sector.

7. Fuel cells, considered as an integral part in a scenario based on hydrogen as energy vector, represent surely a key technology to achieve such goals.

8. Thus technological innovation assumes a fundamental role, allowing to reach in the short term the realization of products that can be applied both in power generation and in transport, the latter representing one of the biggest problems by the fuel consumption point of view and in the environmental one.

STATIONARY AND MOBILE FUEL CELLS

9. Fuel cells have properties that make very interesting their use in the sector of electric energy production, because they allow to:

- Improve conversion efficiency of primary sources
- Obtain a flexibility in the use of fuels
- Reduce pollutant emissions in the atmosphere.

10. It is useful to give a short description of the types of FC that are developed or under study all over the world:

- **AFC** Alkaline Fuel Cells: operating temperature 60-120°C, Potassium Oxide electrolyte, suitable for space and military application, need very high purity of feeding gases. No more studied.
- **PEFC** Polymer Electrolyte Fuel Cells: operating temperature 70 -100°C, polymeric membrane as electrolyte used in transport and power generation 1-250 kW.
- **PAFC** Phosphoric Acid Fuel Cells: operating temperature 200°C, phosphoric acid electrolyte, is the most mature technology for stationary applications as residential;100 - 200kW.
- **MCFC** Molten Carbonate Fuel Cells: operating temperature 650 °C, molten alkaline carbonate as electrolyte into a ceramic porous matrix. Seem to be suitable for power generation in the range 100 kW up to some tens of MW.
- **SOFC** Solid Oxide Fuel Cells: operating temperature up to 800 -1000 °C ceramic electrolyte based on yttria stabilized zirconia, suitable for the same applications of MCFC.
- **DMFC** Direct Methanol Fuel Cells: operating temperature 70 -100 °C, polymeric membrane as electrolyte, at now only for laboratory research.

Table 1. Application of different FC technologies

Application	Type of Fuel Cell	Power Requirement
Isolated	PEFC,SOFC	0.5-10 kW
Residential	PEFC,SOFC	1-10 kW
Commercial and residential cogeneration	PEFC,PAFC	50-250 kW
Industrial cogeneration	MCFC,SOFC	200kW-2MW
Distributed power	PAFC,MCFC,SOFC	2-20MW
Centralized generation	MCFC,SOFC	<50MW
Transport	PEFC,SOFC	5-200kW

Table 2. Installed power by size of power generation capability

Power	World	Italy

Total installed power (MW)	11,300	250
10 -50 MW	25.7%	26.8%
1 -10 MW	28.3%	30.9%
100kW -1MW	28.5%	27.4%
10 -100kW	18.6%	13.8%

PEFC

Stationary applications

11. There are many barriers limiting the development of different technologies and it is also necessary to carry out products having duration, reliability and costs being competitive in comparison to other power generation systems as gas or steam turbines. The latter have registered a strong increase of their efficiency in the last years, but do not show the environmental acceptability that is peculiar of FC.

12. FC are particularly suitable for distributed generation, but the development of the related market is still strongly depending on deregulation of electric system and in general on the whole energy system. The trend is to lower the average size of power plants.

13. In Italy already in 1999 the average size has gone under 50 MW, due to increasing of self production. Thus it is possible to foresee an increasing room for small size generation technologies having low environmental impact and high efficiency, as FC are.

14. Furthermore, FC based power plants may be suitable both for users needing low installed power (kW-some MW) and electric utilities operating in the range some MW – some tens of MW. This due to their modularity, flexibility, efficiency and environmental compatibility.

15. Recent studies have shown a trend of FC penetration for stationary applications expressed as a percentage of the installed power at world level that is about 3% for isolated plants up to 13% for electric generation and 17% for cogeneration at 2020; this meaning a total increase of more than 11000 MW/y. The major contribution to this growth could be given by high temperature FC, having greater efficiency and suitable for bigger values of generating power.

16. In the short medium term a key role shall be played by low temperature FC, mainly PEFC, for residential utilization in developed countries, in which technical and economic conditions are better fitting the development of distributed generation by innovative technologies.

17. As long as **Italian situation** is concerned the foreseen penetration is similar to the world one, in electric generation and cogeneration, with total increase rates of about 250 MW/y at 2020. Low temperature FC contribution will be 100% in first years of 2000 going to 50% in 2010 and 30% in 2020.

18. The main obstacle to the diffusion of FC based power plants is their high production cost. Present production volumes do not allow a scale economy and it is necessary to reduce the costs by a factor 3 to 10 to be competitive with traditional technologies. The up-mentioned hypothesis of penetration is valid for costs of 1000 – 1500 Euros/kW in initial phase of market penetration and a regime cost of 600-700 Euros/kW.

19. But introducing an innovative technology as FC is also a matter of creating gradually the conditions to reach competitiveness, trespassing “environmental” barriers (knowledge of the

technology, specific regulation, O&M procedures, etc.) that may constitute a penalization in initial phases.

20. This means that users must appreciate self - generation of power and heat by small size plants, being aided by simplification of procedures of installation and start up of the plants and of power exchange with electric grid.

21. Introduction of FC requires furthermore that users be trusting in this new technology, over-passing the worries connected in terms of safety (presence of hydrogen), operation procedures and associated costs, reliability, maintenance troubles, and so on.

22. Users have to feel granted about continuity and quality of plant operation, and to reach this confidence it is of fundamental importance to carry out demonstration programs, in conjunction with potential users, both in development and pre-commercial phases. A very good example of this is given by US DOE activities.

Table 3. Market forecast at 2020

Application	Total installed power (GW)	Fuel Cells (MW)	Fuel Cells %
Isolated applications	16.9	540	3.1
cogeneration	23.4	4100	17.5
Distributed generation	45.3	5980	13.2
Other applications	31.9	710	2.2
Total	117.9	11300	

Table 4. Future market of Fuel Cells for stationary generation in MW/y

Installed Power	2005	2010	2015	2020
Italy	5	40	80	250
Europe	80	300	1500	3500
World	300	1000	5000	11300

23. Commercial systems for stationary applications are now accessible for residential, commercial and mobile generation.

Transport

24. Air pollution level is growing up too much especially in urban areas, thus strong efforts are dedicated to solve this problem in science, technology and legislative fields. In the last ten years the final energy consumption for people urban transport has increased by 35%.

25. CO2 emissions have increased too, by 25.3%.

26. Although there has been an improvement in car production technology, that allowed a reduction respectively of 10% and 28% in CO and NOx emissions, urban cars remain one of the biggest source of air pollution.

27. It is therefore necessary to reduce CO2 emissions, to reduce concentrations of other pollutants in urban areas and to reduce acoustic emissions.

28. Using vehicular propulsion systems based on Fuel Cells represents one of the promising alternatives at medium-long term. Due to their almost zero emissions and low consumption, Fuel Cells can be a fundamental element for next future transport systems.

29. The high efficiency of the cells leads to global efficiency of the vehicles that can reach 27-41%, while internal combustion engines are at now on values of 16-18% for Otto cycle and 20-24% for Diesel one.

30. Fuel Cells can be fed by hydrogen and air or by different fuels, deriving hydrogen with a reforming process. The former reach efficiencies extremely high that can't be achieved by other power generation systems; higher efficiencies mean also reduction of emitted CO2, even when hydrogen is produced by reforming of fossil fuels. At last, using a vehicle powered by Fuel Cells leads to zero emission in case of hydrogen and experiences a 90% reduction when on board reforming is actuated.

31. Also the noise produced by FC vehicle is in some way reduced.

32. For transport application the more promising FC are hydrogen fed polymeric cells, so PEFC technology is the most studied one and many automotive industries are developing demonstration prototypes. But technological progress remains insufficient to reach a market penetration; many problems have still to be solved, spacing from weight and dimension optimization up to a necessary strong reduction of production costs. To get these targets intervention is mainly on materials and on manufacturing processes.

33. Today the stacks of polymeric cells cost about 3000-5000 Euros/kW, but good signals are obtained about a substantial reduction at the end of year 2002. The major industrial groups that are involved in development of demonstration prototypes agree in forecasting values of 250-300 Euros/kW in 2004, with a limited production of vehicles, and of 50-100 Euros/kW (comparable to internal combustion engines) when series production will start.

34. Considering the strong environmental benefits achieved by FC in specific sectors of transport (i.e. public transport), values of cost about 250 Euros/kW are considered to be convenient. All automotive industries in US, Europe, Japan, Canada are developing FC powered vehicle prototypes.

Italian situation

35. Italy started to study PEFC in 1989 with a cooperation ENEA-NUVERA that allowed to realize an original cell technology, characterized by low cost and easy supply materials, suitable for series production. In years 1994-98 other activities have been carried out in conjunction with Institute for Energy Advanced Technologies of CNR (National Research Council) based in Sicily. NUVERA technology has been used to realize different prototypes of vehicles in cooperation with different European automotive industries.

36. Many different experimental development activities have been also carried out since 1994 and are continuing in ENEA, in the frame of specific R&D programs financed by Industry Ministry. These activities are aimed at innovative membranes and electrodes and at the development of small hydrogen based systems, using also a dedicated test station.

37. Other programs, essentially devoted to FC transport applications, are carried out in the frame of a program funded by the Ministry of University and Research. This program involves Research Centres as ENEA and CNR, Universities, Industries as follows:

- Development of advanced cell components
  - ENEA
  - Chemistry Department, University of Rome
  - Industrial Chemistry Department, University of Milan
  - NUVERA Fuel Cells Europe
- Development and realization of innovative stacks
  - CNR - ITAE, Institute for Energy Advanced Technologies
  - NUVERA Fuel Cells Europe
- Realization of a 15 kW complete prototype, natural gas fed, for traction
  - ENEA
  - CNR, Institute for Energy Advanced Technologies
  - FIAT Research Centre
  - Environmental Engineering Department, University of Genoa
  - Industrial Chemistry Department, University of Milan

Other activities are carried out , with development of fuel cell vehicles, by:

- FIAT Group (both for buses and cars)
- Ansaldo Fuel Cells
- ENEA
- Aprilia Motorbike Manufacturers

PAFC

38. Phosphoric Acid Fuel Cells operate at about 200°C, have efficiencies in the range 37- 42% and produce heat that can be used for cogeneration. This technology has mainly been developed in US and Japan and it is mature for medium-small size cogeneration plants. The main producers are UTC Fuel Cells in US, and Fuji Electric, Hitachi, Mitsubishi Electric, Toshiba in Japan. The technology is on the market since five years with a 200 kW plant (PC 25) produced and commercialized by UTC. The distributor for Europe is Italian company Ansaldo. More than 200 plants are operating in the US, Europe, Asia and Australia.

39. The open problems for PAFC concern the optimization of performances and duration of the plants and cost reduction, being costs still high when compared to traditional power generation systems. The

targets to be achieved are 40000 hour duration and less than 1500 Euros/kW. The former has been reached by many installed units, the latter needs an intense research effort.

Italian demonstration activities

40. Italian activities in demonstration of PAFC are maybe the major in Europe. It is since the end of the 80ies that ENEA and national industries have developed an adequate capability of design and manufacturing of these systems, leading to the realization of many plants in different sizes that have been operated and tested for a long time, obtaining an evaluation of their characteristics and verifying the electrical and environmental advantages.

41. The most important realization is the 1.3 MW demonstration plant situated in Milan, built by Ansaldo Ricerche, in cooperation with ENEA and Milan Municipal Energy Company (AEM); the plant represents the integration of different European technologies, being Fuel Cells the only component supplied by UTC.

42. Another important plant has been operated by Bologna Society for Energy and Environment (SEABO) for three years. The plant has been the first one in Italy and was realized in cooperation with ENEA in the frame of a EU program. It is 200 kW in power and showed average electric efficiency of 39,8%.

MCFC

43. Molten Carbonate Fuel Cells operate at high temperature (650°C) and allow a major flexibility in feed fuel; they will in perspective allow efficiencies up to 60-70% if used in combined turbine cycles. But high temperatures and high corrosion potentiality of the electrolyte lead to structural instabilities in cell's components, so the technology is far from asserting itself. In the last years there were some progress, ma there is still much to investigate to solve these problems and to reach competitiveness in terms of reliability, duration, production costs. R&D programs are carried out in US, Japan, Europe.

Italian situation

44. A demonstration plant has been developed in the frame of ENEA-Ministry of Industry agreement in cooperation with Ansaldo, CESI and other Industries. The 100 kW module developed by Ansaldo has been tested in Spain and then transferred to Milan and integrated in a "proof of concept" power plant. Other activities have been carried out to develop and increase the performances of cell's components. Nowadays the second phase of the programs trends to demonstrate that MCFC can pass from "proof of concept" to "first of a kind" type plants. Ansaldo is thus developing the "500 series" that is characterized by high efficiency, very low environmental impact, easy fitting to hosting area , fast response to load fluctuations, easy parallel connection to electric grid. The objective is to enter the market of small-medium size distributed generation.

SOFC

45. Solid Oxide Fuel Cells operate at very high temperature (800 -1000°C) to ensure sufficient conductivity to the ceramic electrolyte. There are many different configurations regarding shape, dimensions, thickness of its components and the geometry of flux channels of reagent gases. Materials are independent from the configuration and, being all components at solid state, there are no corrosion problems. Due to high temperature no particular requisites are needed for the fuel and it is not necessary a conversion system; moreover the discharge heat can be utilized in combined cycle with gas turbine, that are expected to attain efficiency up to 60 -70% and power range is about 250 kW - 25

MW thus representing the more promising high efficiency methodology for distributed generation of the future. Siemens Westinghouse is the main producer of SOFC and is the only producer that succeeded in realizing power systems over some kW.

46. The problems to be solved are linked to material degradation and their assembly; some researchers are experiencing a big effort to reduce operation temperatures to 700-800°C.

47. Obviously also this technology could be implemented only when costs will be reduced.

48. In Europe many Universities and Research Centres are involved in R%D activities on SOFC, in the frame of programs funded by EU. Italy carries out some specific activities in ENEA, Enitecnologie and CNR, essentially aimed at developing materials and production processes of small scale components, realizing cells for laboratory use.

AFC

49. Alkaline fuel Cells operate at low temperatures using potassium oxide as electrolyte. They show a series of advantages as:

- Electrical efficiency up to 65%
- Low costs of cell's components
- Long life times

50. The disadvantages are essentially due to the low tolerance to impurities of reagent gases, limiting therefore the use of syngas and of the air itself; the necessary gas purification systems make non-economic the use of AFC in stationary applications.

51. In last years only some European companies are carrying out research activities on this type of cells.

DMFC

52. Direct Methanol Fuel Cells represent the new frontier in FC generation. They operate at low temperature and are directly fed by methanol. This makes them very suitable for on board generation and for mobile generators. It is possible to realize very simple and compact systems in which it is not necessary an external reformer; moreover, methanol stocking is simpler than hydrogen one. The configuration of such cells is very similar to PEFC and their electric efficiency reaches at now 35%, but the power density is still low with respect to PEFC.

53. This technology is therefore still in the state of Laboratory Research and the major problems to solve are connected with electrochemistry of methanol. Many Laboratories are studying DMFC in US, Japan and Europe. In **Italy** only CNR-ITAE (Institute For Energy Advanced Technologies) is involved in such R&D activities, mainly aimed at the development of membranes and catalyzers.

THE MARKET AND THE OPERATORS

Organizational network of actors and institutions

54. Organizational network involved in innovation processes related to fuel cells technologies in **Italy** is structured as to include governmental organizations, typically Public Research Boards as ENEA and CNR, Universities, Large and Small-Medium enterprises. Regarding to industrial sector it ranges from specific technologies developers, that are often part in international groups, up to component manufacturers and final users, that are sometimes also manufacturers of specific application of the technology itself. Forms of cooperation are many and different; in particular the activities that are more strictly research oriented are carried out in public boards laboratories, being these the holders of innovation, while private industries are more dedicated to industrialization and application of the product.

55. A great importance is assumed by consortia devoted to prototype realization and to innovation demonstration; they are constituted with public and private funding. SMEs, that represent the main part of Italian industrial network, get technological transfer by research institutions and study applications of the found technologies in a highly specialized sector.

56. In **Italy** it does not still exist a market for fuel cells, due to being this product still in the phase of technological development. Nevertheless some prototypical applications of the technology are starting a commercialization, mainly in the transport sector. These examples are anyway limited to two wheel vehicles.

57. More significant are instead demonstration applications, both in the stationary and mobile sectors.

58. The actors engaged in the research, development and demonstration of energy systems based on fuel cells are different also if limited in number. We can divide them in the following groups:

- Cell manufacturers
  - ANSALDO FUEL CELLS SPA, developer of MCFC
  - NUVERA FUEL CELLS EUROPE, developer of polymeric cells
  - ARCOTRONICS FUEL CELLS, part of Arcotronics Nissei Group, merged with Roen Est, developer of polymeric cells
- Cell component manufacturers
  - FN NUOVE TECNOLOGIE E SERVIZI AVANZATI, that develops components for MCFC
  - PONTE DI ARCHIMEDE, that develops components for polymeric electrolyte cells
- Users of transport systems
  - Centro Ricerche FIAT, developer of Fuel Cell based cars

- I2T3, developer of FC buses for urban transport
- IRISBUS-IVECO, developer of FC buses for urban transport

- Users/builders of light vehicles (motor-scooters, bicycles) operated by Fuel Cells
  - APRILIA scooters
  - PIAGGIO scooter
  - FAAM bicycles
- Users of systems for FC stationary applications
  - ZINCAR, developer of hydrogen based systems
  - SEABO, energy utility
- Research and development, technological innovation organisations:
  - ENEA
  - CNR-ITAE
  - Several Universities (Genoa, Milan, Rome, Turin, etc.)
  - CESI Institute for electrical applications research

Activities in stack development and fuel treatment system

59. Italian innovation in this field regarded polymer electrolyte cells for automotive traction and has been carried out by Public Research Organization ENEA and Industry NUVERA. This allowed to set up an original cell technology based on low cost materials and production technologies suitable for series production. These activities continued in a second time with the co-operation of another public research organization that is CNR ITAE operating in the frame of an agreement between ENEA and Ministry of Productive Activities, former Ministry of Industry. The transfer of knowledge has been implemented by using these new cells in experimental vehicles, that have in this way represented a demonstration bench. In the frame of the same program agreement some innovative components have been developed, too, in particular membrane/electrodes assemblies.

60. In the last years ENEA has started a cooperation with a small industry , Roen Est, now Arcotronics Fuel Cells to develop new components both of cell and stack. This cooperation represents a typical example of technological transfer and support to SME.

61. ENEA in its own started to develop small hydrogen systems, realizing a mobile device that can be installed on an electric Bicycle and another one for a Hybrid vehicle. ENEA research activity foresees also laboratories for stack characterization.

62. A typical example of integration among the different actors public and private, funded by the government is the MURST three year program aimed at developing a 10-15 kW power system fed by natural gas that is based on the following three lines of activity:

- Development of advanced cell components
- Development of stacks representing an evolution of today technology
- Realization of a complete prototype for automotive traction fed by natural gas

63. The program is carried out jointly by:ENEA, NUVERA, CENTRO RICERCHE FIAT, CNR-ITAE, Milan Technological University, Universities of Turin, Genoa, Rome.

64. The three up-mentioned research lines are responsibility of the partners as follows:

- *Development of advanced cell components. C*arried out by ENEA and Chemistry Department of Rome University, Industrial Chemistry and Chemical Engineering Department of Technological University of Milan, NUVERA Fuel Cells Europe.
- *Development of stacks representing an evolution of today technology.* Realization of a complete prototype for automotive traction fed by natural gas carried out by CNR-ITAE, NUVERA Fuel Cells Europe
- *Realization of a complete prototype for automotive traction, natural gas fed. C*arried out by ENEA, CNR-ITAE, FIAT Research Centre, Industrial Chemistry and Chemical Engineering Department of Technological University of Milan, Department of Environmental Engineering of Genoa University.

65. Moreover, other research structures cooperate in the program as for example the Electrochemical Advanced Technologies project, aimed at demonstration of industrial feasibility of the production of electrodes by gaseous diffusion. The project is funded for 50% by Sicily Region and for the remaining part by the private firm Ponte di Archimede and the Public Organization CNR-ITAE.

Prototype development

66. In the field of prototype development for automotive traction activities are carried out by ENEA, CNR, FIAT Group, ANSALDO Fuel Cells, APRILIA, and others.

67. Innovation in this sector is driven by government, being this one a program funded by the Ministry of Environment and Territory. Also other actors give their contribution to the program as Turin Municipality Mobility Board, SAPIO. In this program have reached demonstration phase a hydrogen fed bus zero emission realized by IRISBUS consortium, the small car 600 Elettra Fuel Cell developed by FIAT Research Centre with the financial contribution of the Ministry of Environment and Territory, the prototype of motorbike Enjoy Fuel Cell of APRILIA and the electric bicycle manufactured in ENEA laboratories .

Demonstration power plants for phosphoric acid fuel cells

68. Innovation in the sector of phosphoric acid fuel cells is carried out by means of demonstration plants which are in operation since approximately ten years. The most important one is the 1.3MW one owned by Municipalized Energy Board (AEM) of Milan. This plant has been realized in

cooperation among ENEA (public), ANSALDO (private) and AEM (public). A second significant plant , having 200 kW of power, is owned and operated in Bologna by SEABO. This facility has been the first Fuel Cell based co-generative power plant in Italy, and has been carried out in cooperation with ENEA in the frame of a project partially funded by EU. Finally a third 200 kW power plant has been installed in Milan at Science and Technology Museum. In this plant, energy produced is used to heat the environment and the recovered heat feeds pre-existing plants; it has been built by the private industry ANSALDO RICERCHE and funded by the Ministry of Environment and Territory.

Molton carbonate cells

69. Development of molten carbonate Fuel Cells is driven by the joint efforts of ENEA, ANSALDO FUEL CELLS and other research organizations, as CESI and FN. At the beginning the program has been funded in the frame of a Program Agreement between ENEA and Ministry of Productive Activities, and the main part of research activities were inserted in a European project in which also some Spanish electric utilities participate. At now activities are implemented by the project and realization of modular units of 500 kW care of ANSALDO FC. These units will be tested as demonstration case reconverting the up-mentioned plant of AEM in Milan.

70. This phase of the program aims at demonstrating how to pass from prototype to pre-commercial power plants, looking for next introduction in the market.

GOVERNMENTAL SUPPORT POLICIES, FUNDING, INCENTIVES

Government organizations involved in funding research

71. Research is fundamentally funded by the Ministries of University and Scientific Research, of Productive Activities and of Environment and Territory. Funding modalities are much different and use funds that are specifically created in the different ministries, being these funds then distributed at regional and local levels. In this way we can distinguish among various level of funding according both to the importance and to the type of research to be carried out

72. Priorities are defined at central level by the different ministries in their own or in accordance to others; sometimes there are joint programs that are agreed also with environmental protection associations, energy producers/distributors, industries of the specific sector.

73. Italian Government issues each year the Document of Economic and Financial Planning, that defines the general objectives and the modalities of implementation of the decided financial interventions. The up-mentioned document evolves according to national and international situation and consequently establishes the priorities of research funding on the different technologies. The schematic frame of the addresses and priorities in the field of scientific research is prepared by the Ministry of University and Research. One of the driving factors with respect to emerging researches is represented by interventions to aid depressed areas in the South, with dedicated rules for extraordinary funding.

74. Another important driving factor is represented by the necessity to intervene in support of specifics scientific sectors to respond to solicitations and needs of internal policies or due to international agreements.

75. This leads to forming National Program of Research, aimed at developing strongly innovative and strategic technologies, that could be industrialized in medium term. A latter effect is the warranted funding to participate in some international organizations.

76. It is important to notice that institutions that supervise to research activities have realized the importance of a close cooperation among the different actors with the aim of enforcing the technological competitiveness of productive sectors, of increasing the production and fostering qualified manpower.

77. The legislative decree n.297 dated July 27,1999 has launched a series of measures to support industrial research, from forming of personnel up to the use of research results. This series of provisions tends to enforce the interaction of enterprises, universities, public research boards, cancelling duplications and existing overlapping.

78. The funding sources are numerous and they generate a complex network of incoming and outgoing fluxes among the groups of operators in the research system. They can be schematized as follows:

- Central and Local Public Administration
- Enterprises
- Non profit sector

79. To the former belong central Public Administrations (Ministries), Public Research Centres, Universities. It must be noticed that Research Centres are considered to be mainly the developers of research activities, even though approximately 8% of their funding is devolved to external partners.

80. Universities are funded by MIUR (Ministry of University and Research), with an ordinary funding covering all fix expenses and the expenses for the research. Research is actually mainly carried out with governmental contribution, being university research very scarcely funded by industrial sector.

81. Local Administrations are mainly constituted by Regional Administrations that fund scientific research activities carried out at universities, public research centres, private laboratories. There are also a certain number of Regional Bodies , directly funded by Regions, that carry out research in specific sectors of interest for local administration.

82. The sector of Enterprises is very homogeneous and includes all firms that declare to carry out research activities to the National Statistical Institute. The expenses of such sector are classified as for economical sectors. This because researches carried out in the public frame are aimed at solving problems rose into a discipline or responding to societal exigencies, while those of enterprise sector are aimed at satisfying the needs of their specific production sectors.

83. Non-profit sector has a very low weight, both in funding and in research carrying out.

ITALIAN SITUATION IN RESEARCH AND DEVELOPMENT

Drivers of innovation

84. Drivers of innovation in energy sector and in particular in fuel cells are essentially constituted by economic factors and environmental factors, mainly the ones imposed by regulations or by the market.

85. In this frame a high influence is given by governmental policy, that through some suitable instruments creates incentives, even though not always sufficient, to allow technological innovation a faster penetration in the market. This is essentially obtained by: 1) adoption of energy-environmental strategies of long term; 2) formulating and applying economic incentives for the diffusion of new technologies; and 3) imposing environmental constraints becoming more and more tight. Surely also societal concerns have their importance, that are devoted to public welfare and environmental protection.

86. These represent as a principle primary driving factors and in particular keeping into account the externalities may influence and foster the research towards new technologies.

87. The role of the developers of new technologies in driving innovation towards energy distributors and final users is essentially of: demonstration; knowledge diffusion, and short-medium term support.

Knowledge creation, diffusion and exploitation

88. How new knowledge and therefore technological innovation are created, diffused and applied? Certainly Public Research Organization as Research Centres and Universities represent the key sources of innovative knowledge. According to funding and in a certain account the developers of research it is necessary to distinguish between starting phase and industrialization one.

89. Actually in the first phase the actors are fundamentally public and governmental, while in the second one there is a strong contribution of private industry. The relative contributions of such groups are variable, because there is a strong governmental support to the activities of research and development in funding the different research projects, but also in industrializing phase it is possible to have particular agreements for supporting private actors, especially SMEs.

90. As a consequence, the roles of SMEs differ from Great Industries in carrying out research, development, demonstration and industrialization activities due to:

- Large Firms are in general conditioned by international agreements with more skilled partners (typical example is the automotive traction sector) and usually tend to get a high percentage of public funding for their activities of Research and Development.

- SMEs usually have more flexibility, that constitutes a good requisite for a fast technological development, but in the meantime they need a support (also in form of a joint venture) by Large Firms, especially in the phases of industrialization and commercialization, due to the high grade of risk that these phase present.

91. The knowledge flow among industry, governmental organizations and universities can assume the most different patterns. The main in importance is actually a strict cooperation in research programs, that can be on a national or international basis. Other means of ensuring knowledge flow are

formalised transfer through patents and licensing, some reciprocal mobility of researchers (very limited in time), consulting.

92. The mechanisms used by firms to acquire new knowledge depend on firm dimension. Large Firms often have internal R&D activities and also use licensing, merging and collaborative R&D. SMEs are more linked to knowledge diffusion from Public Research and joint research efforts. Thus the balance between the different mechanisms varies depending on the change in reference situation.

Public/private partnerships

93. In case of public/private partnership, the more efficient forms for fostering innovation are joint participation in governmental, regional, local or European, etc. public programs, and agreements on specific aspects of the technology. Usually in these cooperation programs central or local government, university and industry play the following roles: Government funds and public and/or private research organizations carry out the activity. It is important to notice that usually public funding is no more than 50%, so also a self financing of activity by industry and research organizations has to be considered.

94. It is clear that conducting activities in partnership presents some advantages with respect to research operated individually. Actually, cooperation allows to access to the huge knowledge “tank” of public research system. In Italy Fuel Cell knowledge is more present in public organizations than in private enterprises.

95. The costs and the results of researches carried out in partnership are shared as follows: 1) Usually activities are balanced among the partners so to make each partner bear its own cost; 2) Results are shared in accordance to the percentage of each partner’s activity in the total program.

Intellectual property rights

96. IPR is a very important topic, since industry of course need it to support market competition. Private- public co-operation is greatly stimulated when a good IPR policy can be set up.

97. The patent system works as follows: Usually, in case of cooperation, when patent is originated by industry, patents themselves are held by all involved organizations. In case of patent originated in public research organization, a recent law gives the ownership of the patent to the single researcher (or group of researchers) that applied for that. In this case, when industry is involved, specific agreements have to be issued with researchers. For what the patterns of patent licensing are concerned, that is whether technology is broadly licensed, whether it happens more for large firms and what be the mix of exclusive and nonexclusive licenses, there is not a defined pattern, but the whole matter is referred to specific agreements, case by case.

98. The contribution of public research to industrial innovation in fuel cell technological sector is fundamental, since the greater part of innovation in this field is at now produced by Public Research Organizations. Actually, industry is more committed to market-entry and low -cost industrialization of products, while most advanced development activities are left to National Public Laboratories..

99. The main challenges faced by private organizations in licensing technologies from Public Research Bodies and the concerns of Public Research Organizations regarding licensing practices regard the effective return of money from industry. The most common way to do that is by royalties industry gives to public organizations when using their know-how, but very often control is quite impossible.

Effects of globalisation

100. Research, development and other innovative activities are greatly globalized. Italy has cooperation agreements with US, European Countries, China and other Far East Countries. The main point is that cooperation is occurring most among academic organizations and not among industries.

101. Primary motivations leading to research and development globalization are due to being knowledge and know-how spread worldwide. Obviously there is a great easiness of changing cooperation agreements in research activities, that are strongly depending on different national program funding.

102. Primary mechanisms for globalizing Research and Development activities are first of all collaborative research and sometimes merging with foreign companies.

Systemic influences on innovation

103. Other factors that channel innovative activities and/or influence the penetration capability in the market of technological innovation depend on two basic reasons: 1) on one side government regulations on energy and environment can stress the main advantages of fuel cell technologies; 2) on the other side diffusion of information about fuel cells and hydrogen is required, since they are a strong element of a “cultural change” in energy sector.

ANSWERS TO THE QUESTIONNAIRES

104. Two different types of questionnaires have been sent to Public Organizations that operate in the sector of Research and Development and to Industries that for different reasons are a part of Fuel Cell sector, as cell manufacturers, components manufacturers, users and users/builders of devices that use Fuel Cells.

105. The questionnaire sent to industries was addressed to different groups, that is:

- Cell manufacturers (3)
- Cell component manufacturers (2)
- Users (7)
- Users and application builders (2)

106. The proposed methodology for answering this questionnaire has been to indicate what are the important and driving factors for fostering innovation in fuel cell energy technologies, and are resumed in the following table. Each answer has been expressed as a value in the range 0 - 5, increasing according to the importance.

107. The results of such a survey are as follows:

- As for Public Organizations are concerned, section 5 of this document represents the conclusion of collected data processing. It can be useful to notice that the main result is knowledge is essentially generated in PRO, with a significant contribution of private sector, mainly referred to joint research efforts , funded by national and EU programs.

- A second aspect to be stressed is that knowledge and innovation diffusion is one of the roles of PRO, mainly ENEA.

LEGEND: **C.M.** **Cell Manufacturer**
C.C.M. **Cell Component Manufacturer**
U. **User**
U/B **User/Builder**

Factors influencing innovation processes

Question 1. How important are the following factors in influencing the types or magnitude of innovative activities of the specific energy technology undertaken by your company?

	C.M.1	C.M.2	C.M.3	C.C.M.1.	C.C.M.2	U.1	U.2	U.3	U.4	U.5	U.6	U.7	U/B1	U/B2
The types of R&D projects undertaken by your competitors					1									
The amount spent by your competitors on R&D		5			1									
To reduce production costs					2							5		
To improve the performance or quality of existing products					3			5			5	5		
To create new products		5			5			5			5	5		
To earn revenue from licensing product/process innovations					5									
External sources of information necessary for innovation					2						5			

Question 2. How important to the innovative activities of your company is technical knowledge obtained from the following sources ?

	C.M.1	C.M.2	C.M.3	C.C.M.1.	C.C.M.2	U.1	U.2	U.3	U.4	U.5	U.6	U.7	U/B1	U/B2
Affiliated firms					2					4				
Mergers & Acquisitions					1									
Joint/cooperative ventures		2			5			5		3	5	5		
Independent suppliers of materials, components or production equipment		5			2			5		3	5			
Independent clients or customers					1					3				
Public research institutes and universities		5			5					5	5			
Technical analysis of the products of competitors		3			3					4		5		

Access to research from public institutes & universities

Question 3. How important to the innovative activities of your company are the following research outputs of public research institutes and universities ?

	C.M.1	C.M.2	C.M.3	C.C.M.1.	C.C.M.2	U.1	U.2	U.3	U.4	U.5	U.6	U.7	U/B1	U/B2
General knowledge obtained from basic research		5			2			5		2				
Specialized or applied knowledge		3			5					4	5			
New instrumentation and techniques		3			4					4	5			
Early versions or prototypes of new product designs		3			5					4		5		

Question 4. How important to the innovative activities of your company are the research activities undertaken by the following actors ?

	C.M.1	C.M.2	C.M.3	C.C.M.1.	C.C.M.2	U.1	U.2	U.3	U.4	U.5	U.6	U.7	U/B1	U/B2
Public research		5			5			5		4	5	5		
Universities					5					4	5	5		

Question 5. How important to your company are the following sources or methods for learning about research conducted in public research institutes or universities ?

	C.M.1	C.M.2	C.M.3	C.C.M.1.	C.C.M.2	U.1	U.2	U.3	U.4	U.5	U.6	U.7	U/B1	U/B2
Publications, patents, technical reports		5			4					3				
Public conferences and meetings		3			5					3	5	5		
Hiring trained scientists and engineers		2			5					3				
Informal personal contacts between your company's staff and public researchers		5			2					3	5			
Temporary personnel exchanges between your company & an institute/university		2			2					3				
Contract research where the work is done by the institute or university		3			4					3	5	5		
Joint research projects between your unit and an institute or university		5			5			5		3	5	5		

Question 6. How important are the following obstacles in limiting the ability of your company to absorb knowledge produced by public research institutes or universities?

	C.M.1	C.M.2	C.M.3	C.C.M.1.	C.C.M.2	U.1	U.2	U.3	U.4	U.5	U.6	U.7	U/B1	U/B2
Lack of internal expertise		3			2							5		
Intellectual property rights		5			3			5			5			

Protection of innovations, IPRs and knowledge transfer

Question 7. How important are the following methods of preventing or deterring your competitors from copying or appropriating your unit's product and process innovations?

	C.M.1	C.M.2	C.M.3	C.C.M.1.	C.C.M.2	U.1	U.2	U.3	U.4	U.5	U.6	U.7	U/B1	U/B2
Patent protection		6			5							5		
Design registration		3			3									
Secrecy		5			4			5			5	5		
Scientific and technical publications		2			3									

Question 8. How important are the following features in making your company's product and process innovations difficult or commercially unprofitable to imitate ?

	C.M.1	C.M.2	C.M.3	C.C.M.1.	C.C.M.2	U.1	U.2	U.3	U.4	U.5	U.6	U.7	U/B1	U/B2
Technical complexity		3			2									
Frequent technical improvements		5			4			5			5	5		

Lead-time advantages from being first on the market

Question 9. Approximately how long would a capable firm require to market a competitive alternative to a significant innovation develop by your company?

	C.M.1	C.M.2	C.M.3	C.C.M.1.	C.C.M.2	U.1	U.2	U.3	U.4	U.5	U.6	U.7	U/B1	U/B2
<1.5 years										x	x			
1.5-3 years								x						
3-5 years		x												
>5 years														

Question 10. In the last three years, an application was made for approximately what percentage of your company's innovations?

	C.M.1	C.M.2	C.M.3	C.C.M.1.	C.C.M.2	U.1	U.2	U.3	U.4	U.5	U.6	U.7	U/B1	U/B2
0-19%														
20-39%														
40-59%										x	x			
60-79%					x									
80-100%		x						x						

Question 11. How important to your company are the following reasons for patenting new products/processes ?

	C.M.1	C.M.2	C.M.3	C.C.M.1.	C.C.M.2	U.1	U.2	U.3	U.4	U.5	U.6	U.7	U/B1	U/B2
To prevent competitors from copying your invention		5			5			5			5	5		
To prevent patent infringements suits against your firm					2							5		
To improve your position in negotiations with other firms, for example in cross-licensing the innovation		5			4			5						
To use as a method of recognizing or evaluating the productivity of researchers in your unit					2					3				
To be able to access foreign markets where legislation requires new technologies to be licensed by a national firm		5			2					3				

Question 12. In the last three years, has your company decided not to apply for a patent for one or more innovations? If yes, how important were the following factors in influencing your company's decision not to patent?

	C.M.1	C.M.2	C.M.3	C.C.M.1.	C.C.M.2	U.1	U.2	U.3	U.4	U.5	U.6	U.7	U/B1	U/B2
The cost of applying for a patent		5			1									
The cost of defending a patent in court		3			1									
Limits to the effectiveness of patents in preventing imitation		5			2			5			5			
The amount of information disclosed in a patent application		2			1						5			

Question 13. In last three years, has your company decided to publish research result in the open literature ? If yes, how important were the following factors in influencing your unit's decision to publish ?

	C.M.1	C.M.2	C.M.3	C.C.M.1.	C.C.M.2	U.1	U.2	U.3	U.4	U.5	U.6	U.7	U/B1	U/B2
Evaluating the productivity of researchers in your company					1									
Finding new R&D partners among public research institutes or Universities					2			5		3	5			
Giving signals to the public research institutes or universities about the company's research fields of interest					5							5		
Government policies and framework conditions					2									

Question 14. How important are the following types of policies and programmes of your country in supporting the ability of your company to innovate ?

	C.M.1	C.M.2	C.M.3	C.C.M.1.	C.C.M.2	U.1	U.2	U.3	U.4	U.5	U.6	U.7	U/B1	U/B2
Subsidies (e.g. tax credits)		5			3					4	5			
Procurement programmes (civil, defense)		5			1									
Regulation/deregulation		3			1									
Public support for research in universities and research institutes		5			1					4				
Demonstration programmes		5			1			5		4	5	5		
Programmes to encourage cooperation in R&D between firms or between firms and research institutes		5			5					4	5	5		

National innovation systems and globalization

Question 15. How important are the following obstacles in limiting the ability of your company to profit from its innovations in home or foreign markets

	C.M.1	C.M.2	C.M.3	C.C.M.1.	C.C.M.2	U.1	U.2	U.3	U.4	U.5	U.6	U.7	U/B1	U/B2
Discriminatory behavior by the legal system on behalf of local firms		2			1									
Copying of your innovations by local competitors		5			2			5				5		
Public procurement rules that favor local firms		2			1							5		

Environmental regulations	5	2		
Incompatibility with local technical standards	5	1	5	5

Summarizing table for identifying relevant information

	Knowledge production	Knowledge diffusion	Knowledge absorption and use
Who	Public Research Organizations, Universities, Industry (when cooperating with the former)	Public Research Organizations, Universities, Ministries, Regional an Local Agencies	Industry, Utilities, SME
What	The created knowledge consists in new components, systems, control units and in general any type of innovated device referred to fuel cells	Knowledge is diffused by technical reports, prototype and/or demonstration plants and facilities, laboratory scale innovated devices, systems and components, patents	Users of innovated technologies must be large or small-medium enterprises devoted to reduce emissions, increase energy efficiency and use of the specific technology for specific applications. Often they are utilities in energy production and distribution, for stationary applications, or vehicle producers for mobile ones
How	The knowledge is produced both with theoretical studies and experimental ones and is created mainly into the laboratories of Public Research Organizations. It can be achieved by joint efforts of different public and private partners	Reports, Conferences, Workshops, Technical meetings, Cooperation agreements, Partnerships in Projects, both national and Community or international	Forms of acquisition and use are mainly the cooperation in joint research programs, national or international. Other important forms are formalized transfer of knowledge through patents and licensing, consulting, reciprocal mobility of researchers and technicians
Where	Different locations in the national territory, where public research centers and main industries are located	Geographical scope: the trend is to diffuse knowledge all over the territory, expecting that new technologies could enter the market of the different applications in short-medium term	Users can be located on the whole national territory. Main locations are those of Municipalized Energy Boards for stationary applications and the manufacturing facilities of vehicles for mobile ones
Why	The drivers of innovation are essentially: a) economic factors, b)environmental factors; that influence governmental policy in order to allow innovation having a faster penetration in the market. Other drivers are societal concerns regarding public welfare and environmental protection	Knowledge flows are mainly from Public Research Organizations towards large and medium-small industry. They are driven by governmental funding , participation in joint research efforts and, in a small account, by direct funding of industrial research activities	Knowledge use is driven first of all by the competition in the market. Actually there are also driving factors constituted by environmental constraints and increasing of energy efficiency

Institutional +Environment	Governmental policy, Ministries of University and Research, Ministry of Environment and Territory, Ministry of Productive Activities. Document of Economic and Financial Planning, National Research Program	International situation on energy demand and supply, oil and gas prices, cost of patenting and licensing	Market perspectives for introduction of new technologies, governmental subsidies and incentives, expenditure for patent and license acquisition, funding to industrial research. Acceptance by the public opinion

108. The answers to the different question posed to industries have been classified on the basis of their value and only the three more frequent have been considered in the following classification.

Question 1 Factors that influence type or magnitude of innovation activities

1. to create new products
2. to improve the performance or quality of existing products
3. to reduce production costs

Question 2 Importance of sources of technical knowledge

1. public research institutes and universities
2. independent suppliers of materials, components or production equipment
3. joint/cooperative ventures

Question 3 Importance of outputs of public research institutes and universities

1. specialized or applied knowledge
2. early versions or prototypes of new product designs
3. new instrumentation and techniques

Question 4 Importance of innovation of research activities by public actors

1. public research institutes
2. universities

Question 5 Important sources for learning from public research

1. joint research projects between the firms and institutes or universities
2. contract research were the work is done by the institute or the university
3. public conferences and meetings

Question 6 Obstacles limiting absorbing knowledge produced by public research institutes or universities

1. intellectual property rights
2. lack of internal expertise

Question 7 Methods for preventing copying innovations by competitors

1. secrecy
2. patent protection

Question 8 Features making innovations difficult to imitate

1. frequent technical improvements
2. technical complexity

Question 9 Time required by a capable firm to market an alternative innovation

1. Ranging from 1 to 5 years, average time 1.5 – 3 years

Question 10 Percentage of application of innovations in the last three years

1. Ranging from 40 to 100%, but too little data collected for a realistic estimate

Question 11 Important reasons for patenting new products

1. to prevent competitors to copy the inventions
2. to improve the position in negotiation with other firms
3. To be able to access foreign markets where legislation requires new technologies to be licensed by a national firm

Question 12 Factors influencing the decision of not applying for patent in last three years

1. limits to the effectiveness of patents in preventing imitation
2. the amount of information disclosed in a patent application
3. the cost of applying for a patent

Question 13 Factors influencing the decision to publish research results in the open literature

1. finding new RD partners among public research institutes or universities
2. giving signals to the public research institutes or universities

Question 14 Importance of national policies and programmes in supporting innovation

1. programmes to encourage cooperation in R&D between firms or between firms and research institutes
2. demonstration programmes

3. subsidies (e.g. tax credits)

Question 15 Obstacles limiting to profit from innovations in the markets

1. copying of innovation by local competitors
2. incompatibility with local technical standards
3. public procurement rules that favour local firms

CONCLUSIONS

109. The study results to be not so in-depth as desired, due to a limited cooperation by industrial operators and utilities, in which only about 30% has given answers to the questionnaire, not allowing a good data elaboration. In particular it has been impossible to give information about demographic and economic dimensions of the operators. This is essentially due to being these operators a part of a larger group for which this kind of data is considered proprietary.

110. On the other side, a certain degree of variability in the definition of National Energy Programs, even if they foresee a strong fostering of innovative energy production and use, did not allow to collect significant economic data, that therefore are not reported. Spite of this, it is possible to outline a frame about the operation of Italian system of innovation penetration in energy field and in particular in fuel cell sectors and some significant deductions can be achieved.

- The drivers of innovation are economic and environmental factors, and partially societal concerns.
- The higher influence is given by governmental policy that states the rules for the evolution of energy sector, imposes environmental restraints, defines economic and financial incentives and, by means of the Document of Economic and Financial planning, issues the National Research Program.
- The role of PRO and universities, that is public research, is fundamental. These are the sources of knowledge, even if there is often a strict cooperation with industry and utilities to conduct joint research activities.
- Funding is essentially public (ministries, regions, local administration, municipal boards, etc.), each one of these having its own instrument of planning and financing research activities and/or demonstration. A great importance is assumed by funding of joint programs in the frame of EU projects.

- It is necessary to increase the participation of industry, both Large and SMEs, and in general of private sector, to research activities. This must be achieved by promoting consortia, joint ventures, joint participation to national and international programs, and increasing information exchange.

- A major attention must be given to environmental aspects with the aim to obtain an energy management that be more efficient and environmentally consistent.

- The diffusion of innovation is task of technology developers, mainly PRO, in agreement and cooperation with ministries, local boards, regional boards.