2. The future of fuel cells in a long term inter-technology competition framework

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2.1. Introduction

New technological options generally represent solutions to new requirements or constraints. While the solutions in the framework of existing technologies are generally expensive, clean technologies are often considered as best alternatives for meeting sustainable development targets [24]. Nevertheless new technologies have to compete with the existing ones, whose environmental performances appear unsatisfactory today but may improve, sometimes significantly, in the future. Thus new technological options involve significant risks and costs but also anticipations of future opportunities and profits that play a central role in the decisions to involve in new development.

The process of inter-technology competition has received renewed attention through the work of Christensen [5]. He uses the term of disruptive technology to characterise technologies that offer a novel mix of attributes compared to the established ones but are initially inferior to the established technology according to their costs or to the needs of consumers in the primary (mainstream) market segment. Usually disruptive technologies in their early developments are mostly used in niche markets that value their non-standard performance attributes. Subsequently, further development raises the disruptive technology’s attributes on the focal market, up to a level that is sufficient to satisfy mainstream customers. During a transition period, the performance of disruptive technology remains inferior to the performance offered by the established mainstream technology, which itself is improving as well [1]: the outcome of the inter-technology competition is at that point nothing but trivial as this process confronts, on both sides, dynamic attributes and performances.

Unexplored options are developed by risk-prone agents showing innovative attitudes in front of new challenges. But they are also often strongly influenced by government R&D spending as well as government energy and environmental technology-push. Uncertainty is higher for new options than for existing ones, but the possibility of a breakthrough opening the way to a new paradigm, confers a technological option value. The accumulation of knowledge related to the new technology provides an endogenous information to the decision makers, creating irreversibility effects [18] that may shift the decision in favour of new options for

We warmly thank Mr P Cohendet for his comments.

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an equal ratio of output/risk. One enters thus in a process of “technological competition” at the border of the paradigm [22]. In the short term the society is locked in conventional technologies which have low performances in certain aspects (like environmental pollution), and isn’t incited to choose new clean technologies as long as these criteria are not anticipated to be taken into account.

Fuel cells are taken here as an example of a disruptive technology that has required a long period from the stage of invention to the stage of innovation and is passing by market niches to lead to a threshold of the ‘percolation’ kind which will permit to enter in a process of technological competition and reach the phase of the diffusion. The process of evolution from one niche market that accepts high fuel cell investment cost to another with more interesting economic performances and the acceleration of the dissemination through niche markets to attain the “percolation” threshold is also argued.

The progress made, as well as the increase in the environmental concerns, is at the origin of a renewed interest towards the development of the fuel cells. This effort’s intensification could be regarded as a transition from the pre-paradigmatic phase to the stage of auto-organisation. The further evolution towards the establishment of a new paradigm (the paradigmatic stage), will probably depend on the willingness to use fuel cells as a new model of solution to problems of sustainable energy development.

Boosted by the expected efficiency, low emissions and maintenance costs of fuel cells, the industry has been growing rapidly in the past few years, with new companies joining the sector every day. 250 Phosphoric Acid (PAFC), 35 Molten Carbonate (MCFC), 12 Solid Oxide (SOFC) have been or are operating in as many as 19 countries with a capacity of around 45 MW. About one hundred pre-commercial Proton Exchange Membrane (PEMFC) co-generators have already been installed in the US and Japan. More than 70 projects of fuel cell transit buses and cars are planned or under development world-wide. Different studies consider that fuel-cells will have opportunities to establish themselves in the stationary power, automotive and portable equipment markets. However uncertainties remain as concerns the dynamics and extension of these markets, on how fuel-cells will compete with other conventional technologies and on which category of fuel-cells may be the “winner”. Furthermore, other studies put forward the difficulties concerning large-scale hydrogen production, transport and storage. They also question the higher efficiency of fuel cells compared to other conventional technologies, when the losses in the complete chain of hydrogen production, transport and storage is taken into account.

After ups and downs along a more than one hundred years-old history, the future of fuel-cells is still hard to predict. In the first and second section of this paper we provide qualitative insights on the key uncertainties mentioned above and the competition between different types of fuel cells, while in the second section we develop a quantitative assessment of the future of fuel cells for a long-term horizon (2030) and in an inter-technology competition framework while using, the POLES model3, a world energy sector simulation model.

3 POLES is a simulation model of the world energy system in 38 countries/regions, with endogenous energy demand, supply and prices, up to 2030. The model has been