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Approaching the fuel cell technologies from an industrial perspective

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Outline

- Context of this research
- Fuel cell technologies and applications
- Research questions
- Theoretical framework to analyse technological diffusion
- Methodology to capture industrial expectations
- Results
- Conclusion and perspectives

Context of Fuel Cell technologies development

Fuel Cell technologies

- belong to new technologies of energy
- participate to the emergence of a discarbonated economy in order to address sustainable transition

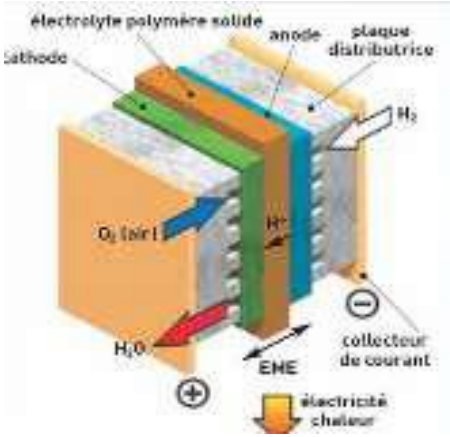
Context of Fuel Cell technologies development

The major challenge of sustainable transition and new energy technologies development :

- climate change and global warming induced by the growing emissions of greenhouse gases (especially CO2)
- lake of energetic efficiency
- high fuel prices due to the fossil resources rarefaction
- security of energy supply
- deterioration of local air quality due to towns congestion ...

Fuel Cell technologies : brief presentation

- A fuel cell is a device that produces power from electrochemical reaction
- FC needs a continuous supply of fuel
- In most design, hydrogen is used as a fuel (but it is also possible to use, methanol or natural gas)
- The hydrogen fuel cells convert hydrogen gas to electricity without emission (except water and heat)



More information :
http://www1.eere.energy.gov/hydrogenandfuelcells/fuelcell_animation.html

Fuel Cell technologies : brief presentation

- Fuel cell is not a new technology
  - Scientific principles are discover in 1839 by Sir William Grove
  - First applications : Gemini and Apollo Mission in 50-70
- Different types of fuel cells - depending on the nature of the electrolyte used : AFC, PAFC, PEMFC, MCFC, SOFC
  - Different knowledge base
  - Different materials
  - Operating temperature (high / low)
- Each types of FC is connected to specific applications : stationary , portable or transportation

Fuel Cell applications : brief presentation

MOBILITY - TRANSPORTATION

Produce electricity for Electric Vehicles

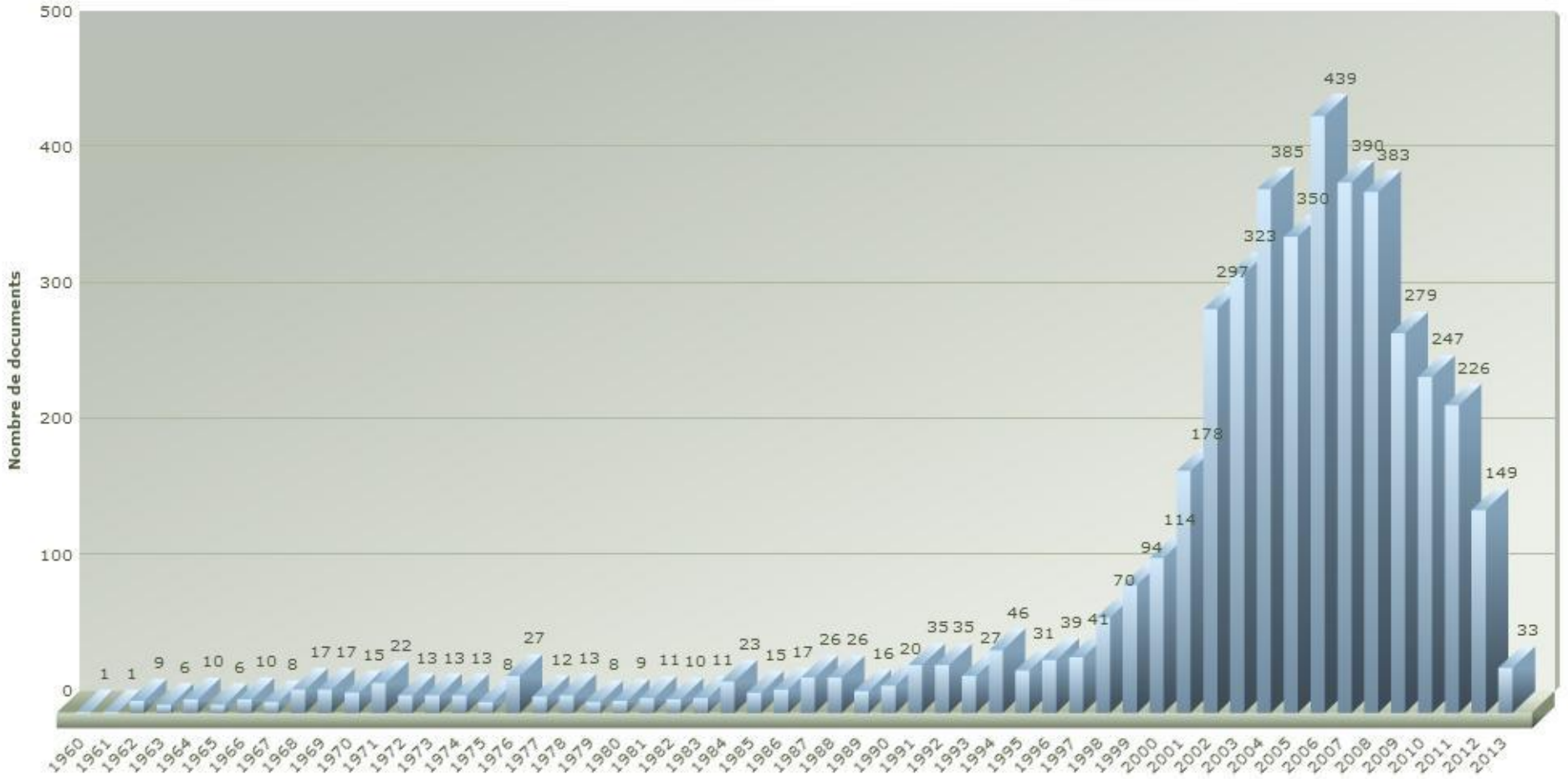
STATIONARY

Provide power to build

PORTABLE

Factual worldwide evidences

- Fuel Cells granted patents: a growing trend from 2002 to 2008



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Research questions

- Do expectations of the industrial actors constitute a barrier to the diffusion of fuel cell technologies ?
  - How to analyse the diffusion of a (new) technology ?
  - How to characterize and to capture the industrial actor expectations ?

Analytical framework

- The emergence and diffusion of a new technology is a complex process describes by the *Innovation Studies* and *Transitions Studies*
- These both traditions share globally the same vision of innovation
  - Innovation does not take place in isolation : interactions between actors (firms, universities, research institutes, intermediaries, customers,…) are central.
  - Innovation is a complex process matching technical possibilities to market opportunities, involving interactions between different actors : actors cocreate products, technologies but also the institutional framework.
  - Institutions (e.g. regulation, law, culture, habits, values…) are also crucial to regulate economic behaviours and interactions by reducing uncertainty.
  - Innovation is an evolutionary process generating variety and selection, confronting to lock-in and path-dependency.

Analytical framework : Innovation Studies

- According to the *Innovation Studies*, diffusion is a step in the innovation process dealing with
  - The direction and speed of adaption of a technology toward the market
  - The actors capacity to address barriers
- Standard models : the diffusion is linked to information spread (Mansfied 1968, Geroski 2000)
- Technological competition : analysing the switch to low carbon technologies from fossil-based technologies (Collantes 2007, Kim and Moon 2008, Struben and Sterman 2008, Mau et al. 2008)
- But : « *How does societies and institutional structure change and which social and institutional changes are necessary for a radical shift to sustainable transport systems* » (Köhler et al. 2009)

Analytical framework : Transitions Studies

- According to the *Transitions Studies*, diffusion of new technologies refers to structural changes
  - In the **socio technical systems** approach (Kemps and Ripp 1998, Schot and Ripp 1997, Geels 2002, Berkhout 2002) the new sociotechnical regime results from a co-evolution between technological capacities, knowledge and societal trends (Grin et al. 2010)
  - In the **innovation systems** approach (Elzen et al. 2004), innovation systems are the heart of sociotechnical transitions ; they induce changes in industries, firms, knowledge and also in uses, expectations and meaning.
  - The **sociology of expectations** (Borup et al. 2006) focus on the collective expectations as a way to reduce informational incertainty and to oriente the decision process (Van Lente 1993, Van Lente and Rip 1998, Bakker et al. 2011, 2012, Konrad et al. 2012)

From expectations to satisfaction value

- According to Bakker and Van Lente « *expectations are of great importance for the development of technologies as the stimulate, steer and coordinate actions of actors* »
- Our hypothese is to consider that the industrial actor **expectations** are linked to the business value attached to the hydrogen-fuel cell system
- This **business value** is composed by 4 dimensions (Cohn)
  - Financial value (ROI)
  - Economic value (costs)
  - Risk value
  - Satisfaction value
- In the hydrogen-fuel cell area if the three first values are well documented it is not the case for the last one : the **satisfaction value**

A methodological proposal to capture satisfaction value: Kano approach

- To identify industrial actors regarding hydrogen-ful cell technologies we propose to use the Kano approach
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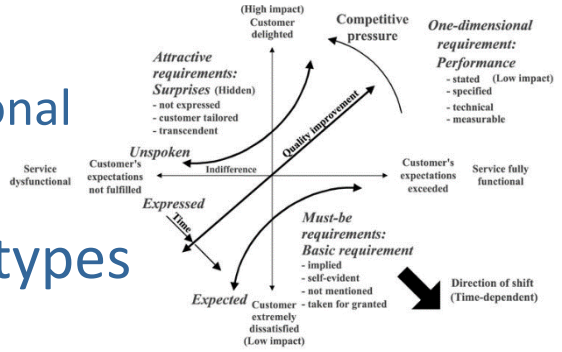
A methodological proposal to capture satisfaction value: Kano approach

- Satisfaction value depends on
  - The characteristics, attributes, functionalities, performance of products or services used,
  - The perception of users of the ability of a product or service to address their needs, to meet their requirements
- Lack of symmetry between customer satisfaction and non satisfaction
  - A specific characteristic of a product can bring much satisfaction as the lack of this characteristic will not generate a proportional dissatisfaction

    => specific survey with functional and disfunctional questions
- Expectations could be classify in three main types
  - Must-be / Expected / Attractive



Source: Kano *et al.* (1984), *ASI Quality Systems* (1992), Mazur (1993), Rolstadas (1995),Wakhlu (1994), Matzler and Hinterhuber (1998), Cohen (1995)

Application to the french firms imply in hydrogen-fuel cell technologies

- Functional and disfunctional survey around 10 Hy-FC technologies
  - Increasing the life time of fuel cell
  - Power efficiency of fuel cell
  - Power efficiency of fuel cell system (FC + auxiliary)
  - Integrating the maintenance in the design
  - Identifying the performance degradations
  - Identifying the failures origin
  - Knowing the remaining life of the fuel cell main components
  - Reducing the mass of the fuel cell system
  - Reducing the volum of the fuel cell system
  - Faciliting the dismantling of the fuel cell system

Survey
(10 answers)

If this attribute <u>is achieved</u> by the fuel cell technology, what is your opinion

Attributes (10) of fuel cell	C'est normal	Je m'en contente	Cela me plaît	Ca m'est égal	Cela me déplaît	Non applicable pour mon entreprise	Commentaires
Des stack PàC ayant une durée de vie de 5 000 h pour le transport (véhicule particulier) et 20 000 h (stationnaires) (source Dpt of Energy - US)							
Amélioration du rendement énergétique de la PàC (stack) de 10% (définition du rendement énergétique comme la puissance électrique produite / puissance fournie par le combustible à savoir Hy dans la majorité des cas)							
Amélioration du rendement énergétique des systèmes PàC de 10% (définition du rendement énergétique comme puissance électrique produite / puissance fournie par le combustible à savoir de l'Hy dans la majorité des cas ou du gaz naturel							
Prise en compte des actions de maintenance dans la conception du système PàC (notamment si vous êtes fournisseur de PAC)							
Identification des dégradations, pertes ou instabilités de performances/ (=cessation de l'aptitude du système à remplir une fonction) des stacks PàC (notamment si vous êtes intégrateur)							
Identification des causes des (modes de) défaillances au niveau du système PàC							
Identification de la durée de vie restante des composants les plus sensibles/importants (à partir de quand le système ne remplit plus sa fonction de façon satisfaisante)							
Réduction de la masse du système PàC de 20% - hors stockage							
Réduction de l'encombrement du système PàC							
Facilitation du démentèlement des systèmes PàC, notamment en vue de leur recyclage (dépend du niveau)							

If this attribute <u>is not achieved</u> by the fuel cell technology, what is your opinion

Attributes (10) of fuel cell	C'est normal	Je m'en contente	Cela me plaît	Ca m'est égal	Cela me déplaît	Non applicable pour mon entreprise	Commentaires
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Facilitation du démentèlement des systèmes PàC, notamment en vue de leur recyclage							

Results

- No must-be (obligatory) attributes probably due to the youngness of the technology and the emerging nature of the market
- 5 expected or normal attributes which concerns the improvement of power efficiency, the improvement of technical characteristics (mass, volum, life time, maintenance) ;
- 1 attribute is indifferent : dismantling for recycling
- 2 attributes are attractive : failures origin and life cycle management ; these attribute are linked to the health management of the fuel cell and their achievement will generate high value satisfaction for the client.

Conclusion and perspectives

- Focus on optimization of traditional characteristics (efficiency, mass, volum)
- Don’t really take into account sustainable transition paradigm (recycling, health management)
- Finally, a new technology of energy without a sustainable business model ?

- To answer to this question we have studied two different actors of fuel cell field: the researchers and the industrial actors (firms), and today we want to speak more specifically about industrial actors and their vision of this technology. Our results open the debate on two main issues about the conditions of new technology diffusion, needing to change the researcher representations: firstly, transforming the debate of social acceptability of technologies by moving from a functionalist vision of technology to a systemic vision and secondly considering globally the process of value creation in a more open and sustainable business model.
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Thank you for your attention and questions

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