A System Dynamic Approach to Model the Innovation Process of Fuel Cell Powered Cars in Germany

DIMETIC
Maastricht

Bjoern Bertram
Agenda of This Presentation

- Introduction of...
  - fuel cells
  - the theoretical background
  - an existing model
- Approach to design the model and first results:
  - actors of the invention phase
  - actors of the innovation phase
  - cooperation among them
- Summary & outlook
The Fuel Cell - An Old System with Different Applications? An All-Rounder?

Yes! → The inversion of electrolysis: Oxygen and hydrogen create electricity by an electrochemical process first mentioned by Groove 1839
Different types of fuel cells: PEM, DMFC, SOFC, ...

Yes! → Different areas of applications:
- Portable (notebooks, cellular phones)
- Stationary (decentralised generation of electricity and heating)
- Mobile (cars, buses, planes)

FOCUS of my research: PEM fuel cell for mobile application

Fuel cell as an answer to current and future challenges:
- Economic (cross-sectional technology, automotive industry, limited range of fossil fuel will lead to dramatically increasing prices, ...)
- Ecological (local pollution, global warming,...)
- Political (peaceful accessibility, dependency must be minimized)
- Ethical (are we allowed to use all the fossil energy?)

Two reasons for research activities in the research field of fuel cells
- Challenges should be motivation enough
- Fuel cell market is still a young market (Still before the first boom in the technology cycle)
The Theoretical Background

A simple innovation process in three phases:
- Invention – Innovation – Diffusion
- Cannot be separated accurately
- Backward loops (incremental innovation)
- Influence of technology policy

Evolutionary Economics according to Darwinian process:
- Main part is the individual (organisation, private person) with routines (processes)
- Changing routines over time to achieve goals (e.g. maximize turnover) based on knowledge and experience; The change in the routines leads to mutation
- Ineffective routines are displaced (=selection)
- Idea: Merge this approach with the simple innovation process (see above)

Variety of Innovation System (IS): national, regional, sectoral or technological
- Focus: Technological Innovation System (TIS): PEM fuel cell
- Each system consists of:
  - components (actors of different organisation types)
  - relationships among them (cooperation)
  - institutions (surrounding conditions like infrastructure, political systems)
Aim of this Thesis is a System Dynamic Model Simulating the Innovation Process. Basis of this Model will be a Work of Milling (1996): “Invention, Innovation und Diffusion”

Basic structure of the model:
- Market (Diffusion)
- One type of organisation (Invention, Innovation)
- Exogenous Sector (Tech. Policy)
→ Strong interaction of those parts (interdependencies)

This model structure act as a general approach and need to be adopted to the research field of PEM Fuel Cells. The merger of the theory and this model will help to depict a detailed picture of the model structure.

The invention and innovation phase need to be modelled more sophisticated. It cannot be done by only one type of organisation.

For this young and science based market the exogenous sector, especially the technology policy, plays an important role.

The innovation process cannot be treated isolated. Which role do foreign organisation or lead markets play?
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The Innovation Process Forms the Theoretical Framework. The Approach of Innovation System Provides the Methodology and Therefore the Empiricism.
The Results of the Bibliometric Analysis Show That Germany is Following the International Trend

Bibliometric Analysis:
- ISI Web of Science
- Date of query: February 2008

Search Strategy:
- Keywords in abstract and title
- All document types: but nearly 100% articles
- All years: 1945 – 2008
- All languages: but nearly 99% in English

With the help of this data it is possible to identify the actors and classify them.

Problem occurs with names.

Results are not surprising in the invention phase.
The Results of the Patent Analysis Show That Germany Follows the International Increasing Trend

Patent Analysis:
- Patstat 10/2007

Search Strategy:
- Complete classes
- Combination of classes and Keywords
- “Meta-Office” (WIPO, EPO)
- Country assignment: applicant, not inventor

The change in the trend in 2003 is an external economic effect. This change is not technology driven.

Again, there is a problem with data inconsistency:
- Name & country problems

High contribution of “Others”: professors or employees (co-applicants)
The Results of the Invention and the Innovation Phase Determine the Structure of the Model. Different Types of Organisation are Involved in the Process.

Innovation process

Evolutionary Process

Mutation

Selection

Organisation

Universities 29%
Firms 23%
Research Institutes 48%

Organisation

Others 21%
Firms 68%
Research Institutes 11%

Market

Diffusion model (Bass 1969)

Exogenous Sector

Technological Innovation System PEM

Research Players

Industry Players

Institutions

Akers and cooperation
Cooperation is an Important Element of a Technological Innovation System. The Analysis Shows how the Different Organisation Types in Germany Cooperate:

Definition of Cooperation:
- Invention: two or more authors on a publication
- Innovation: more than one applicant on a filling ("co-applicants"). This can be so-called "core cooperation" because not any cooperation is revealed

Invention Phase:

- University: 14%
- Firm: 27%
- Research Institute: 58%

Innovation Phase:

- University: 0%
- Firm: 0%
- Research Institute: 70%
- Other: 69%

→ Those cooperation patterns determine the cooperation structure of the model
The Analysis of Cooperation Can be Used to Show the Role of Foreign Actors

The social network analysis is done with the software “Pajek”

Size of vertices: patent/publication activity
Size of ties: cooperation activity

Invention Phase:

Innovation Phase:

There are international knowledge flows in both phases

The model must be open for countries abroad

Germany plays an important role in the two phases. That shows the betweenness centrality. The actors are aggregated on country level
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Fuel cell is an answer to current and upcoming challenges

The theoretical background in combination with the existing model of Milling lead the way to the model structure. The innovation process sets the theoretical framework and the TIS provides the empirical input (structure of actors, cooperation)

Still unclear:
- Level of actor aggregation?
- Integration of alternative fuels (strong position of battery-powered cars)

Next steps:
- Working on institutions in the TIS –> survey among actors
- Start modelling

Research objectives:
- Evaluation of business strategies and their resulting future prospects of the involved organisations
- Evaluation of technology policy with the help of different scenarios
- Management and policy recommendations
Thank You For Your Attention!

When?
### Annex 1

#### Different Network Characteristics of the Invention Phase

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Annex 2

The Betweenness Centrality in The Invention Phase Represented by The Size of The Vertices
## Different Network Characteristics of the Innovation Phase

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Annex 4

The Betweenness Centrality in the Innovation Phase Represented by the Size of the Vertices
Technology Cycle of the PEM Fuel Cell Technology. We Are Still Before the First Boom, Waiting for the Science Push

Annex 5

Number of PEM patent application (Meta-Office)
Number of PEM publications (ISI Web of Science)