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Fuel Cells & Hydrogen – Research Needs in Times of Technology Roll-Out

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Hydrogen production
- from renewables, green hydrogen
- high efficiency electrolysis
- synthetic fuels

PEFC development
- reduction of platinum loading (e.g. using nano particles, µ-organisms etc.)
- increase in operating temperature (IT-PEFC)
- optimisation of components (BiP coatings, GDL, etc.)

FC integration
- LDV/HDV, off-road vehicles
- marine & rail
- aircraft, UAV

SOFC development:
- planar and microtubes
- fuel impurity tolerance
- improved internal reforming of HC
- reducing degradation & improving lifetime

Socio-economic studies
- understanding FC market uptake
- environmental impact assessment
- nano-particle health impact

Centre of Fuel Cell & Hydrogen Research and Centre of Doctoral Training (CDT)

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35 PhD students, 5 post-docs, 5 staff

Starting Oct 2021: blended learning (online) MSc programme in Fuel Cells and Hydrogen Technologies

TeacHy

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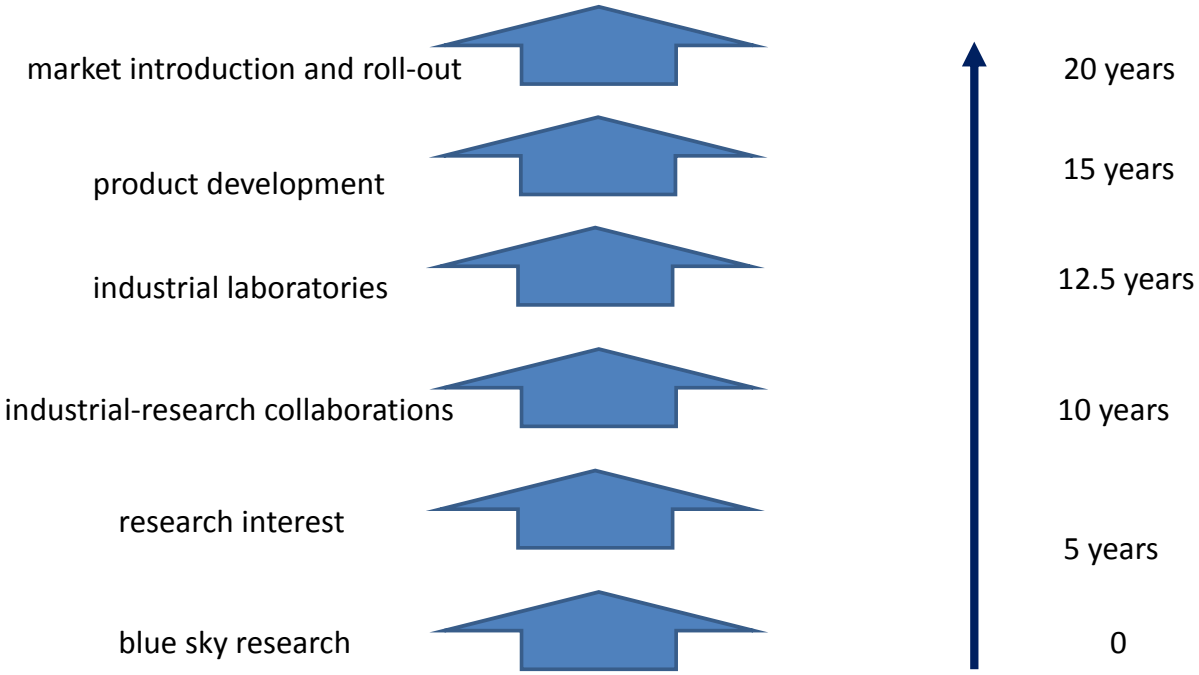
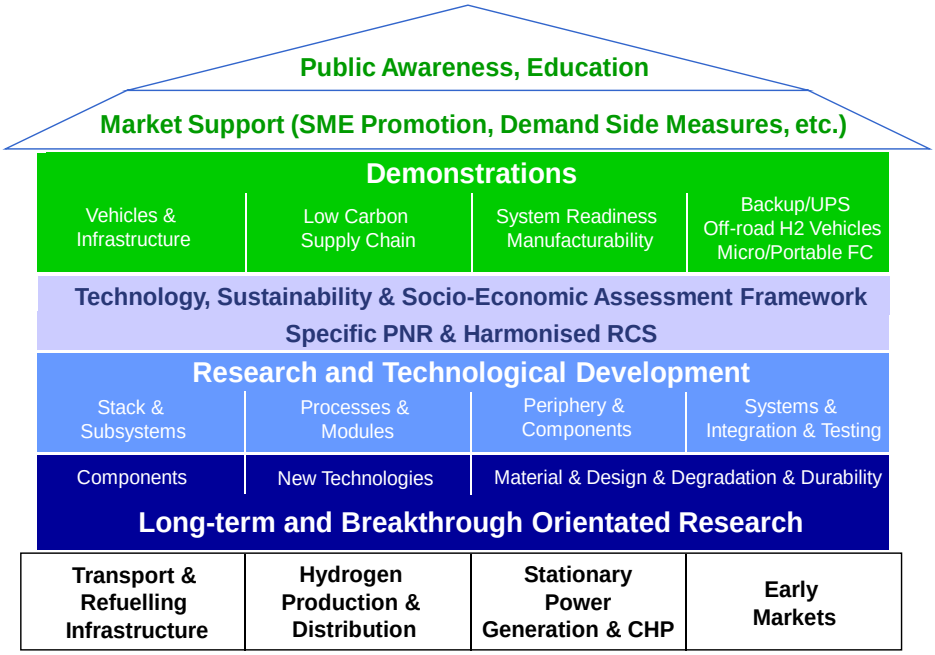
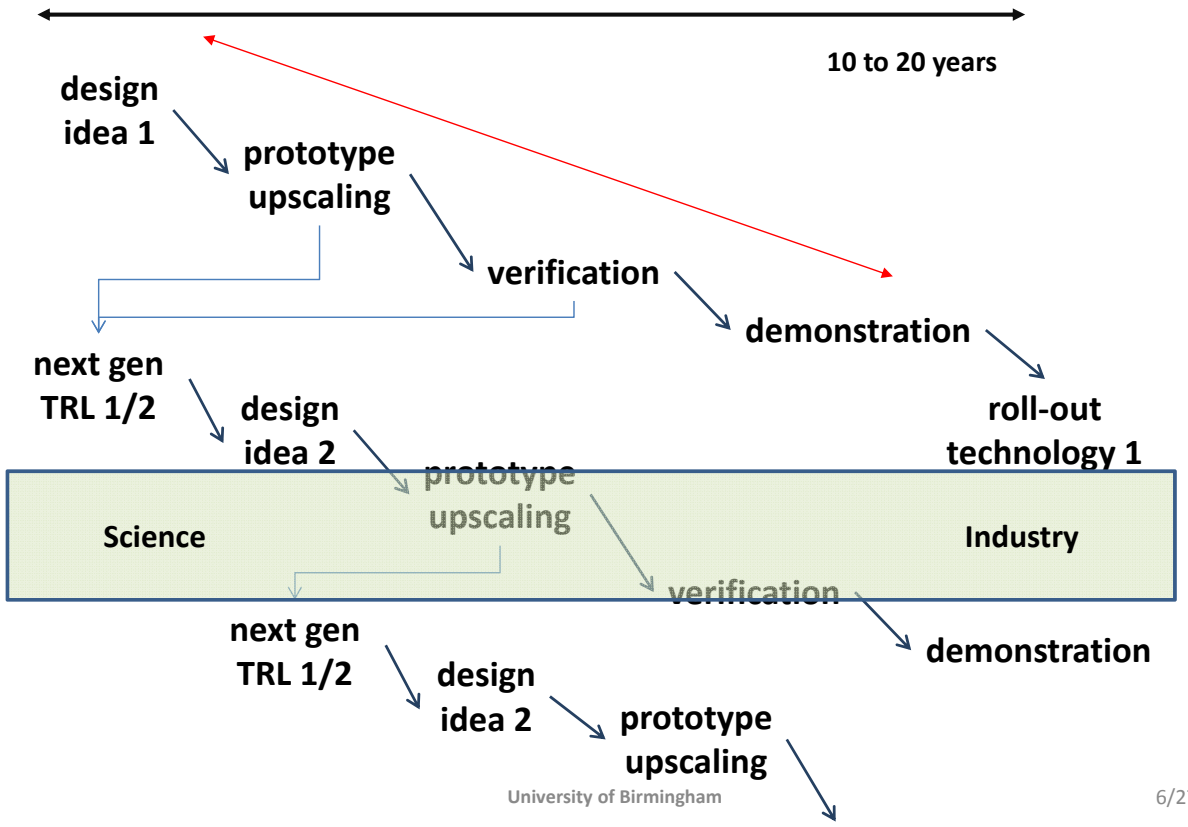
Introducing New Technologies



FP 7 EU-Approach FCH JU



Technology Development Phasing



EU Technology Development Ladder

TRL 9 – large demo trucks 20 MW ELY

TRL 8 - demo ships

TRL 7 field test remote pwr

TRL 6 prototype verification biogas SOFC

TRL 5 full prototype aerial FC

TRL 4 lab validation NxtGen autom MEA

TRL 3 experimental GameCh autom stack

TRL 1/2 principles solar thermolysis

MRL 8 – supply chain

MRL x – cost reduction

MRL 5 – manufacturing

MRL 4 – manufacturability

PNR: road tunnels
X-Cut: admixing, ALT, schools

PURECELL® FUEL CELL SYSTEM

Flexible fuel cell application and varied experience

Assured Power

First National Bank of Omaha
Nebraska

On-Line Emergency Power

Verizon Communications
New York

Green CHP Power

Whole Foods Market
Connecticut

Renewable Fuel (ADG)

Wastewater treatment plants
New York, New York

Indoor CHP Power

Mohegan Sun Resort & Casino
Connecticut

Off-Grid Power

Central Park Police Station
New York

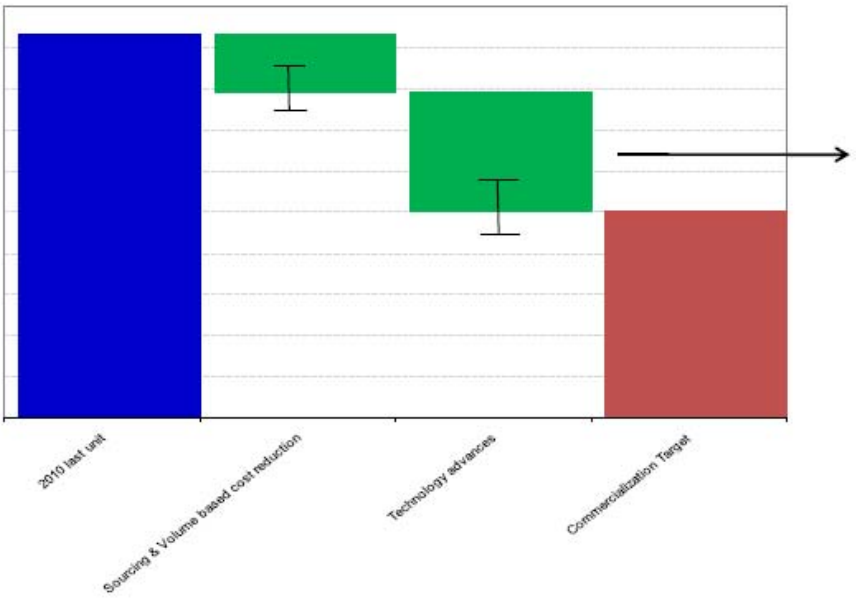
UTC Power
A United Technologies Company

source: UTC 2009

PURECELL® FUEL CELL SYSTEM

Powerplant cost

Cost reduction



- Alternate electrolyte
- Active catalyst
- Low cost manufacturing
- Low cost HEXs
- Non NH_3 producing FPS

Significant technology advances are required to meet commercialization targets

UTC Power
A United Technologies Company

source: UTC 2009

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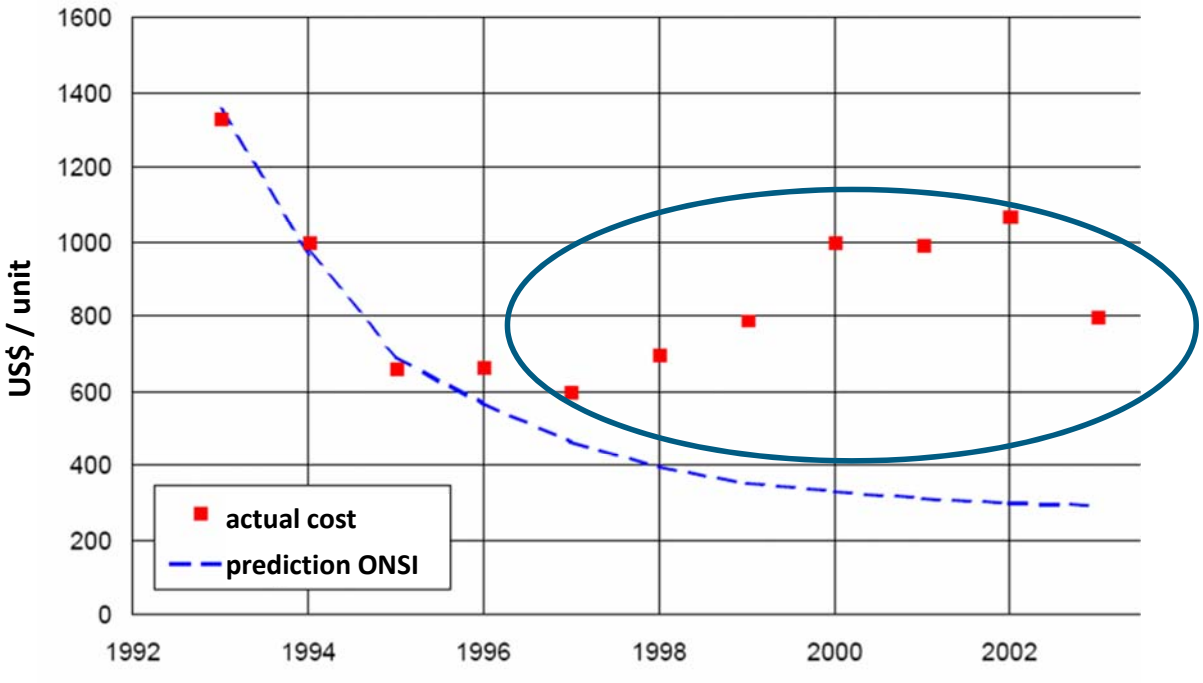
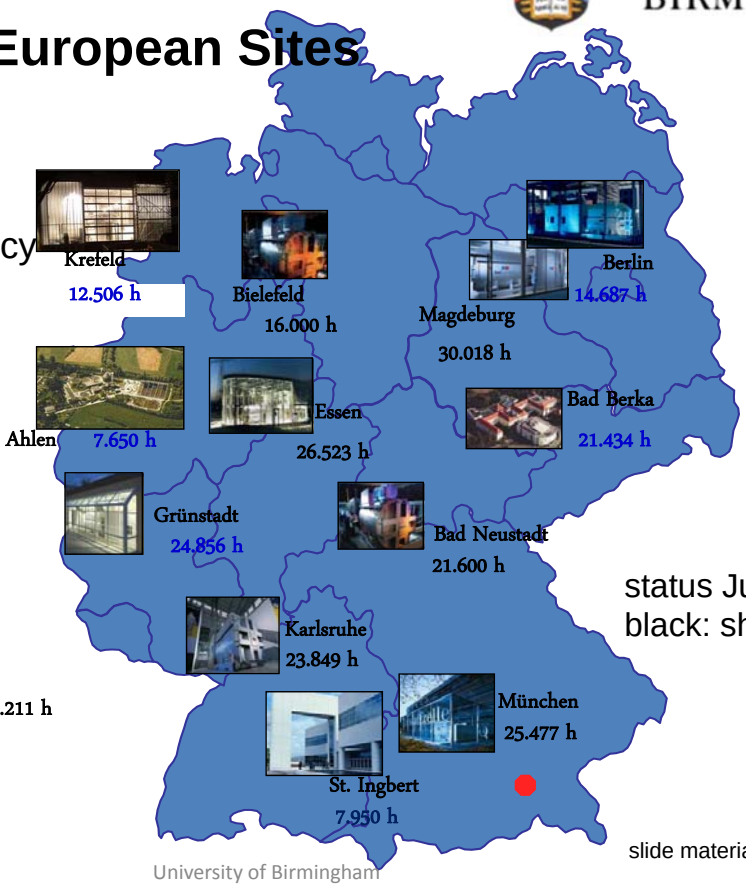
Cost development PAFC Purecell



source: Pehnt

HotModule European Sites

- total number 14
- electrical efficiency 47%
- accumulated operating time > 170.000 h



Cartagena/Spain

24.211 h

status June 2006
black: shut down

slide material courtesy MTU

CUTE Project Sites – incl. Iceland & Australia

Perth, Australia

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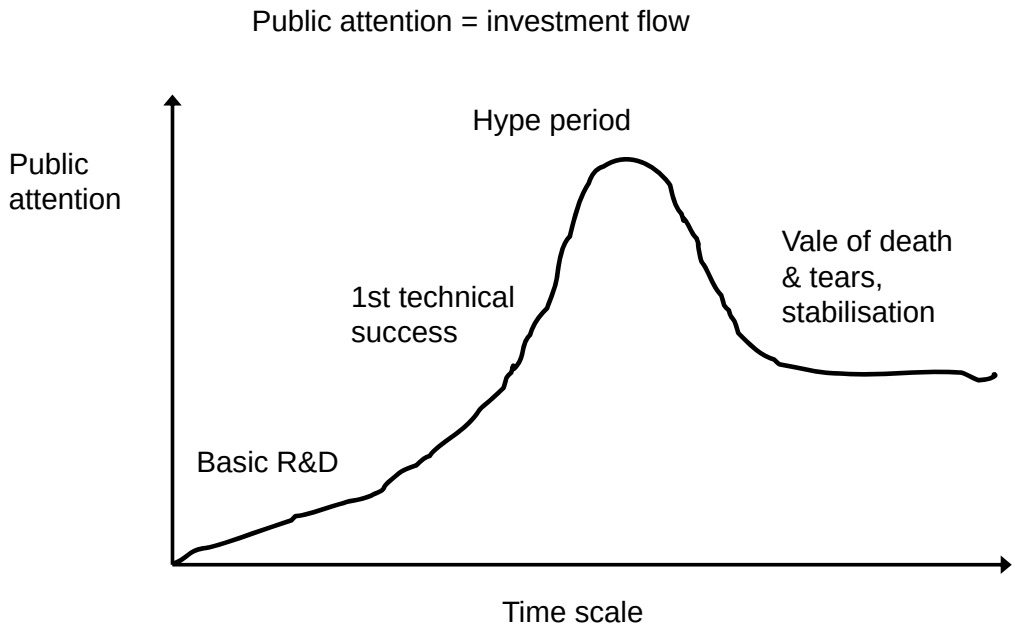
Hype-Cycles



According to Ph.Doran

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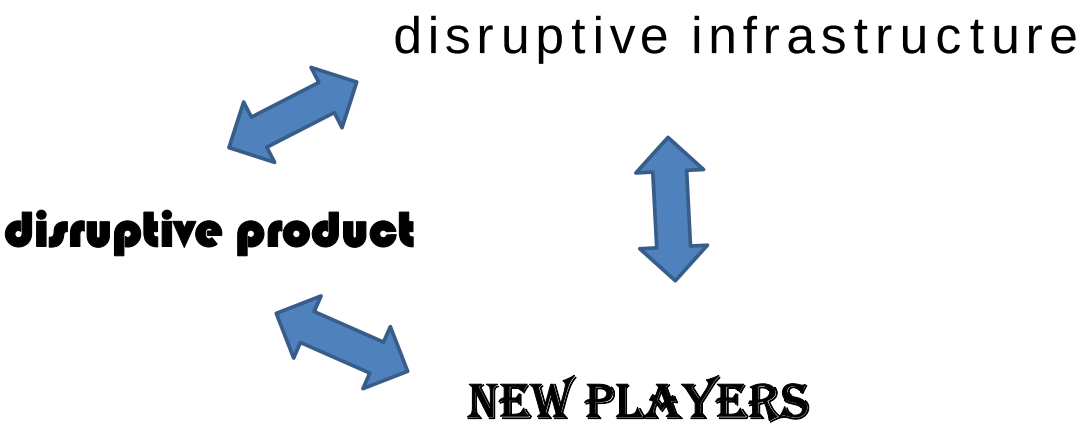
Disruptive Technology



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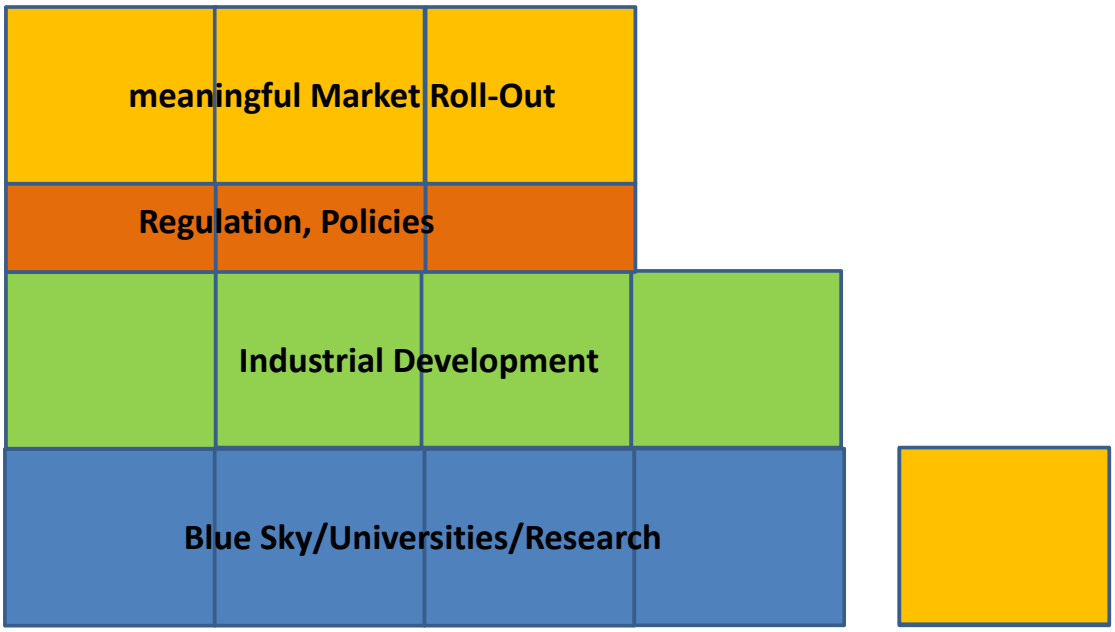
The Lemmings Principle



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What Happens When Industry Roll-Out and Science Get Disconnected?

- lack of supporting university creativity
- decrease in publications → less interest in the scientific community, no awareness of issues
- divergence in research topics
- no kick-off in development of next and next-but-one generations of technology
- subsequent lack of serendipity, and SME and supplier-base input

→ industry needs to support a certain level of 'free research' and demo/field test projects need to publicise results

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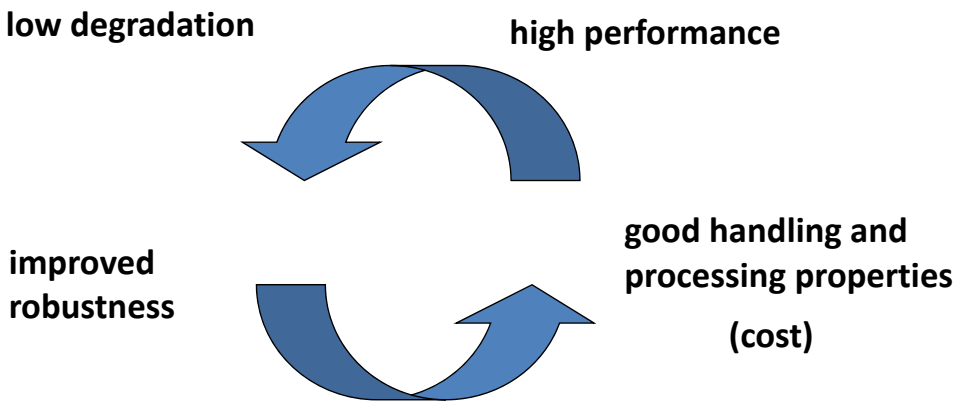
Consolation of Conflicting Properties



for instance:
redox stable materials (SrTi, LSMC),
with low conductivity and brittle structure

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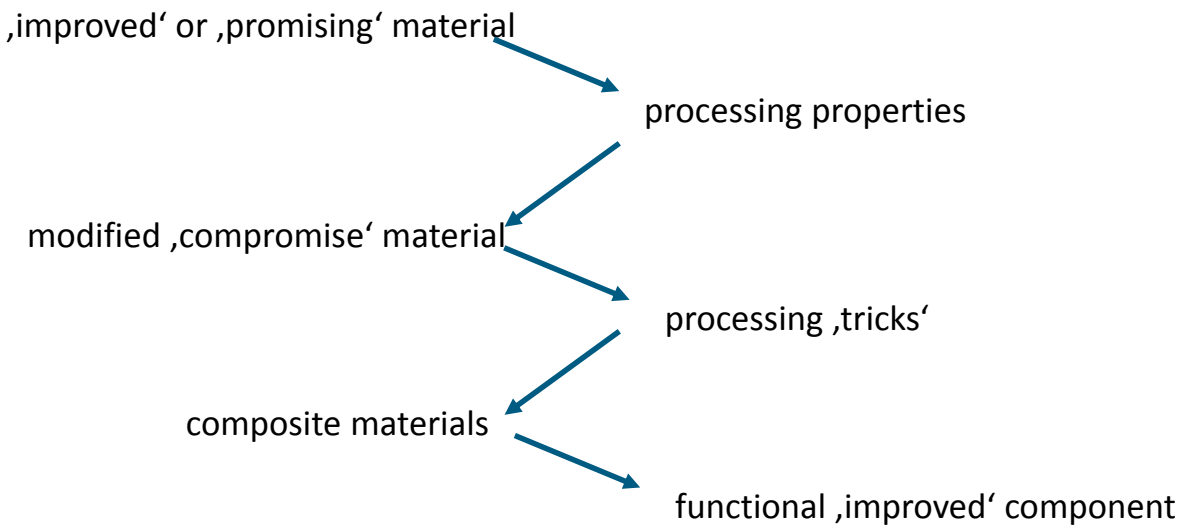
Interaction of Materials Developers and Manufacturers



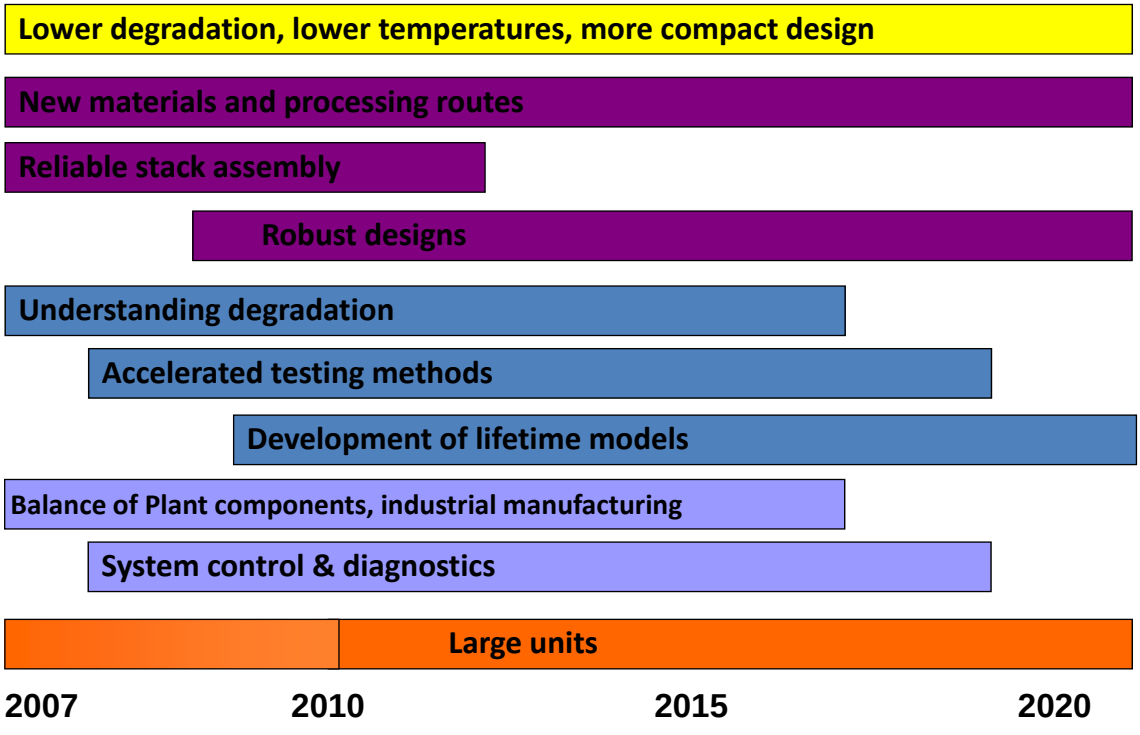
building a bridge from materials research to component manufacturing

Development Aim: Increased Stack Lifetime

- **long-term stable** electrode materials
  * thermodynamically stable, or slow stabilisation kinetics, slow de-mixing and volatisation
  * low tendency to particle agglomeration
  * high inner surface and porosity
  * high electrical and ionic conductivity
  * low/no reactivity with other stack materials
- **long-term stable** electrolytes
- **long-term stable** interconnect materials
- protective **coatings** for steels
- **methodologies**: accelerated testing
- **operational strategies:** keeping the system happy

materials development topics

Future Focus of European SOFC Development



R&D Development Goals

- **Materials**
  - currently **best performing** materials have already been known for many years (no surprises)
  - optimisation with respect to processing and **cost** necessary
  - **Lifetime** is still insufficient (but: trade-off with cost)
  - **breakthroughs** are nevertheless necessary (new materials integrated with processing and manufacturing)

- **RTD challenges**
  - **purpose-designed** materials incl. *ab-initio* understanding
  - **low-cost**, standardised, mass-production oriented manufacturing
  - extended **lifetime** of components, **robustness**
  - sufficient testing capacity for reliably & rapidly predicting materials performance (**optimisation loops**!)

What Happens When Industry Roll-Out and Regulatory and Economic Framework Disconnect?

- ‘surprise’ at high cost of hydrogen
- lack of level playing field destroys immediate economic prospects
- lack of immediate customers due to high initial cost destroy interest of management
- lack of follow-up investments due to lack of credible business cases

→ level playing field approach to energy cost and environmental costing is a requirement for market roll-out

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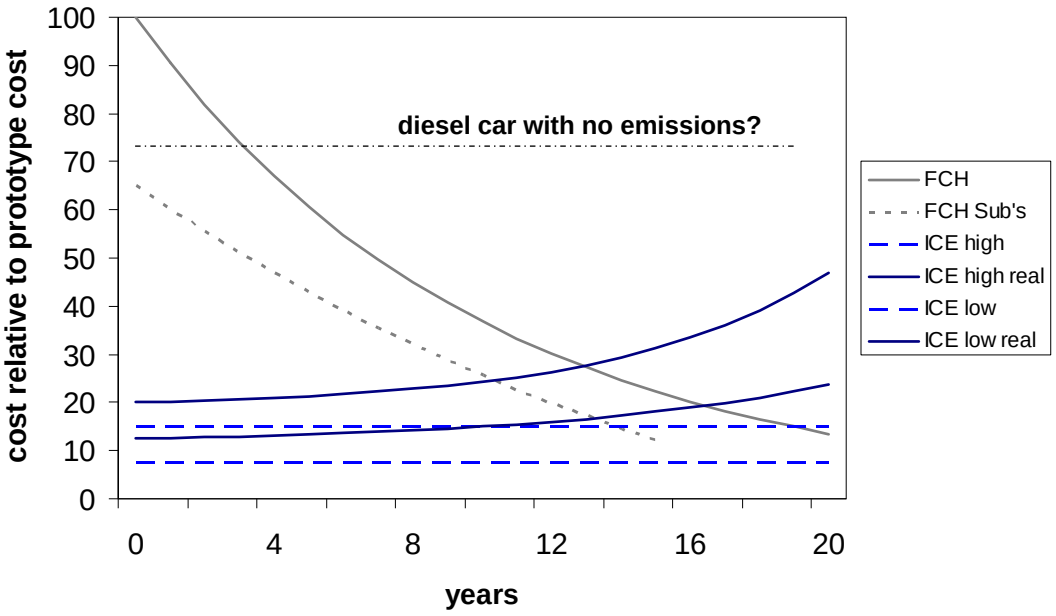
Cost Projections – Moving Targets



free market vs. regulatory vs. subsidy approach

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Dominance of 'Large Scale' Projects

- there is a continued confusion about 'field tests' (necessary to prove technology) and 'demo' (public demonstration – but often used as a replacement market introduction tool)
- demo projects have been used to 'spark off' developments – certainly rather successfully although projects are often 'one of a kind' (novelty-based)
- result 1: only first runners are funded by and large, predominately large OEMs
- result 2: all the large bus demos since 1999 were based on one OEM who still does not have a commercial product; second runners have now taken over through the repeated demo projects -> can this be justified?

Learn to Walk Before You Run

- stop the large scale demos – this is the task for dedicated market introduction tools
- create scope for ‘repetition’ projects/topics to get on board more, different and smaller industry; esp. thinking of low TRL, ‘NextGen’, ‘Game Changer’ and ‘Disruptive’ projects
- more preparation for the market in the sense of ‘market readiness’ instead of only TRL (building supply chains and reducing costs); introduce MRL KPI’s
- more alignment with e-mobility and renewable energy/storage programmes (such as within NOW in Germany), also thinking of hybrid systems with batteries

Summary

Hydrogen (less so fuel cells) is a ‘hype’ topic currently.

In order to avoid disappointment

- product development needs to be sufficiently supported by (free) research,
- the regulatory framework needs to reflect the environmental benefits,
- sustainable business cases need to be clearly visible,
- public funds are required for market introduction support and supporting research, not for large scale ‘demonstration’ projects.

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Upcoming events:

Fuel Cell & Electrolyser Degradation Workshop, 5 May 2021, Webinar.

Fuel Cell Systems Workshop – 19/21 May 2021, Bruges, Belgium (?).

EFCF 2021 – Low Temperature Fuel Cells, Electrolysers, and Hydrogen Handling – **29 June to 2 July 2021**, Lucerne, Switzerland.

JESS 2021 – Joint European Summer School, **6 to 12 & 13 to 18 Sept 2021**, Athens.