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Views on future FC research

Why fuel cells?

- Energy security and climate change are the grand challenges of the millennium.
- FCs promise to have a significant role in the new energy mix, embracing transport and stationary power applications.
- Reversing their electric potential (i.e., electrolyser cells, EC) can be a game changer in renewable power storage.
- The maturity of FC/EC technologies is growing, which is manifested by the increasing numbers of FC products entering more and more niche markets (e.g., Toyota Mirai).
- However, there is still a need for cost reduction for the technology to become commercially viable.

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Why fuel cells?

- To achieve such reductions in cost and an increase in lifetime, a stronger bond needs to be established between the critical issues of design, materials, operating conditions and electrochemistry.
- These complex aspects are most effectively linked, analyzed and optimized through accurate simulations, mathematical modeling and virtual prototyping.
- Compared to the established automobile, aerospace and power industries, numerical simulations of FC/EC:s as power generating and storage devices have not reached the same degree of specialization.

Current status SOFC - IEA annex 32

- The efficiency and electrochemistry issues of SOFC are well known: the state-of-the-art SOFC show reasonable efficiencies and stable electrochemical performance.
- Lifetimes over 75,000 hours reached for stack in laboratory environment (FZ Jülich). [still running]
- Electrical efficiency over 60% (LHV) achieved for as small systems as 1.5 kW(el). [Example CFCL year 2015]
- Durability and cost still remain the major barriers to SOFC systems' commercialization. Complete understanding of all the physical phenomena inside the cell is still lacking. **Needs for experimental and modeling development.**

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Current status of FC research in Sweden

- A few relatively small research groups at LU, Chalmers, KTH, HV and others.
- The groups collaborate mostly with partners outside Sweden, due to lack of coordinated national funding.
- No cell/stack manufacturers, but industry active in niches.

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IEA Annex 37 - FC modeling

This annex aims at developing, maintaining, and applying a suite(s) of *open source* computational fluid dynamics (CFD) software for application to FCs, electrolyzers and other electrochemical applications (hydrogen storage, batteries, etc.) including validation and verification by comparison with other CFD codes, physical experiments and “benchmark problems”.

Fuel cell modeling today

- FC/EC stack operation is governed by several complex interlinked phenomena occurring contemporarily at multi-scale levels and in different regions of the system.
- Modeling and numerical simulations in parallel with carefully designed physical experiments are crucial in progressing the understanding and knowledge to enable improved FC/EC designs in terms of performance, lifetime, cost and safety.
- At this stage, the modeling approaches have gained progress in electrochemistry, chemistry and transport mechanisms, propagating high-performance simulation processes, in particular to develop design optimization tools based on complete physics.

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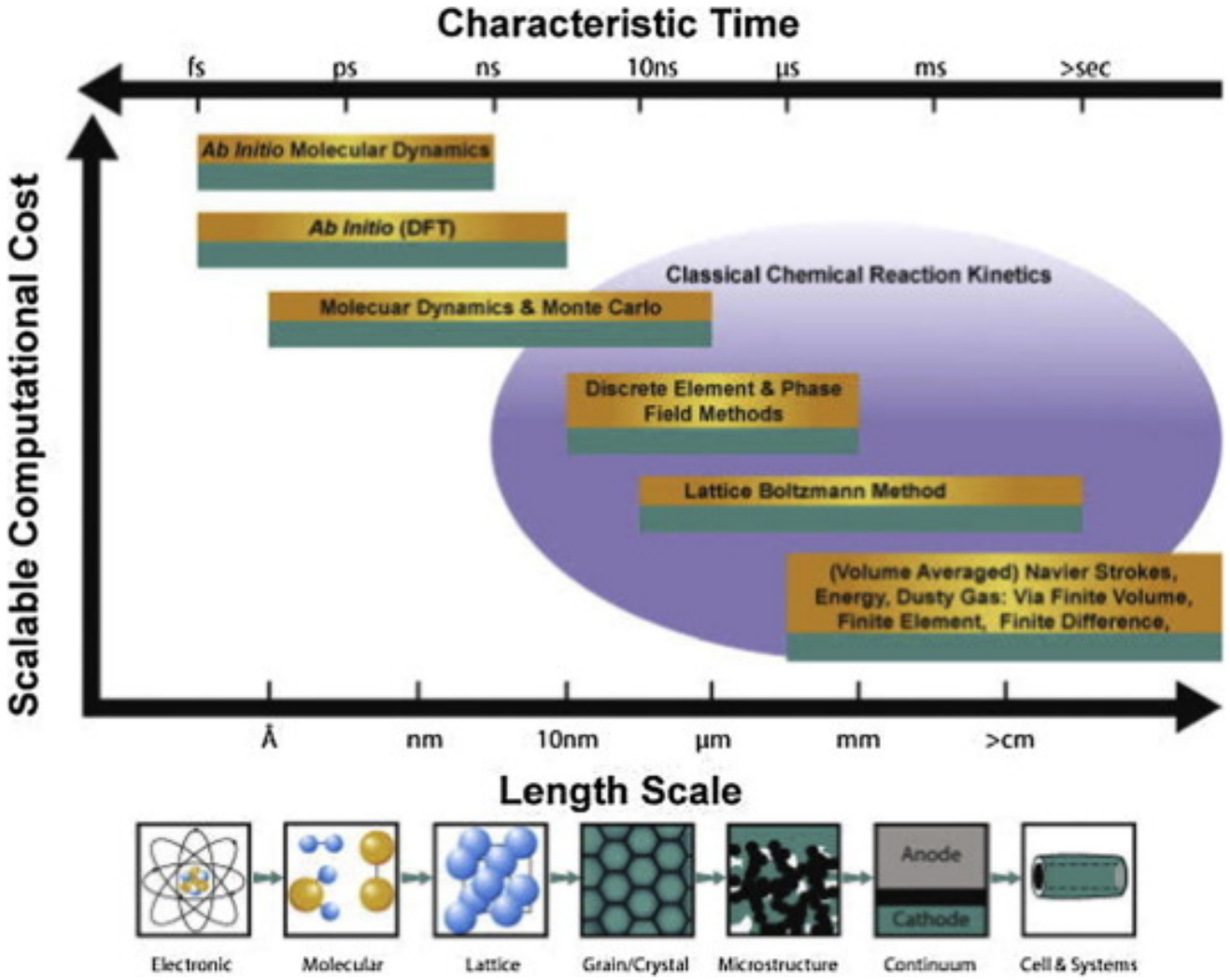
Multiscale and multiphysics modeling for SOFCs and PEFCs



Modeling and simulation methods for FCs.

Scalable cost is plotted versus the time and length scales to be resolved

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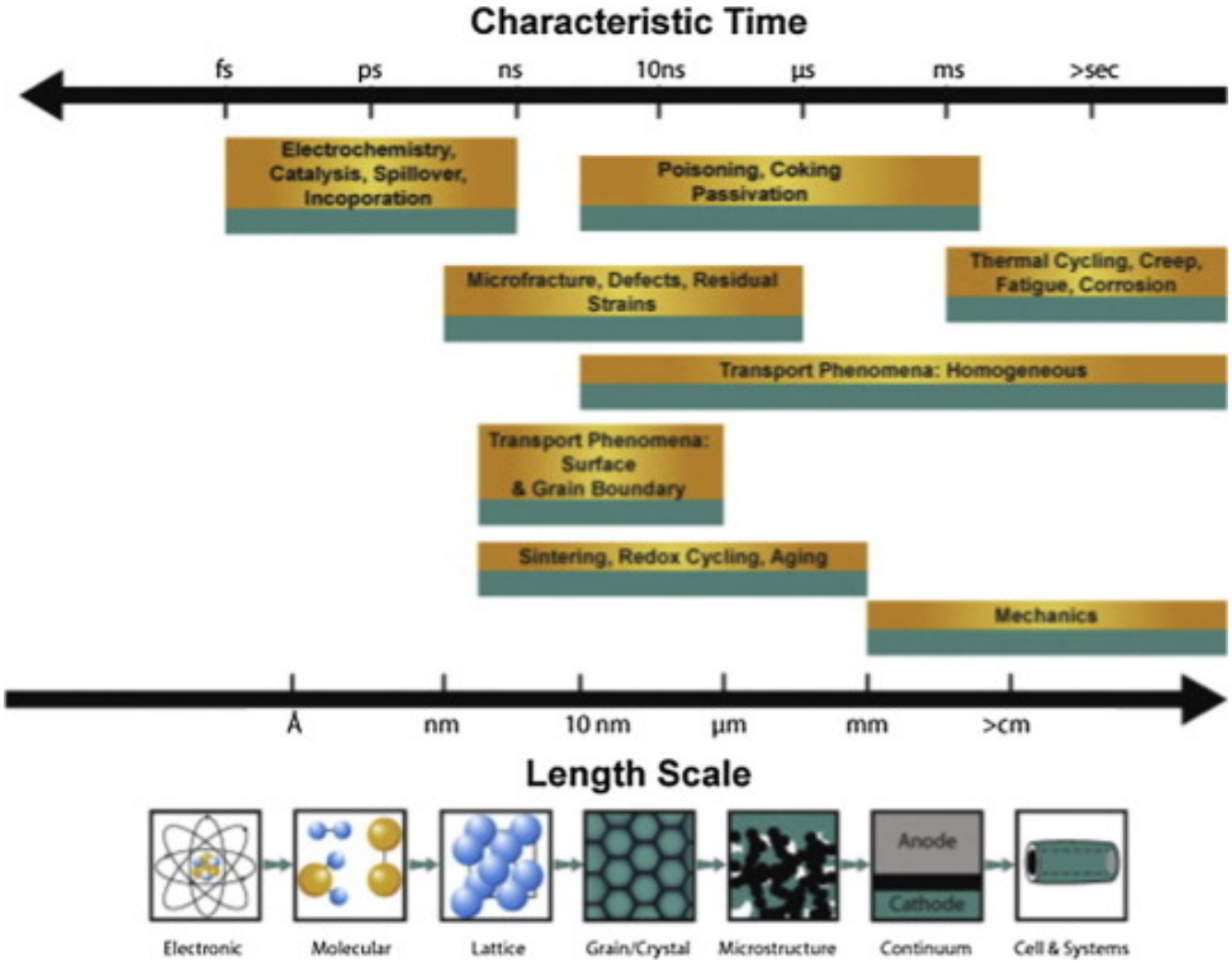
Multiscale and multiphysics modeling for SOFCs and PEFCs



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Overview of conceptual time and length scales for phenomena in FC structures

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Opportunities to couple modeling research to Swedish needs

- Modeling at system scale (FCs but also system integration), i.e., research and development at a higher TRL.
  Possible to include industrial PhD-students

- Investigation of the transport processes inside interconnects (similar TRL to current research)
  Possible to include industrial PhD-students

- Focus on key issues for industries

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Contribution from educational activities

- Provide well educated PhDs in the FC area
- New course in M. Sc. Engn. Program “Hydrogen, Batteries and Fuel Cells” starts spring 2017
- M.Sc. thesis studies abroad
- Training courses on Open Source modeling of FC – a target

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Swedish opportunities

- Collaboration between academy and industry may increase the probability for each research group and/or companies to participate in EU funded projects.

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Recommendations

- National funding is required for Swedish research groups to reach a critical mass that makes them relevant for EU funding
- Collaboration between the current research groups would be beneficial for the research progress in all groups
- Should focus on a few areas where Swedish groups could lead the development.
- Industrial PhD students improves the collaboration between academia and industry.

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