Direct Carbon Fuel Cell

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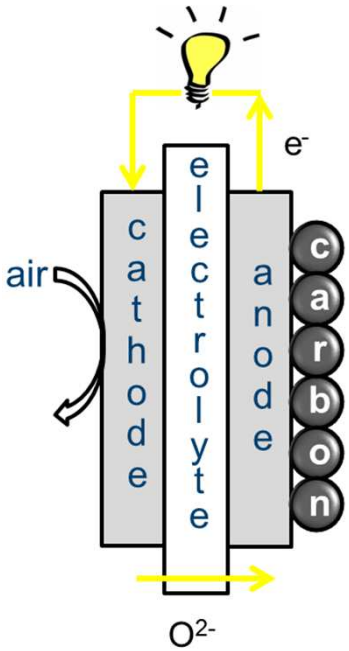
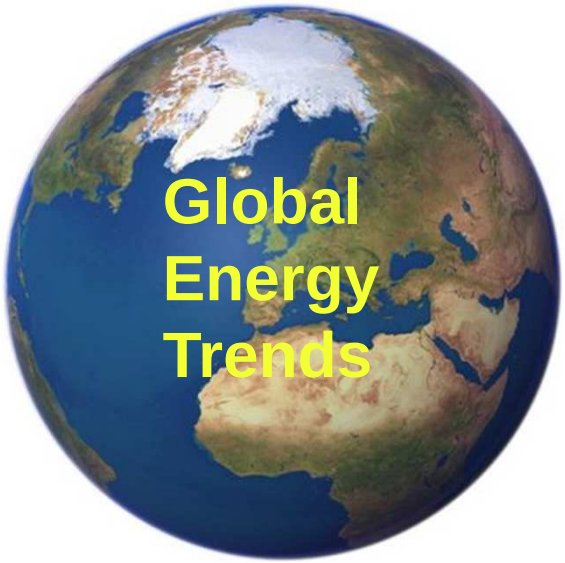


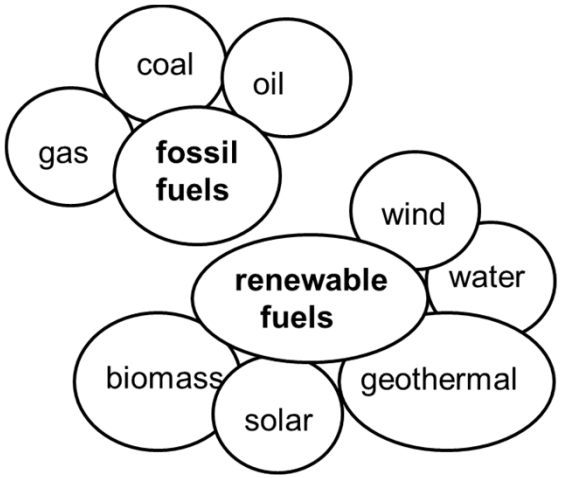
Motivation



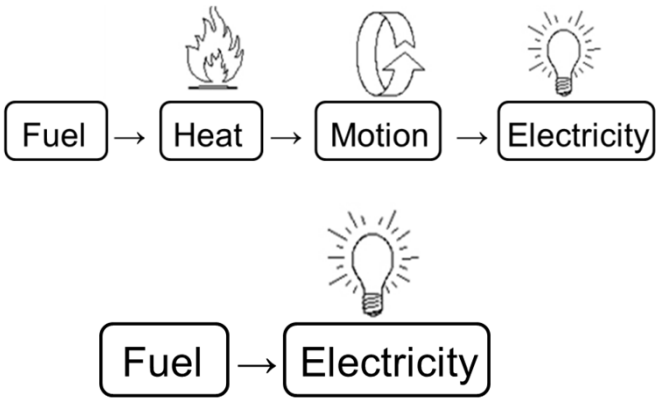
I. Increasing energy demand
II. Limited fossil resources
III. Climate/ CO_2

Energy challenges 2050

Energy Resources



Energy Conversion



Energy Efficiency

Energy saving light bulb

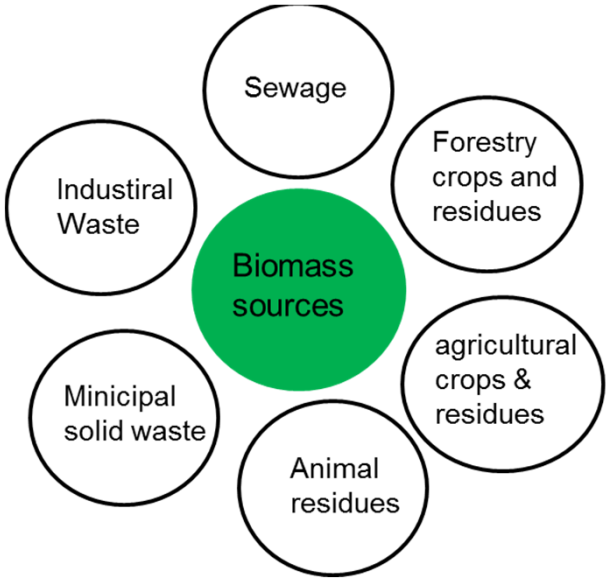
Clean Coal Technology

= technology to reduce the environmental impact of coal energy generation

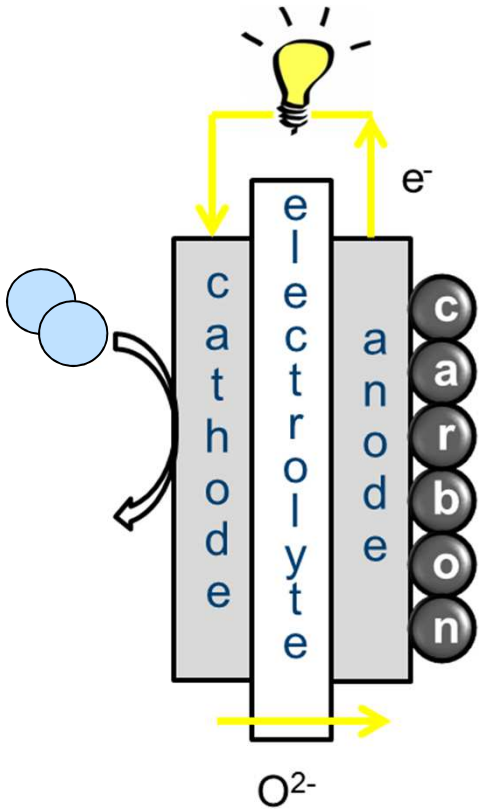
Carbon from Biomass

via hydrothermal carbonization (HTC)

- Suncoal Industries
- AVA CO_2
- REVATEC GmbH, HTC



Direct Carbon Fuel Cell - Concept



Overall Reaction $C + O_2 \rightarrow CO_2$

- not combustion with O_2 at anode
- electrochemical oxidation with O^{2-}

Cathode: e^- consumed (reduction)

Anode: e^- released (oxidation)

Electrolyte: no e^- conductivity,
but O^{2-} ions above 800°C

Carbon

Oxygen

Electron

Cathode $O_2 + 4e^- \rightarrow 2O^{2-}$

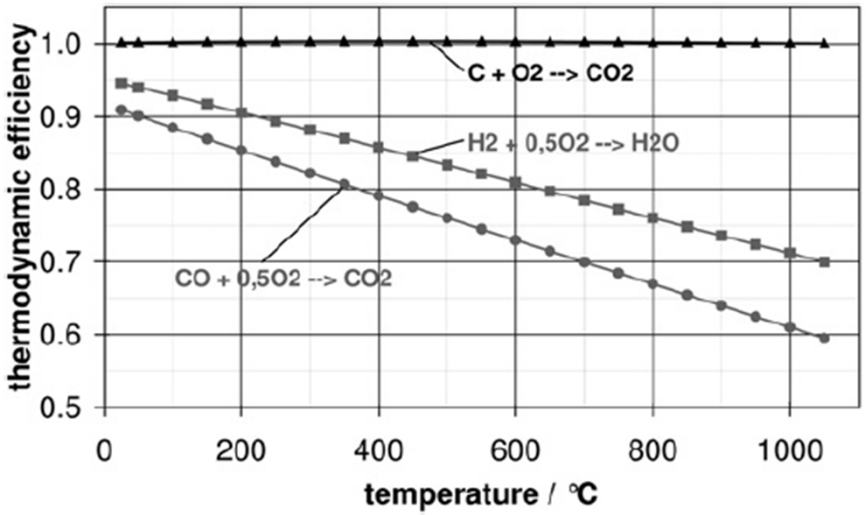
Anode $C + 2O^{2-} \rightarrow CO_2 + 4e^-$

Overall $C + O_2 \rightarrow CO_2$

Advantages

- ✓ High thermodynamic efficiency
- ✓ CO_2 sequestration
- ✓ High fuel comsumption
- ✓ Scale up/down
- ✓ High volume energy denisty
- ✓ Carbon readily available

Application: decentralized power unit



S. Nürnberger et al, Energy Environ. Sci., 2010, 3, 150

$\Delta H = \Delta G + T\Delta S$

$\eta_{FC} = \Delta G / \Delta H = 1 - T\Delta S/\Delta H$

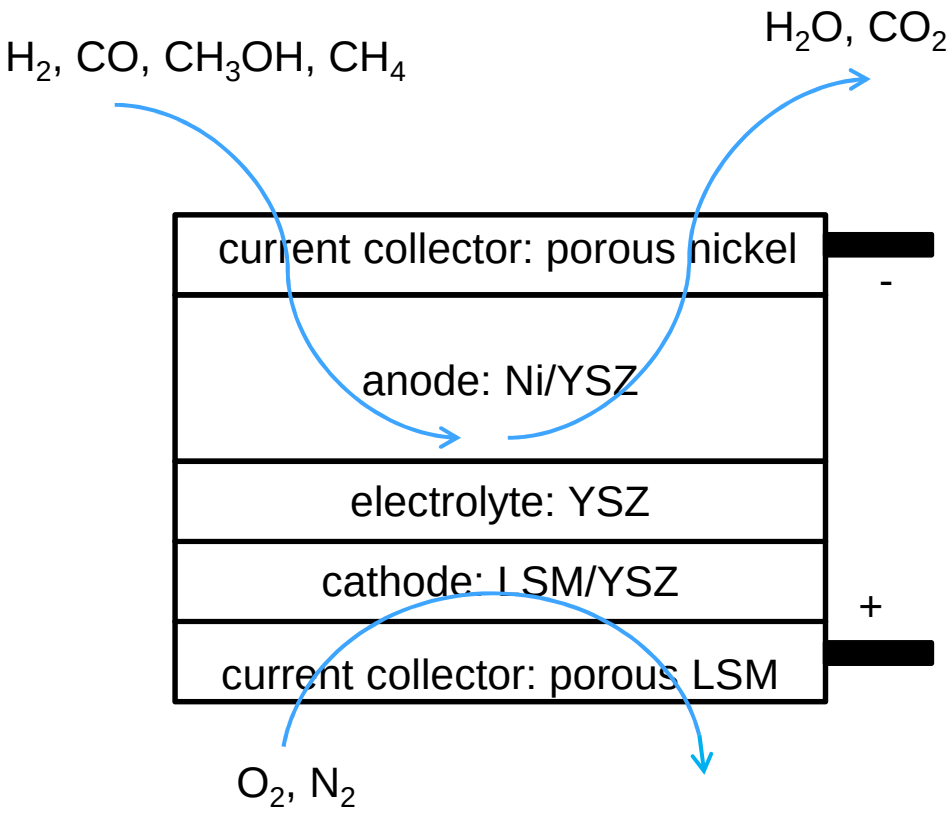
For **$C + O_2 \rightarrow CO_2$**

At 800°C, ΔS = 1,6 J/(mol K)

Technical Challenges

- C as fuel
  - → CO oxidation
  - → catalysts
  - → purity/ contaminations
- Manufacturing of anodes
  - → thin, dense, with catalyst
- Solid fuel
  - → solid/solid interface
  - → new fuel supply concept
  - → new anode design

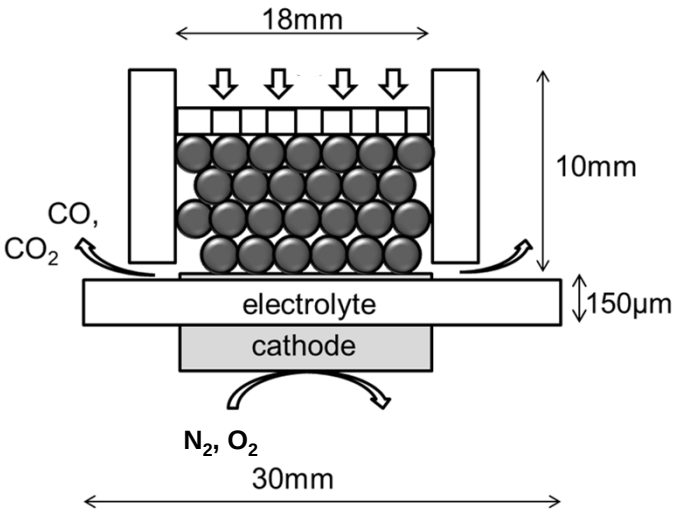
Conventional SOFC Design

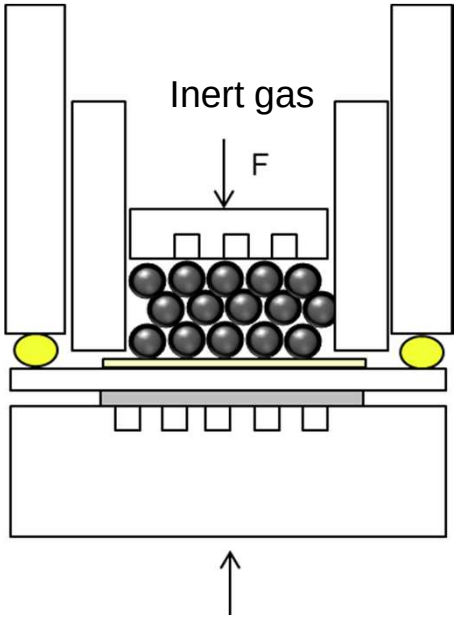


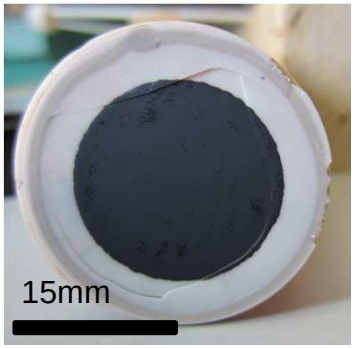
YSZ: yttria stabilized zirconia

LSM: lanthanum strontium manganite

Direct Carbon Fuel Cell – Setup



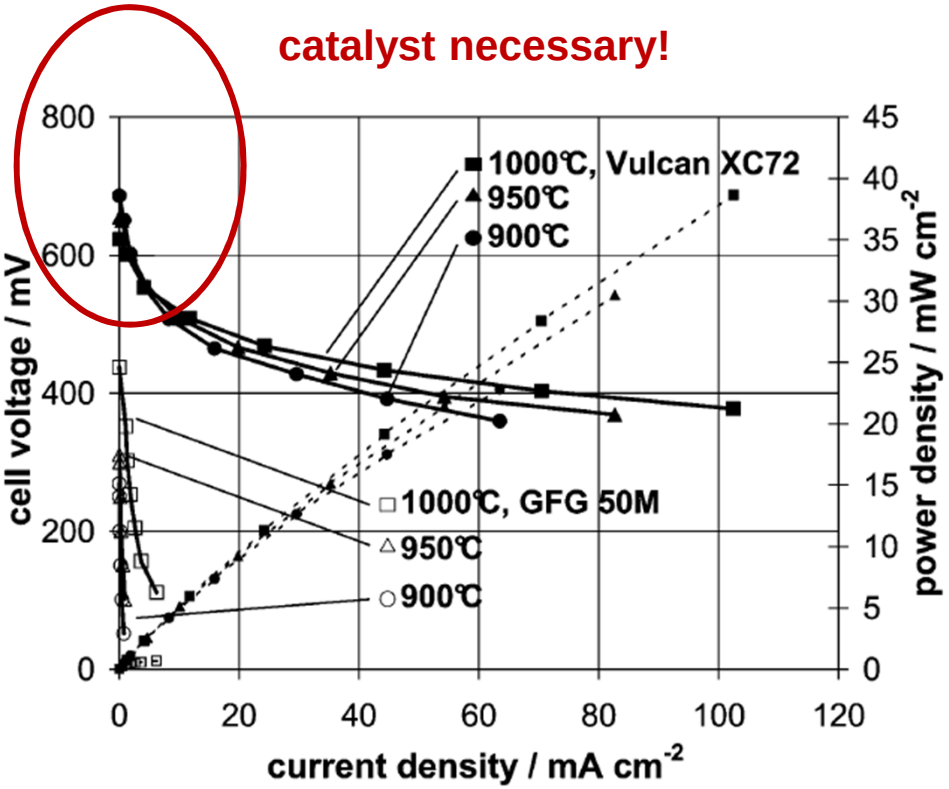




Direct Carbon Fuel Cell - Voltage Efficiency

Sluggish kinetics

catalyst necessary!



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Carbon powder as fuel

→ amorphous (Vulcan)

→ graphitic (GFG 50M)

Carbon as anode

→ directly on electrolyte

Summary: Direct Carbon Fuel Cell (DCFC)

- DCFC is a high temperature energy conversion device for direct electricity generation from carbon
- High potential for efficient energy conversion
  - high theoretical efficiency
  - carbon from biomass or coal, high energy density and easy to handle/to store
- Possible application as decentralized electricity generator at varying scales
- Challenges: New system design, anode design, catalysts for accelerated kinetics

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Thank you for your attention!