A steam-carbon-air fuel cell (SCAFC) enables co-generation of electricity and hydrogen from solid carbonaceous fuels in a single processing chamber:\(^1\):

SCAFC advantages:
- High efficiency
- Fuel flexibility (coals, biomasses, other solid wastes)
- Solid-state design (no moving parts)
- Concentrated CO\(_2\) product (near-capture ready)

A finite element model, implemented in COMSOL, was developed to predict SCAFC performance and understand the tradeoffs between maximizing system efficiency, power output and hydrogen production.

The model includes:

**Electrochemistry**
- Detailed electrochemistry is used to predict current-voltage relationships
- Kinetic parameters derived experimentally

**Carbon Bed Chemistry**
- Boudouard reaction modeled by a 7-step reduced mechanism
- Steam gasification modeled by a 13-step reduced mechanism\(^2\)

**Mass Transport**
- Transport by convection and diffusion of CO, CO\(_2\), H\(_2\), H\(_2\)O through the fuel bed
- O\(_2\)/N\(_2\) transport in air domain
- H\(_2\)/H\(_2\)O transport in steam domain

**Heat Transfer**
- Gas phase convection and conduction
- Wall-to-wall radiation in air and steam domains
- Fuel bed convection, conduction, and radiation
- Heat sources/sinks (chemical reactions, joule heating)

**Electrochemistry**

**CO Oxidation**

Electrochemical impedance spectroscopy (EIS) was used to extract kinetic rate parameters for the electrode reactions.

**H\(_2\) Oxidation**

Hydrogen is present in all practical carbonaceous fuels (coal, biomass). When released into the carbon bed it will sustain itself through a "H\(_2\) shuttle" mechanism, similar to the "CO shuttle" mechanism depicted above. Hence, we need account for electrochemical oxidation of H\(_2\).

The equation fits the empirical data well

Need to predict OCV accurately
- From IV curves above: Syngas OCV affects performance
- Need to predict OCV accurately
- The equation fits the experimental data well

Acknowledgements
The authors would like to acknowledge and thank the Global Climate & Energy Project (GCEP, grant number 106796) and its sponsors for their funding and support.

References