Polymer Electrolyte Fuel Cells: Fabrication and charaterisations

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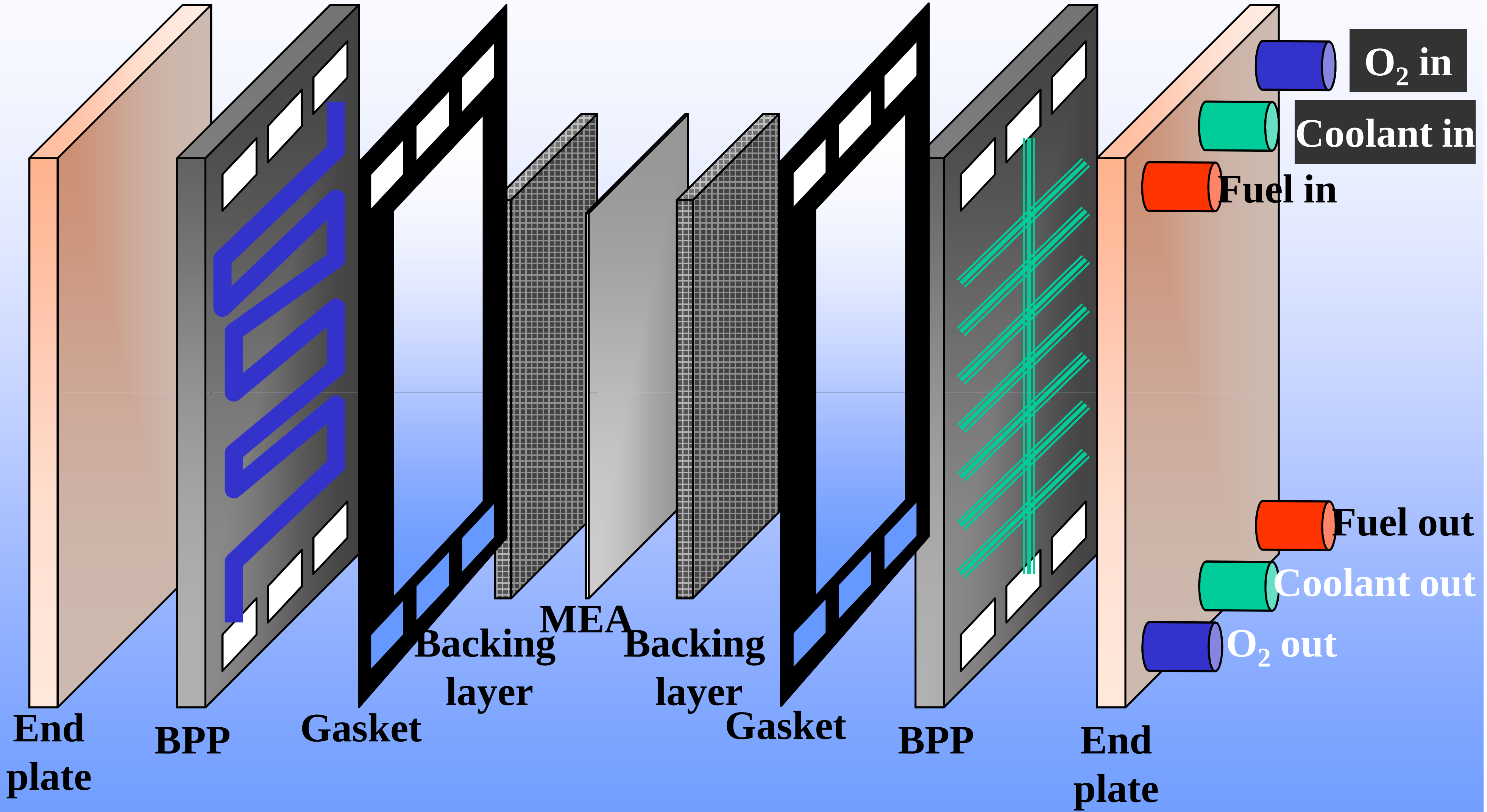
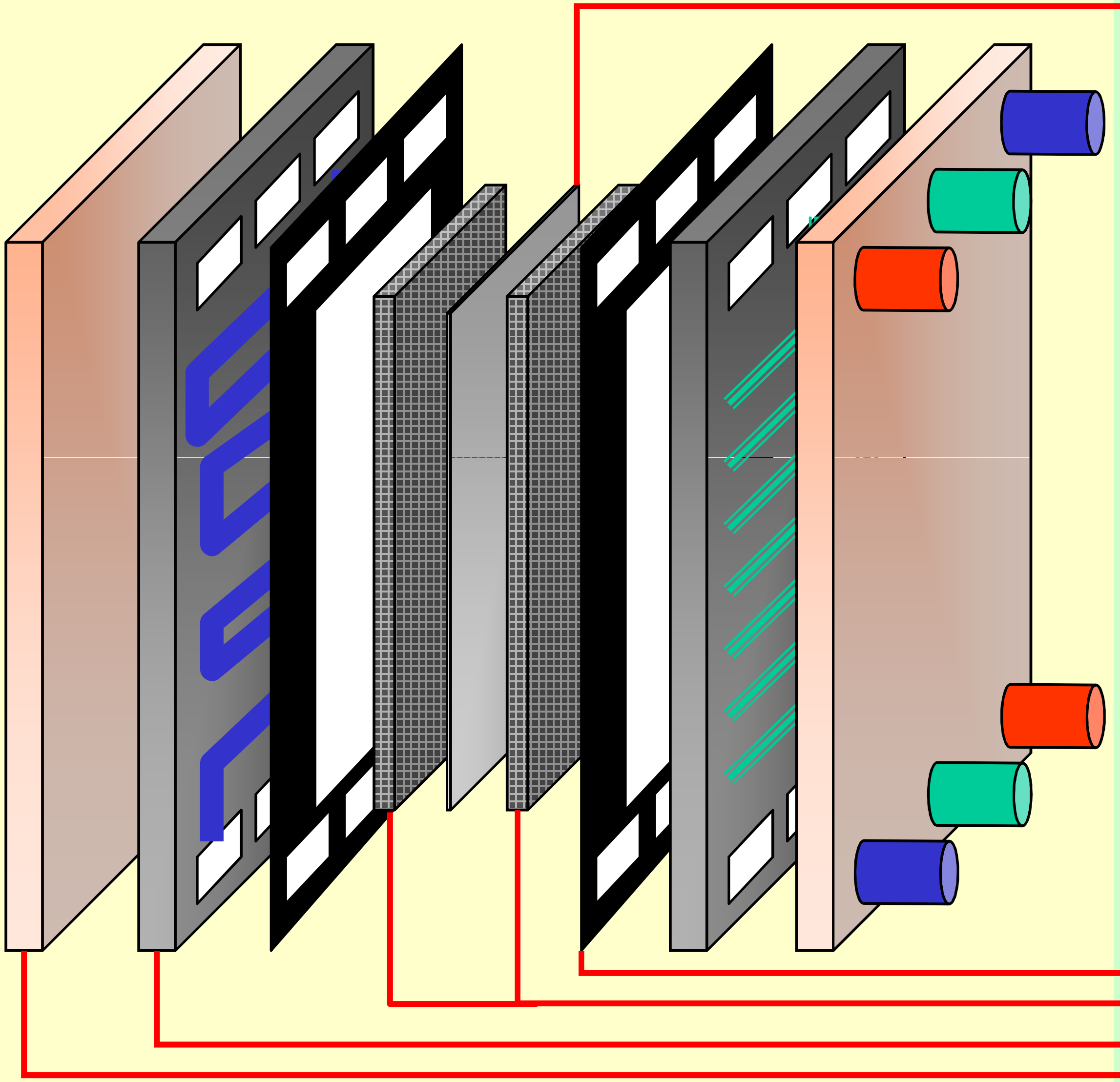
Unit cell assembly



Fuel cells: targets & achievements

		TARGETS	ACHIEVEMENTS
Fuel Cells	Efficiency	:40%	✓?
		60%	✓?
	Durability	:40,000 hours (stationary)	✘
		5,000 hours (automobile)	✘
	Cost	:$400-$750/kW (stationary)	✘
		$45/kW (automobile)	✘
	Power density	:220 W/L & 325 W/kg	?

Fuel cell components & challenges

Fuel cell	Components	Responsible for
	Membrane & Electrode	Cost & Durability
	Design factor	Durability
	Gasket	Volume
	GDL	Volume
	Bipolar plate	Volume, Weight
	Endplate	Volume, Weight

Membrane & Electrode challenges: Cost

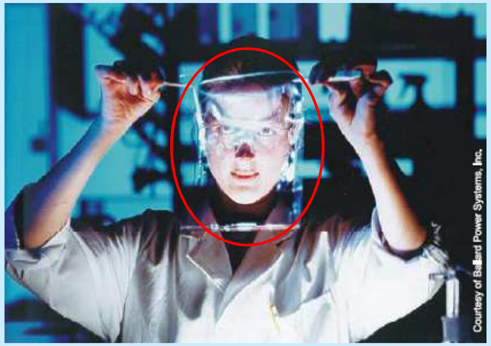
Membrane

- Type: Sulphonated (Nafion)
- Cost: ~200 US$/sq. m
- Area/kW: 2000 sq. cm @0.5 W/sq. cm
- Cost/kW: 40 US$

Electrode

- Catalyst type: Platinum
- Cost: ~75 US$/gm
- Loading/kW: 2 gm @0.5 W/sq. cm and 1mg/sq.cm
- Cost/kW: 150 US$

Sulphonated Membrane



- Dupont (Nafion®) membrane is commonly used
- Chemically resistant
- HSO_3 is ionicaly bonded to the side chain
- Clusters are formed
- Backbone is hydrophobic alongwith hydrophyllic side chain
- Large quantity of water can be adsorbed
- In hydrated region H^+ ions are relatively weakly attracted
- In presence of water it acts as an ionic conductor

Challenges: Sulphonated Membrane

Issues	Solutions
Membrane: ● Water dependent conductivity High system cost Large system volume & Complexity Swelling and shrinkage: Durability ● Operating temperature <100 ^oC High activation losses Low CO tolerance Limits fuel options Increased cost for H_2 production	Water independent ionic conducting membrane
Electrode: ● Catalyst type: cost & durability ● Catalyst utilizations ● Catalyst loading	•Innovation for low cost & high durability catalyst !  •Improved fabrication technique • Improved surface area/mass

Geometry for gas distributions

- **Manifold: Channels for distributing gases in different cells in a stack**
- **Flow field: Channels enables distribution of gas on the active area of the cells**

Inlet

Outlet

•Serpentine type flow filed is commonly used

<u>ISSUES:</u>

- **Heterogeneous performances due to uneven gas distribution in different cells**
- **Causes water flooding at high current densities**
- **Heterogeneous gas pressure distribution**
- **Degradation in performance**

Solution:

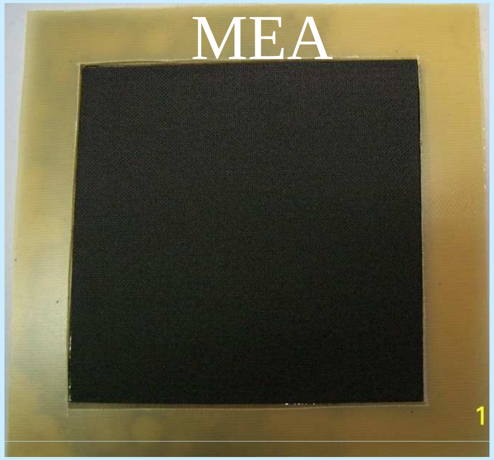
- **Optimum flow field design**

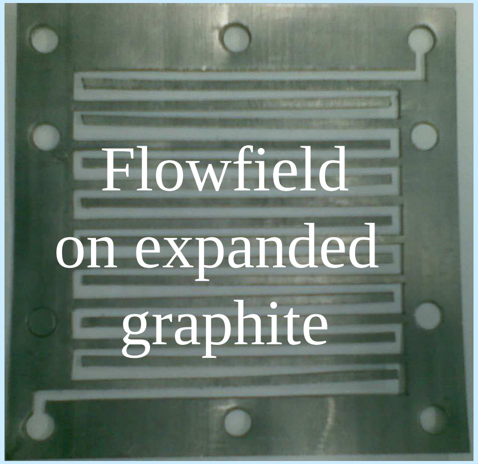
PEFC related activities

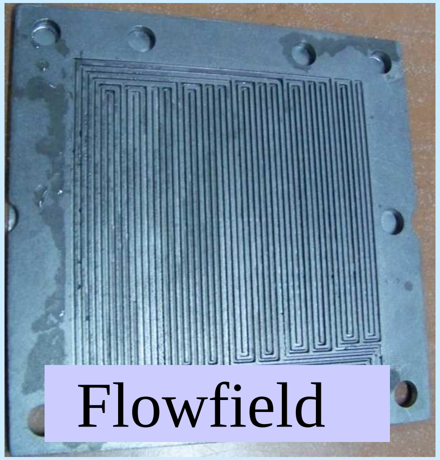
- **Optimum Designing**
- **Systematic Fabrications Methodology for Stacks**
- **Sealing analysis and contact pressure distributions**
- **CFD Modeling**
- **High Temperature PEFC (HT-PEFC) @ 120 ^{o}C-200 ^{o}C**
- **MEA fabrication**
- **PEFC along with hydrogen in PV system**

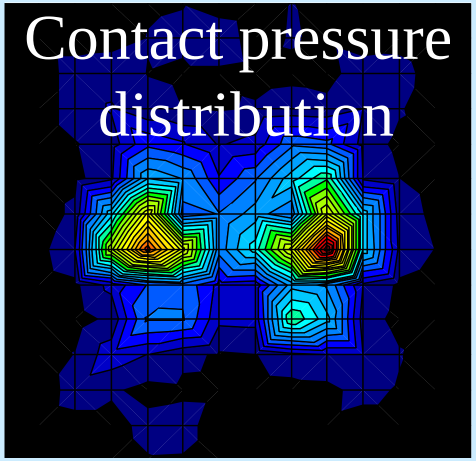
PEFC activities: Designing

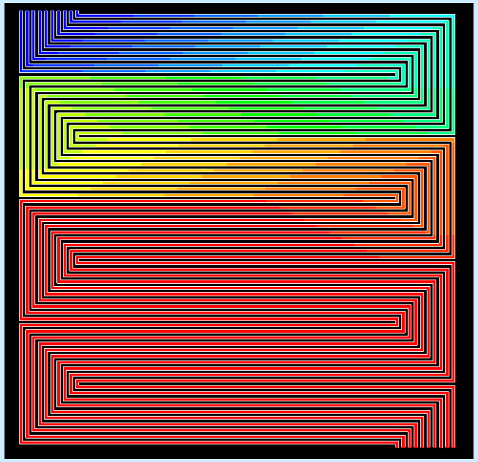
- Designing of bipolar plate and flow field
- Sealing geometry by contact pressure distributions
- CFD modeling of fuel cells
- MEA fabrication
- Thermal analysis of HT-PEFC





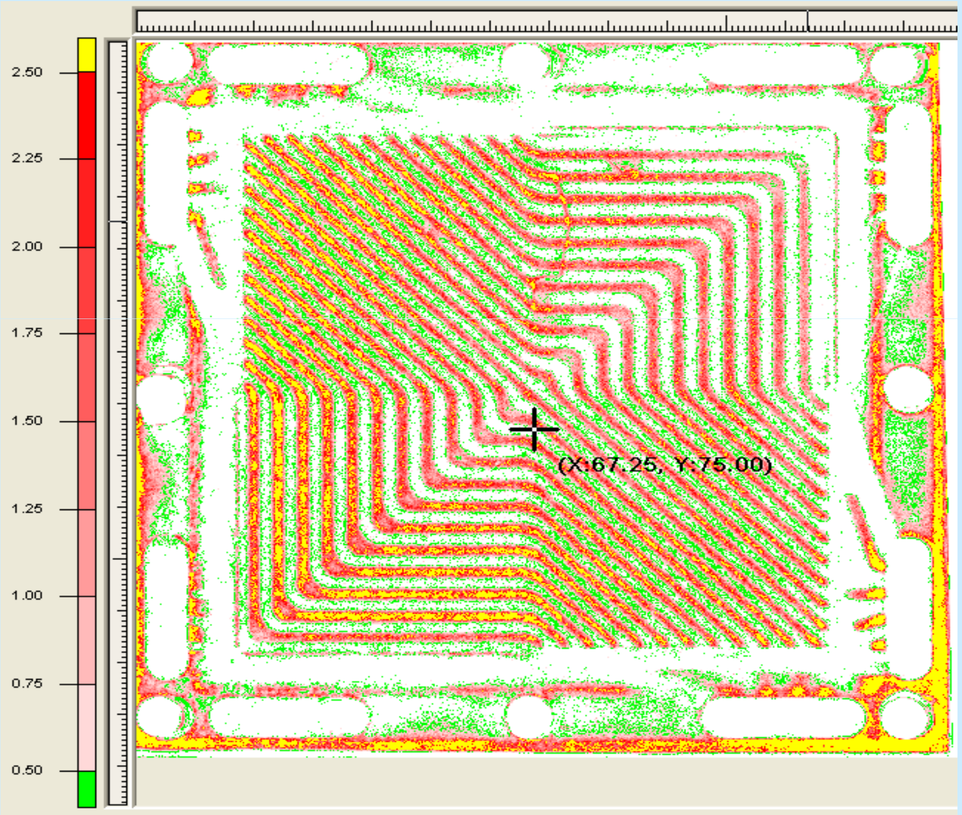




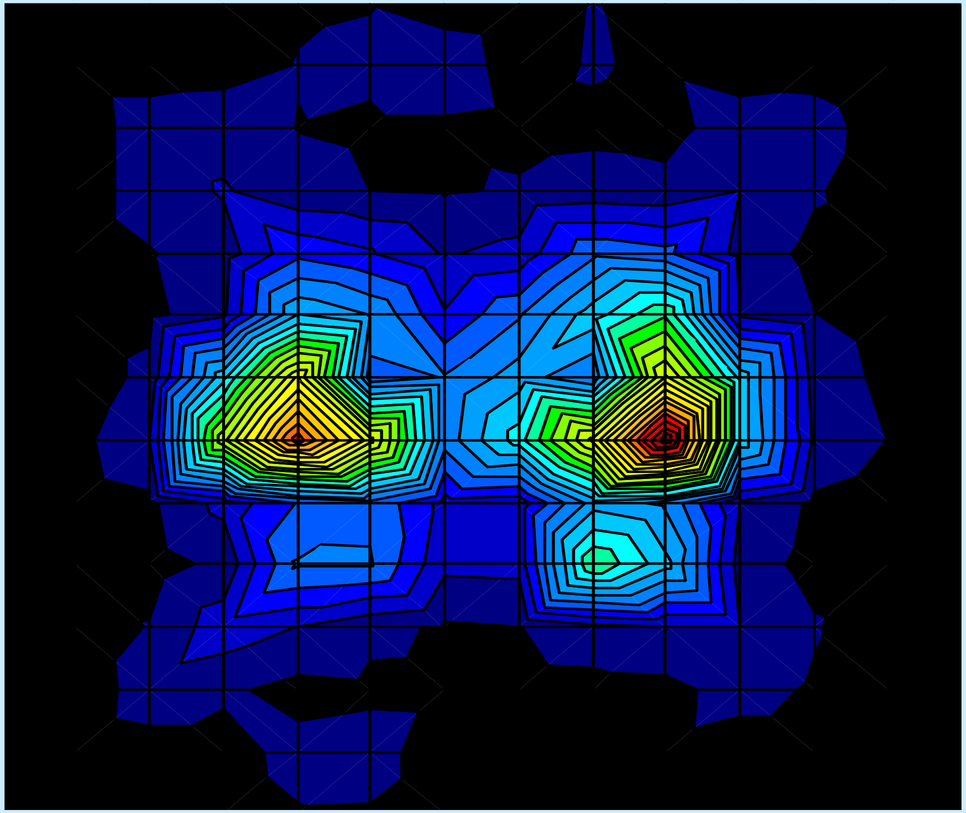


In-situ contact pressure analysis

Direct measurement

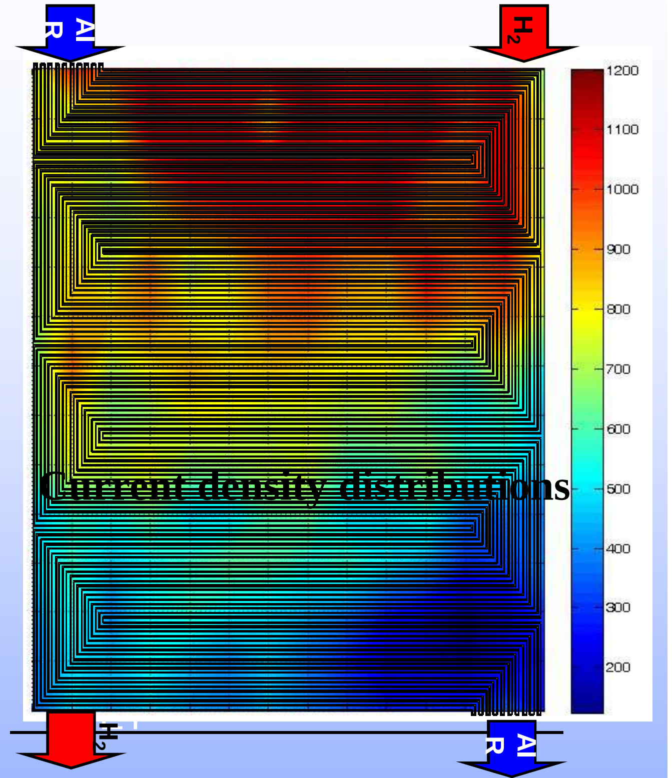


Indirect measurement

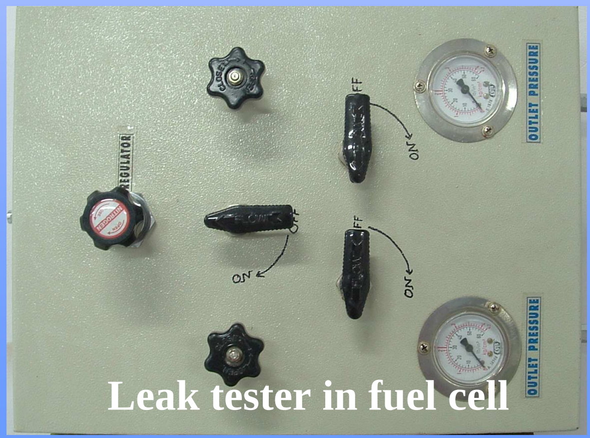


PEFC: Characterisations

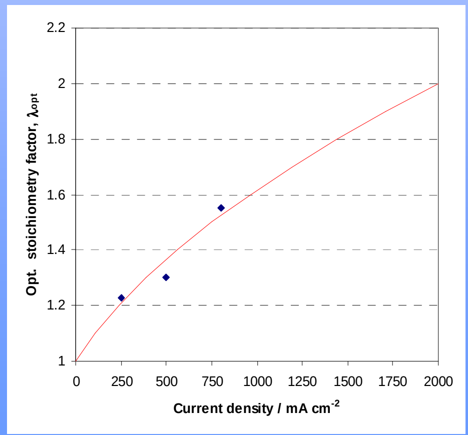
- Leak testing of fuel cells
- Current density distribution measurement
- Electrochemical characterizations
- Operating conditions optimization
- Startup time of HT-PEFC

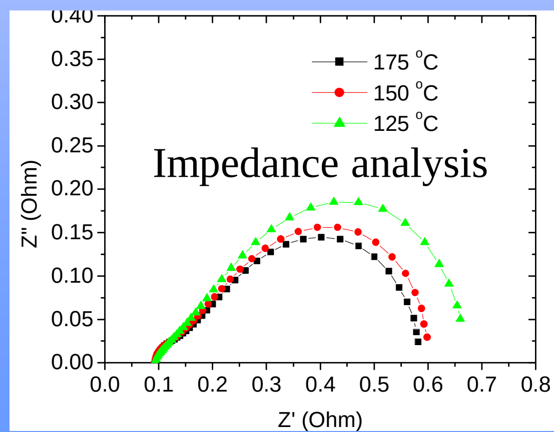


Fuel cell test station

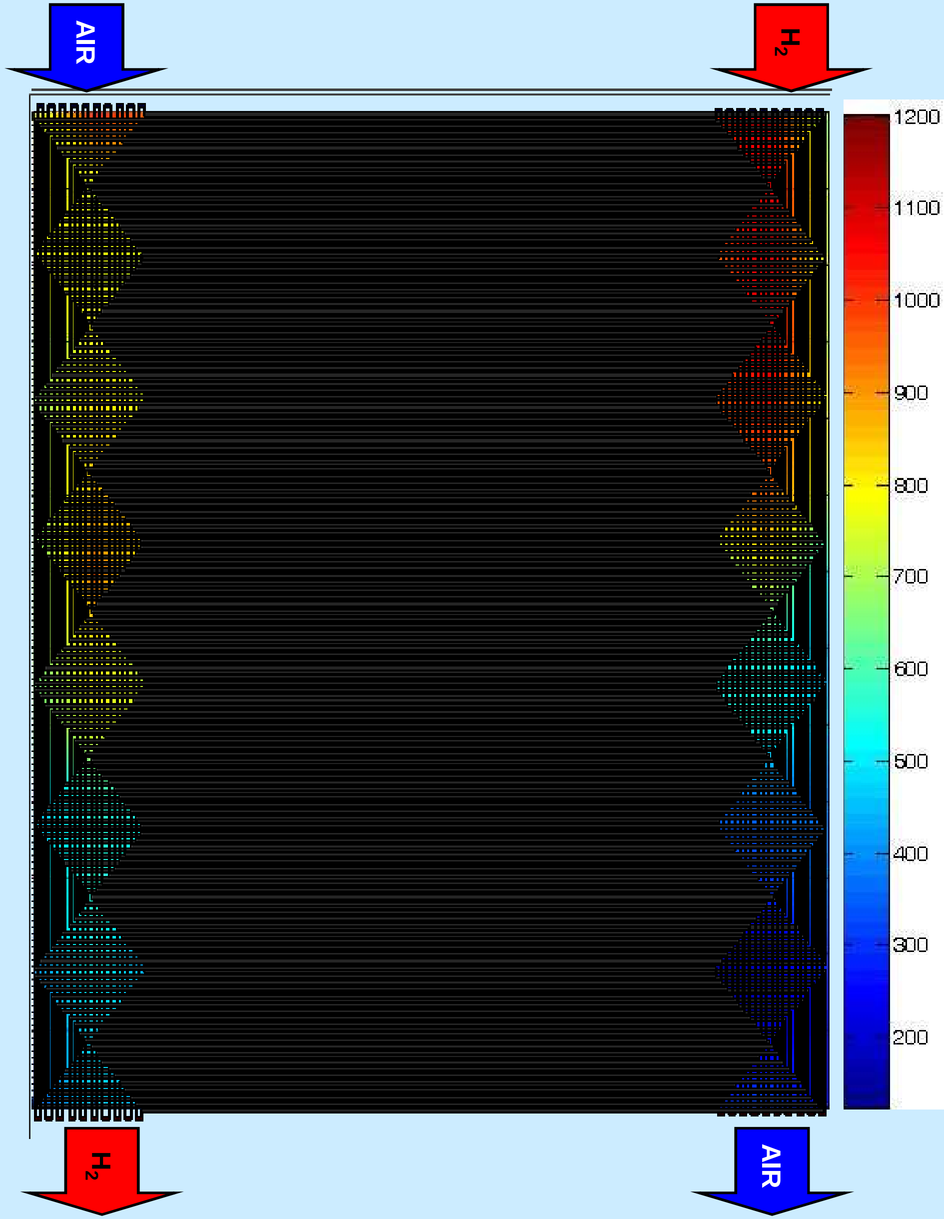


Leak tester in fuel cell





PEFC characterisations: CDD



Operating conditions:

Air stoichiometry factor = 1.5;

H_2 stoichiometry factor = 1.2;

Pressure 1.5 bar;

H2 relative humidity = 100 %;

Air relative humidity = 100 %;

Cell temp. 60 °C,

Mean current density = 800 mA-cm^{-2}

HT-PEFC Start-up Modelling

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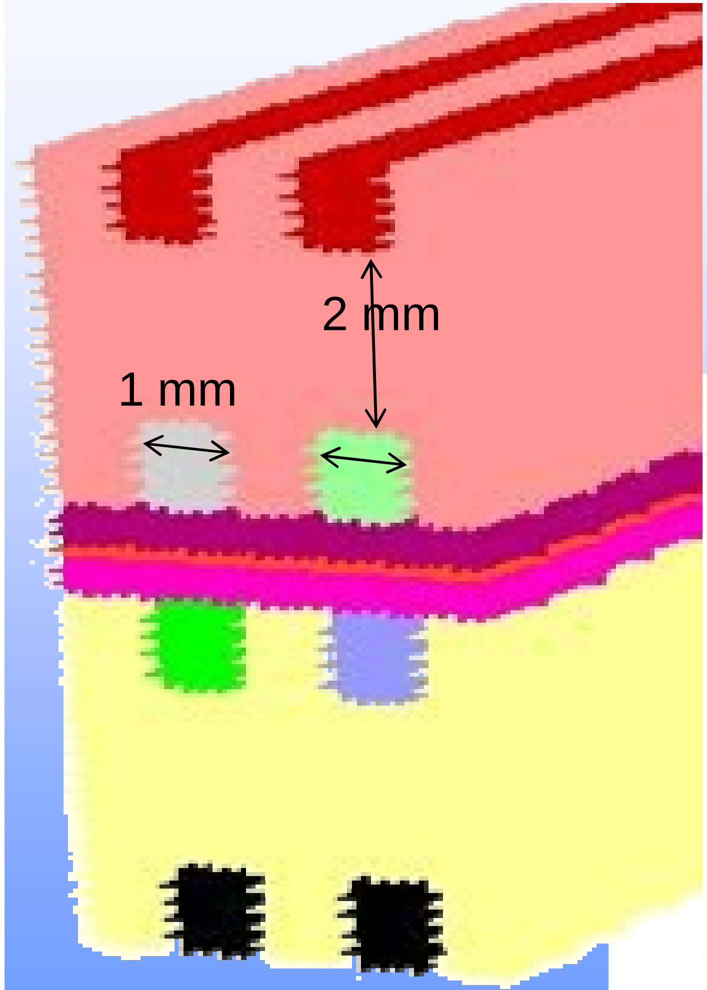
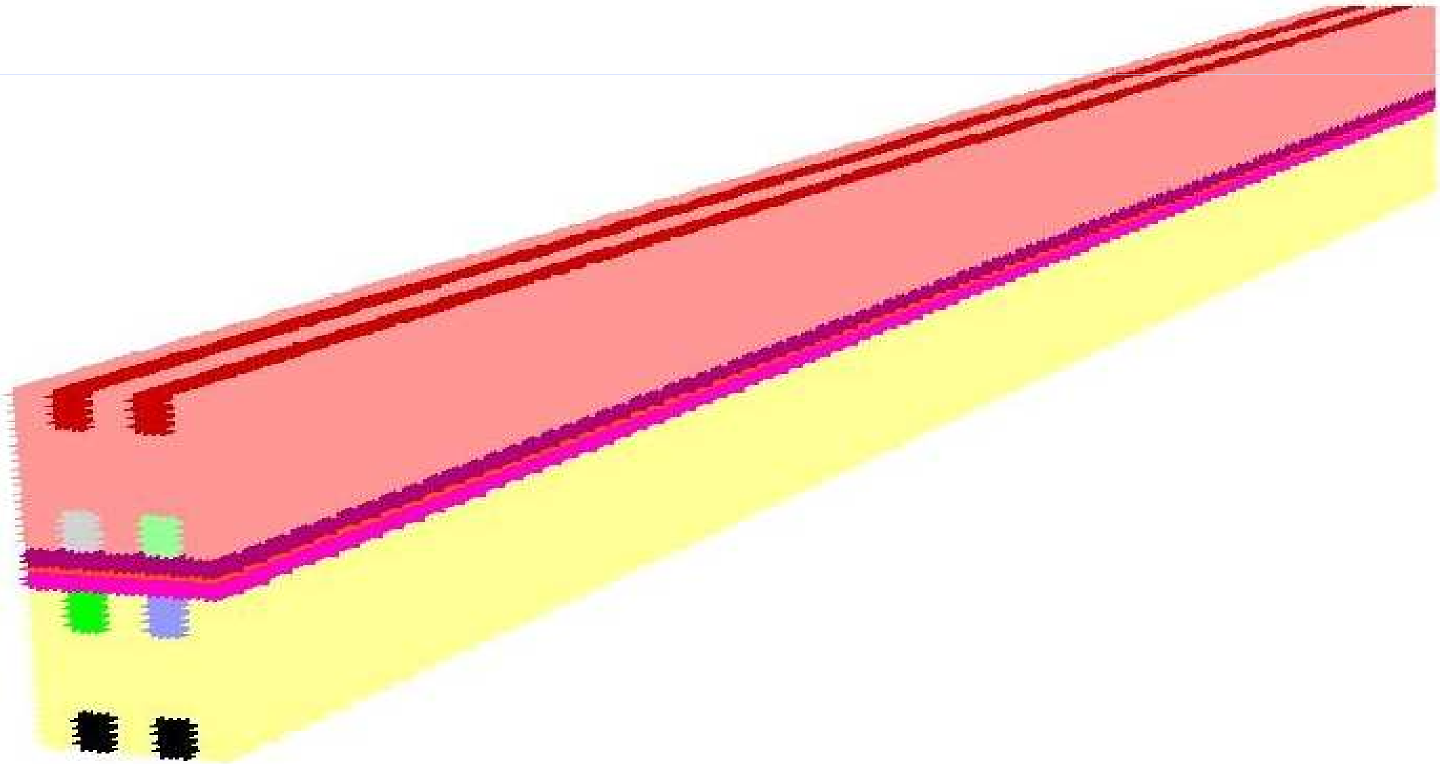


- Graphite BPP of thickness 4 mm
- 2 straight coolant channels (1mm x 1mm x 100mm)
- 2 gas channels (1mm x 1mm x 100mm)
- GDL (5mm x 100mm) of porosity 0.5
- PBI membrane of thickness 0.1 mm
- Membrane area (5 cm²)



Materials properties & boundary conditions

Coolant: UCOTHERM
- Density: 885 kg/m^3
- Sp. Heat: 2290 J/kg-K
- Thermal conductivity: 0.158 W/m-k
- Viscosity: 0.0016 kg/m-s

PBI: 80% Phosphoric acid
- Density: 1771 kg/m^3
- Sp. Heat: 2090 J/kg-K
- Thermal conductivity: 0.45 W/m-k

BPP: Graphite
- Density: 2250 kg/m^3
- Sp. Heat: 1732 J/kg-K
- Thermal conductivity: 24 W/m-k

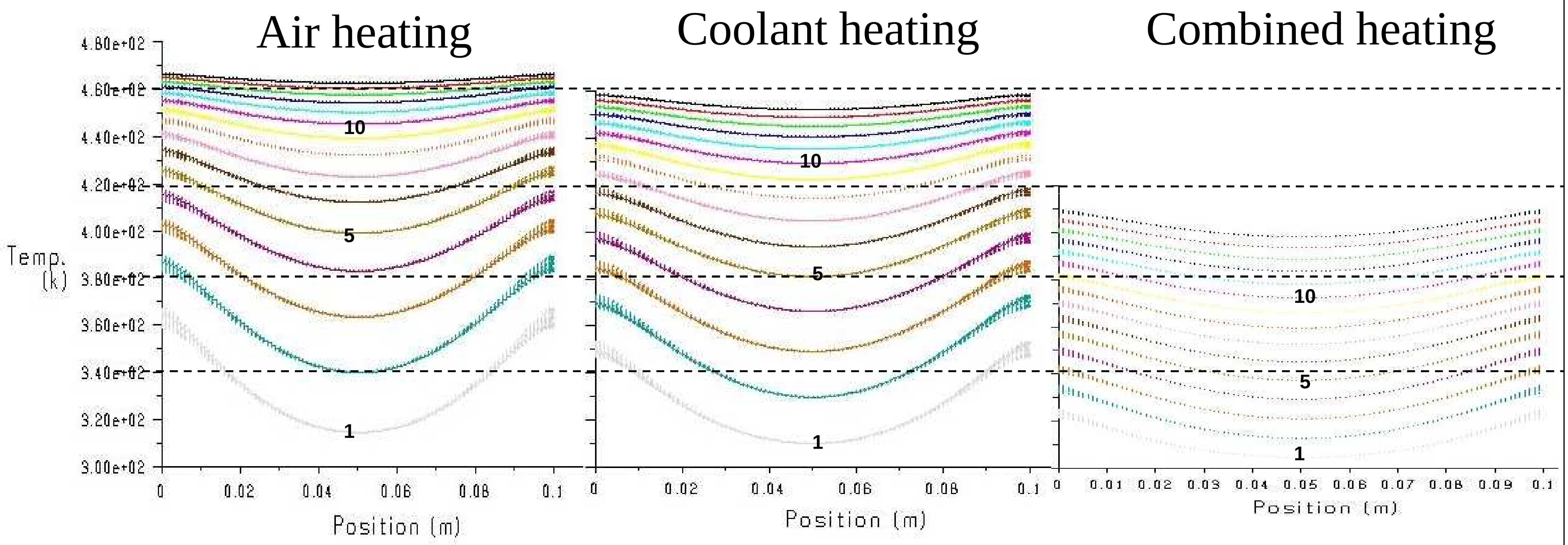
Reactant gas: air
- Density: 1.225 kg/m^3
- Sp. Heat: 1006.43 J/kg-K
- Thermal conductivity: 0.0242W/m-k
- Viscosity: 1.789×10^{-5} kg/m-s

Op. pressure. 1 atm

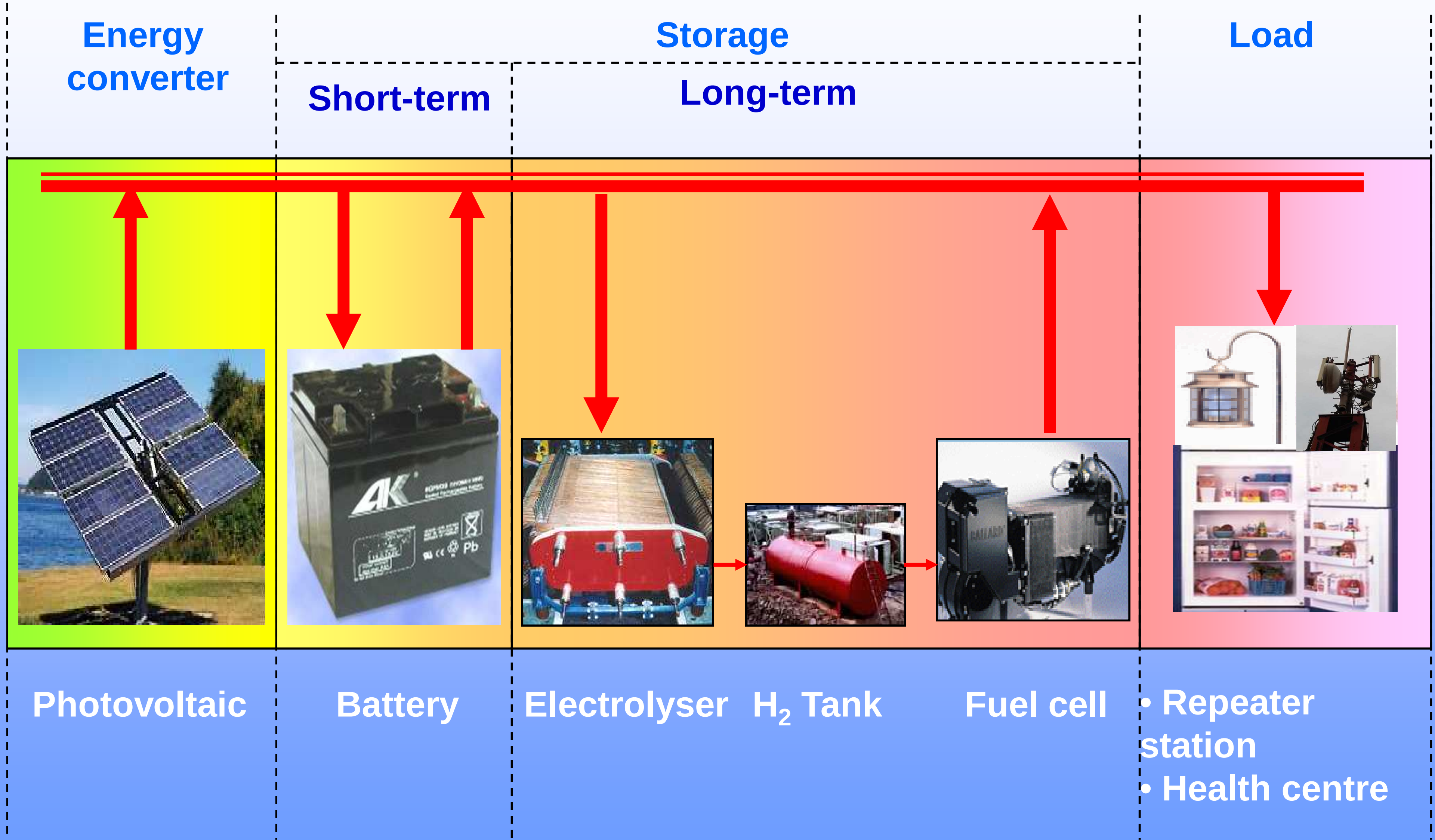
Initial temp. 300 K

INLETS
- Anode gas: 3 m/s
- Cathode gas: 3 m/s
- Cathode coolant: 0.005 m/s
- Anode coolant: 0.005 m/s
- Total coolant flow: 0.354 $kg/s\text{-}cm^2$

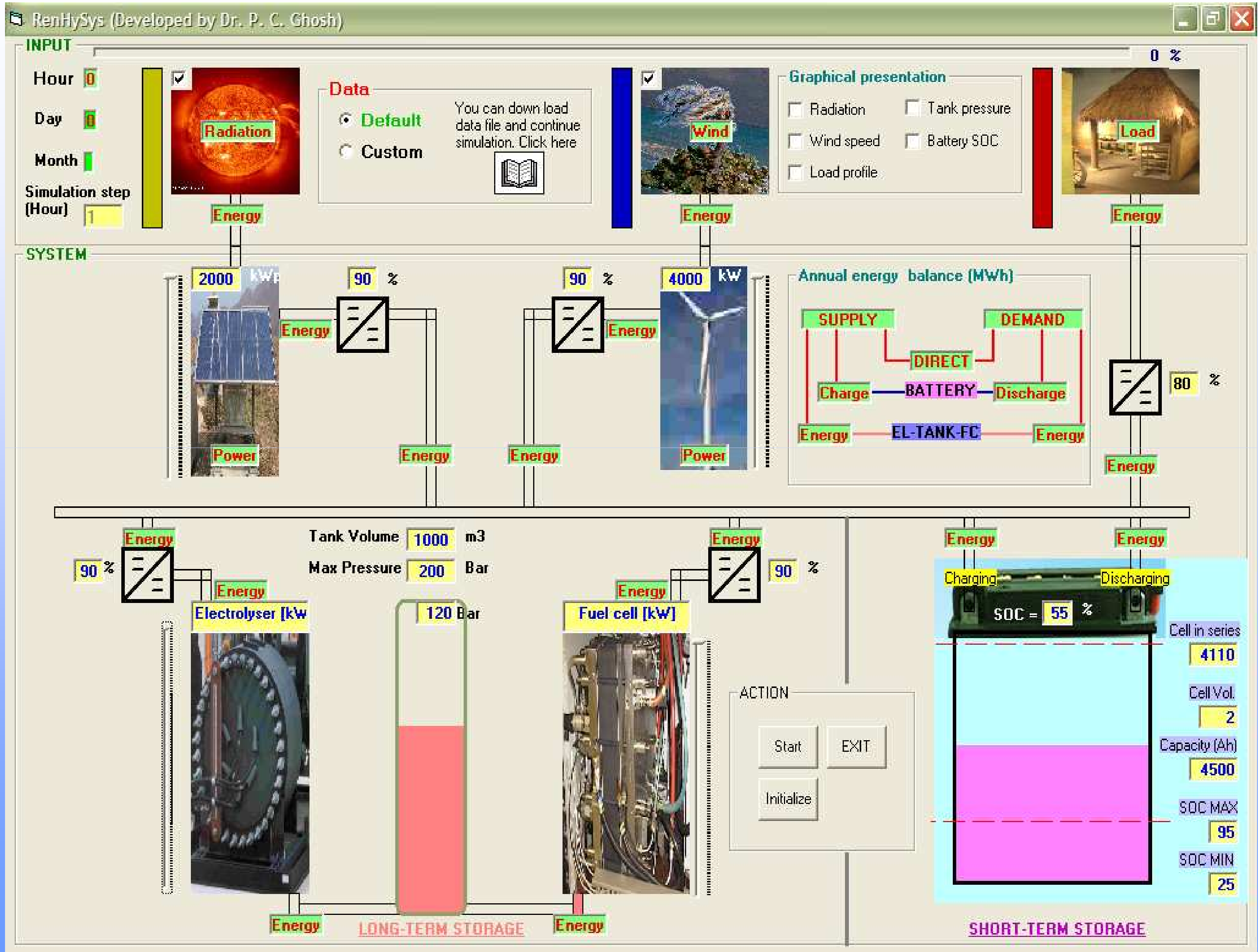
Start-up heating comparisons



PV system: hybrid storage



RenHySys: Tool for visualization



INPUT

- Solar radiation or/and wind
- Load demand

RUN

ENERGY STORAGE

- Status of battery
- Status of hydrogen

Conclusions

- PEFC challenges include
  - cost
  - durability
  - weight and volume
- Nafion membrane has technological issues in addition to cost
- Invention of new catalyst is required for low cost and high durability
- Electrolyte with water independent conductivity is important for
  - more fuel options
  - reducing hydrogen production cost
- Gas distribution geometry is important for
  - performances
  - durability of PEFC

THANK YOU

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