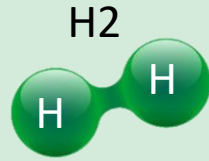


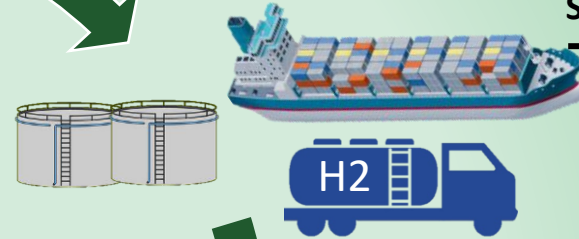
Environment friendly

- Bio-Production
- Oxygen helpful for environment



Storage & Distribution

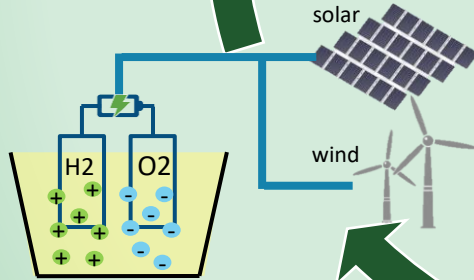
- H₂ storage
- Distributed by fuel cell truck



Peak Carbon
2030
carbon Neutrality
2060

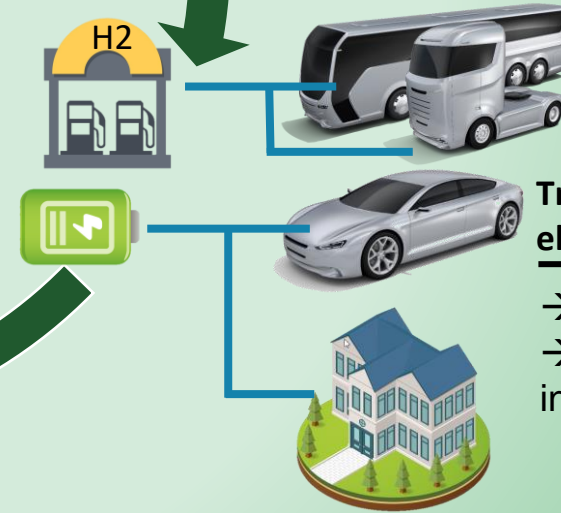
Hydrogen production

- Electrolyze water
- Fossil fuels



Transport & electricity generation

- H₂ used in truck
- Use in homes and industrial



BOSCH fuel cell system model customized based on Simscape

BOSCH fuel cell R&D



2st phase done,
test bench for BoP, stack,
system & sample line for
stack

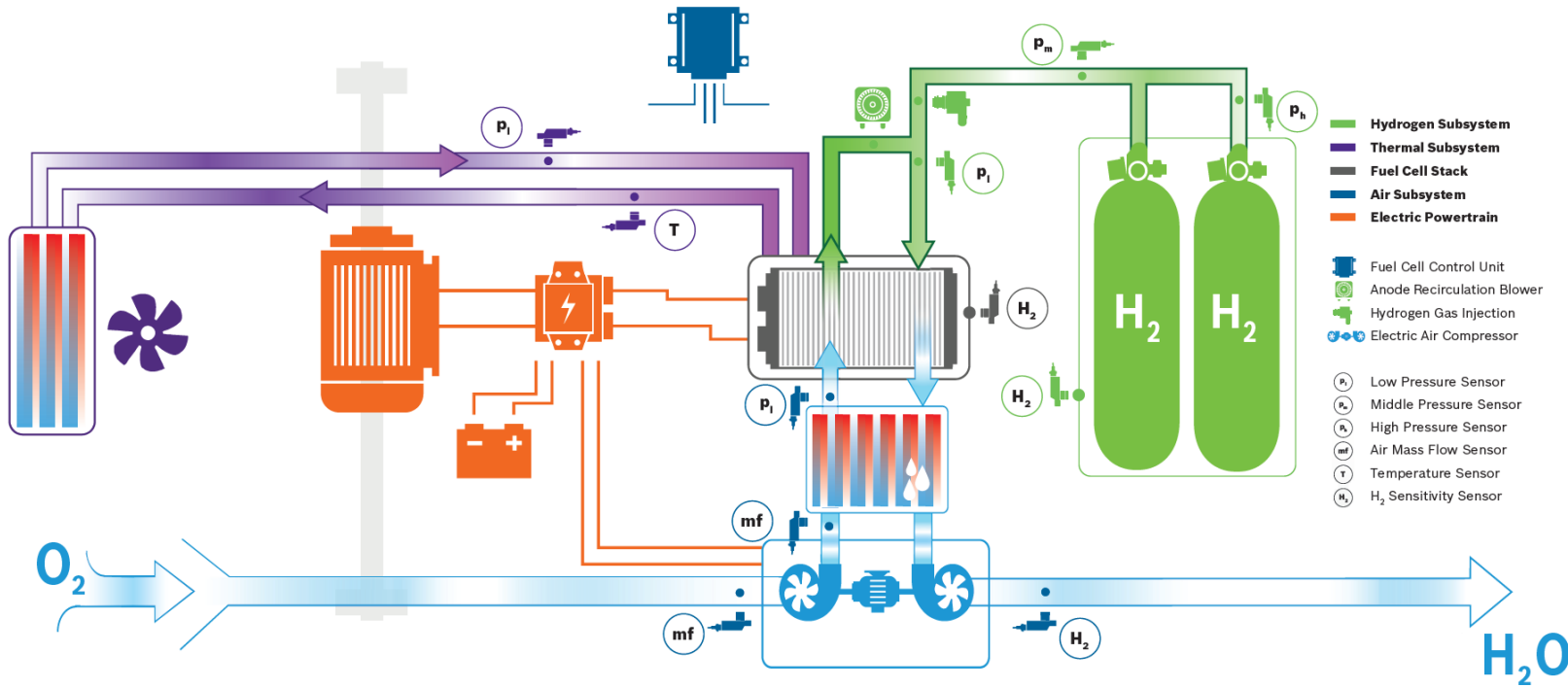






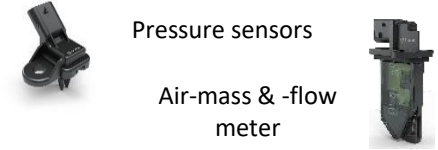

1st phase done,
system test bench
under calibration

Fuel cell competence :
Customer interface
Engineering
Application
Testing
Manufacturing

BOSCH fuel cell system model customized based on Simscape

BOSCH fuel cell component products



-  Hydrogen gas injector (HGI)
-  Anode recirculation blower (ARB)
-  Electric air compressor (EAC)
-  Fuel cell stack
-  Pressure sensors
Air-mass & -flow meter
-  Fuel cell control unit (FCCU)

Comprehensive portfolio of Fuel Cell products with SOP 2021 to 2023

BOSCH fuel cell system model customized based on Simscape

Fuel cell simulation challenge and solution

fuel cell simulation

Challenge

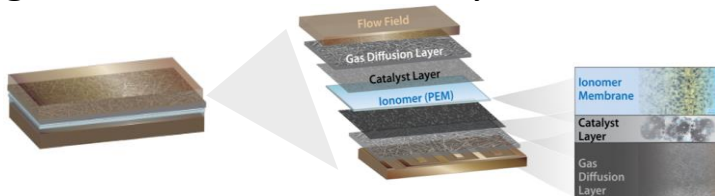
Description

Counter measure



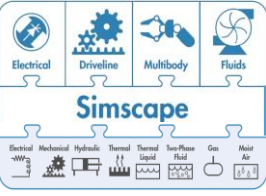
Multi domain

“gas — water — electricity — heat — force”



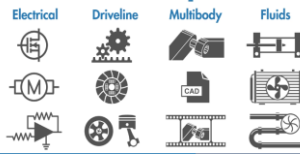
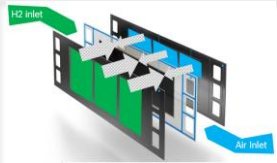
Ion-conductive Polymer with Phase-separated Nanostructure and semi-crystallinity
Heterogeneous porous structure with C, Pt and ionomer thin film
Porous structure for optimum water (liquid/vapor) transport

Basic tool

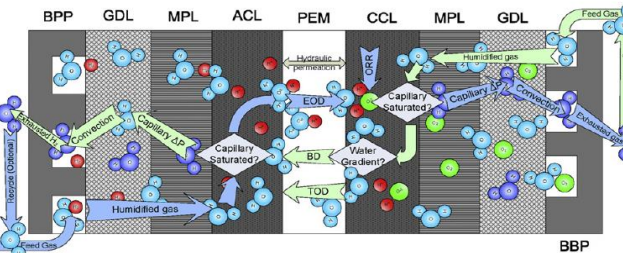


Add on

Simscape

Original know-how



Water transport

- Hydraulic Permeation
- Electro-Osmotic Drag
- Back Diffusion
- Thermo-Osmotic Drag

Water transport equation

HP: $J_{mw,hyd} = -c_{mw} \frac{K_{mw}}{\mu_{mw}} \nabla P_{mw} = -\lambda \frac{\rho_m}{EW} \frac{K_{mw}}{\mu} \nabla P$

EOD: $J_{mw,EOD} = n_d \frac{I_{H^+}}{F}$

BD: $J_{mw,diff} = -D_{mw} \nabla c_{mw} = -\frac{\rho_m}{EW} D_{mw} \nabla \lambda$

Stack with original water transport know-how

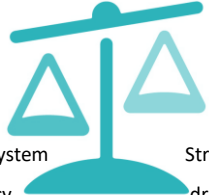
```

1 | simulation('cell_model', 'Fuel_Cell_Model')
2 | % Unit: microsecond, C, m, kg, N, J, Pa, s, V, A, W, Hz, rad, deg
3 | % Unit: (1000, 10^12)
4 | % Unit: (1000, 10^12)
5 | % Unit: (1000, 10^12)
6 | % Unit: (1000, 10^12)
7 | % Unit: (1000, 10^12)
8 | % Unit: (1000, 10^12)
9 | % Unit: (1000, 10^12)
10 | % Unit: (1000, 10^12)
11 | % Unit: (1000, 10^12)
12 | % Unit: (1000, 10^12)
13 | % Unit: (1000, 10^12)
14 | % Unit: (1000, 10^12)
15 | % Unit: (1000, 10^12)
16 | % Unit: (1000, 10^12)
17 | % Unit: (1000, 10^12)
18 | % Unit: (1000, 10^12)
19 | % Unit: (1000, 10^12)
20 | % Unit: (1000, 10^12)
21 | % Unit: (1000, 10^12)
22 | % Unit: (1000, 10^12)
23 | % Unit: (1000, 10^12)
24 | % Unit: (1000, 10^12)
25 | % Unit: (1000, 10^12)
26 | % Unit: (1000, 10^12)
27 | % Unit: (1000, 10^12)
28 | % Unit: (1000, 10^12)
29 | % Unit: (1000, 10^12)
30 | % Unit: (1000, 10^12)
    
```



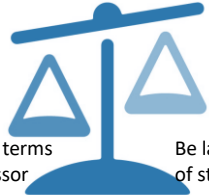
Trade off

Increasing air flow



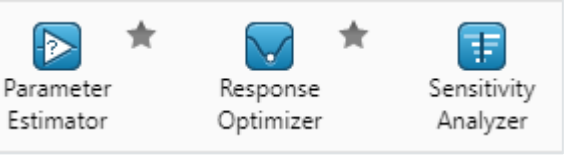
Lower system efficiency vs. Strength water drainage

Air pressure



Be small in terms of compressor vs. Be large in terms of stack

Optimization tool box



BOSCH fuel cell system model customized based on Simscape

Multi domain challenge



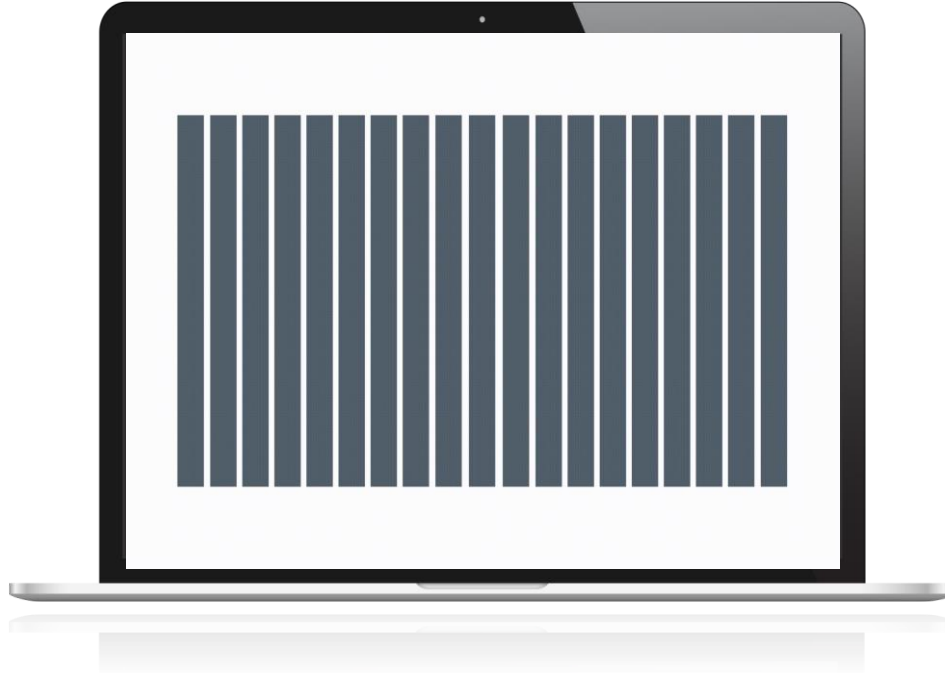
Electrical potential

- High calorific value and low calorific value
- Activation loss
- Ohmic loss
- Concentration loss



Multiple gas

- N₂ permeation
- liquid H₂O and gas water
- H₂ Joule-Thomson effect
- O₂ stoichiometry



Fluid state

- Diffusion : Fick's law
- Convection : Bernoulli equation



Precise control

- Air circle : pressure & flow decoupling
- Purge & drainage strategy

BOSCH fuel cell system model customized based on Simscape

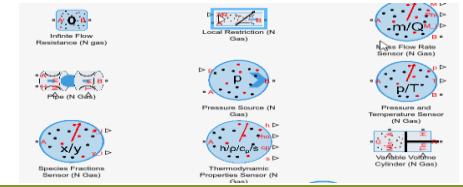
Multi domain challenge



MATLAB Simscape function for modelling

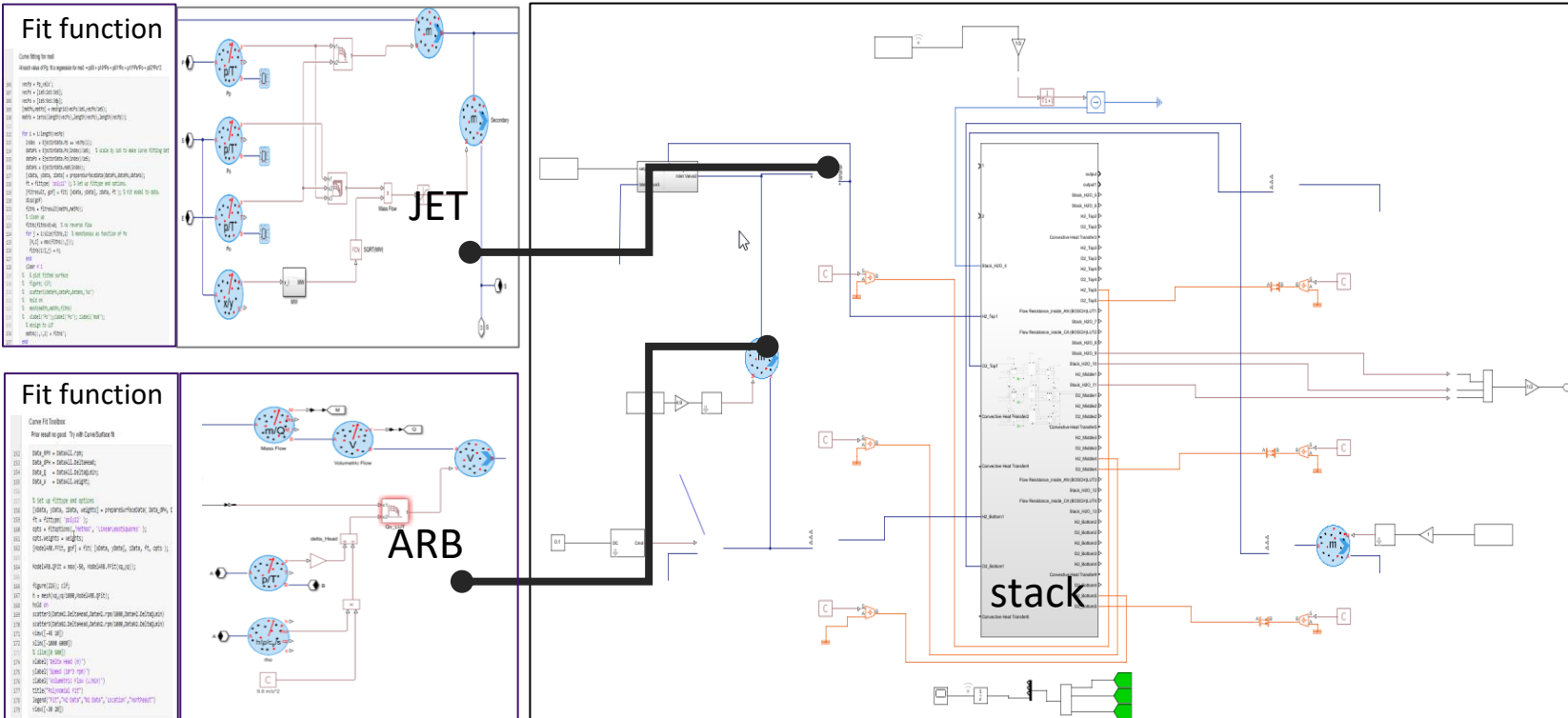
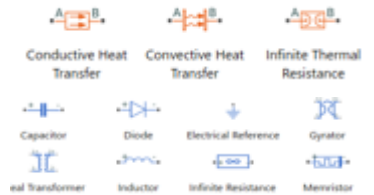
Customization-oriented

→customize fuel cell component template based on customer requirement



Basic Simscape library

→electric/thermal/control library



BOSCH fuel cell system model customized based on Simscape

Parameter trade off challenge

Key messages



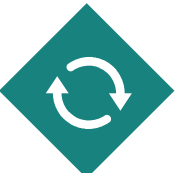
Insert test data and exclude useless data



Conform parameter numbers being optimized



Sweep the parameter range and find out limitation value



Iteration based on the deviation between test and simulation result

Parameter estimation tool box

The screenshot shows the Parameter Estimator software interface with several key components:

- Parameter Estimation Panel:** Lists parameters to be estimated: $k_{a,b}$, $k_{a,m}$, $k_{a,t}$, $k_{c,b}$, $k_{c,m}$, and $k_{c,t}$.
- Experiment Plot:** A graph titled "Exp Output" showing "Measured" (blue line) and "Simulated" (red line) data over time (0 to 20 seconds). The y-axis ranges from 0 to 1.0.
- Results Table:** A table showing the convergence of the optimization process.

Iteration	F-count	Exp (Minimize)
0	13	12.7913
1	26	5.6586
2	39	1.5237
3	52	0.5974
4	65	0.2423
5	78	0.1489
- View Result - EstimatedParams:** A dialog box showing the final estimated parameter values:
 - $k_{a,b} = 0.74042$
 - $k_{a,m} = 0.70699$
 - $k_{a,t} = 0.98467$
 - $k_{c,b} = 0.91638$
 - $k_{c,m} = 0.86759$
 - $k_{c,t} = 0.52767$
- Optimization Process Plot:** A graph titled "1. Optimize process" showing the value of parameters over iterations (0 to 10). The y-axis ranges from 0 to 1.0. The legend includes:
 - $k_{a,b}$ (blue line with circles)
 - $k_{a,m}$ (red line with squares)
 - $k_{a,t}$ (green line with triangles)
 - $k_{c,b}$ (purple line with diamonds)
 - $k_{c,m}$ (orange line with stars)
 - $k_{c,t}$ (yellow line with crosses)

BOSCH fuel cell system model customized based on Simscape GUI for efficiency improvement

Key messages



Input setting

- H2/Air side setting
- Current setting



Results display

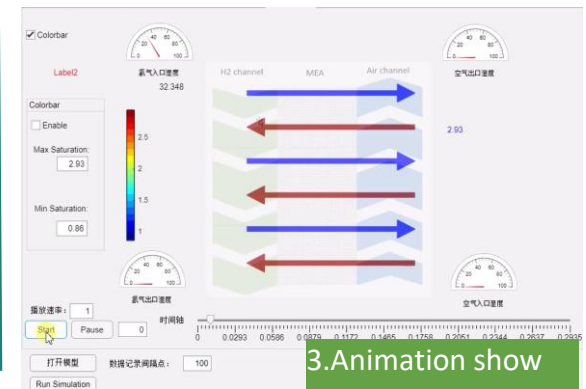
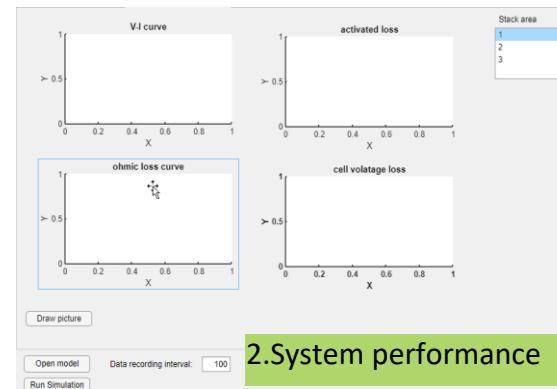
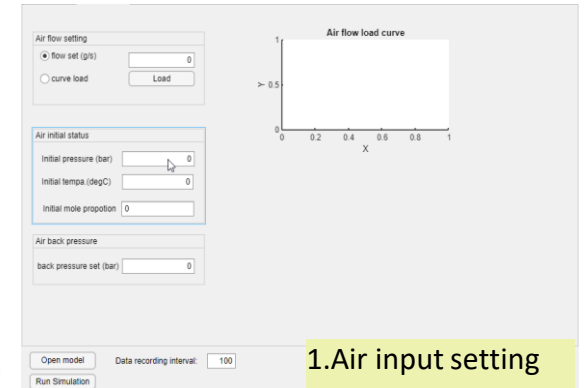
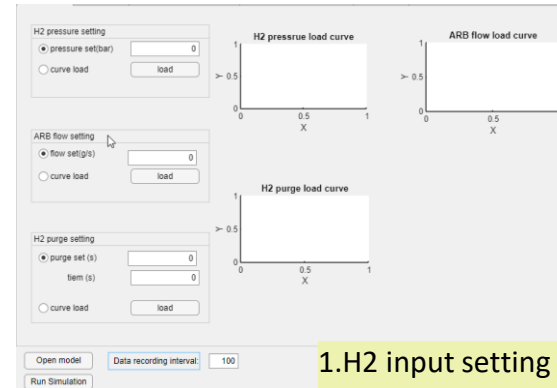
- Display the performance curve
- Support three area display



Animation

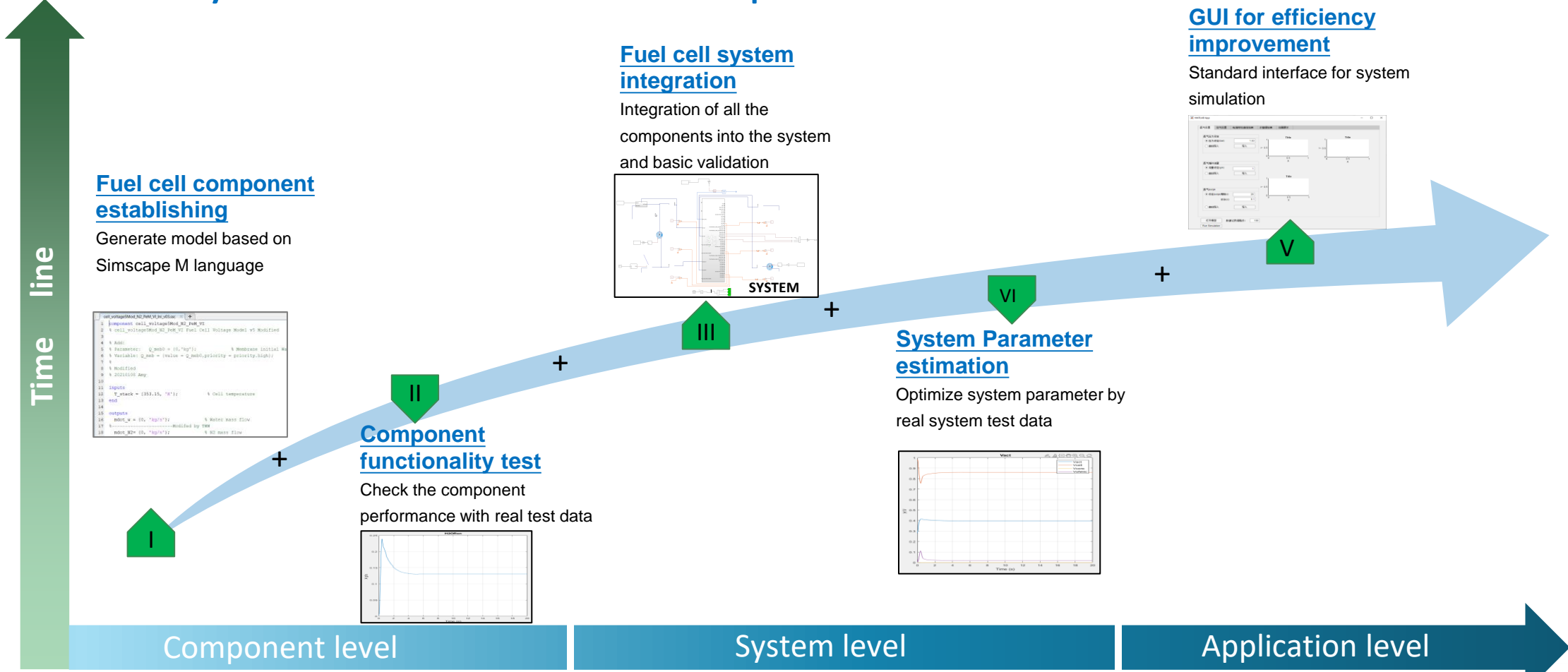
- Using arrow to show the water transport flow
- Using gauge to show the inlet/outlet humidity

Fuel cell App demo



BOSCH fuel cell system model customized based on Simscape

Fuel cell system simulation roadmap



Engine performance



128 Kw

Rated power



-30 °C

Cold start



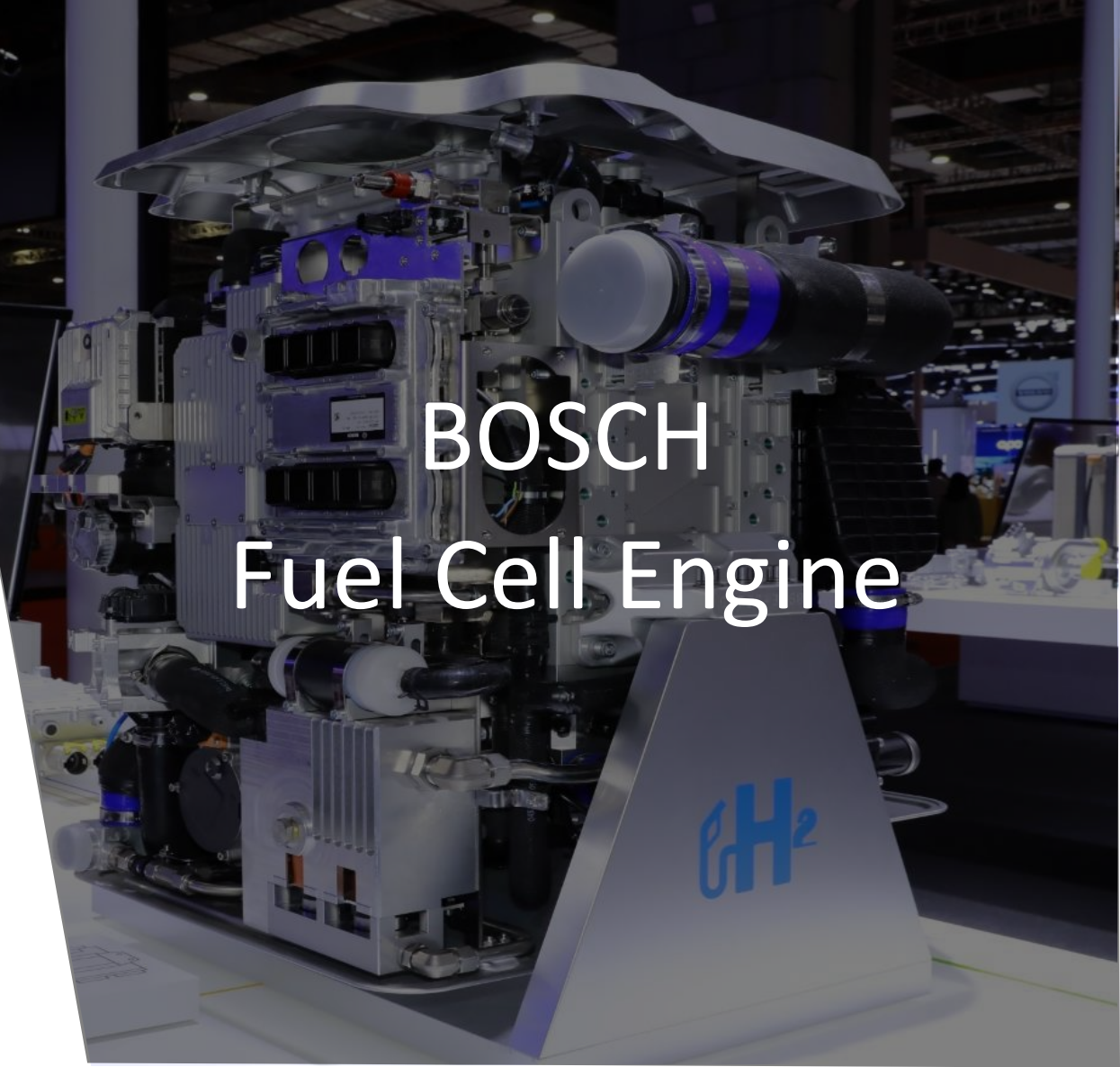
≥60/50

Max system efficiency/normal



30 Kw/s

Dynamic performance



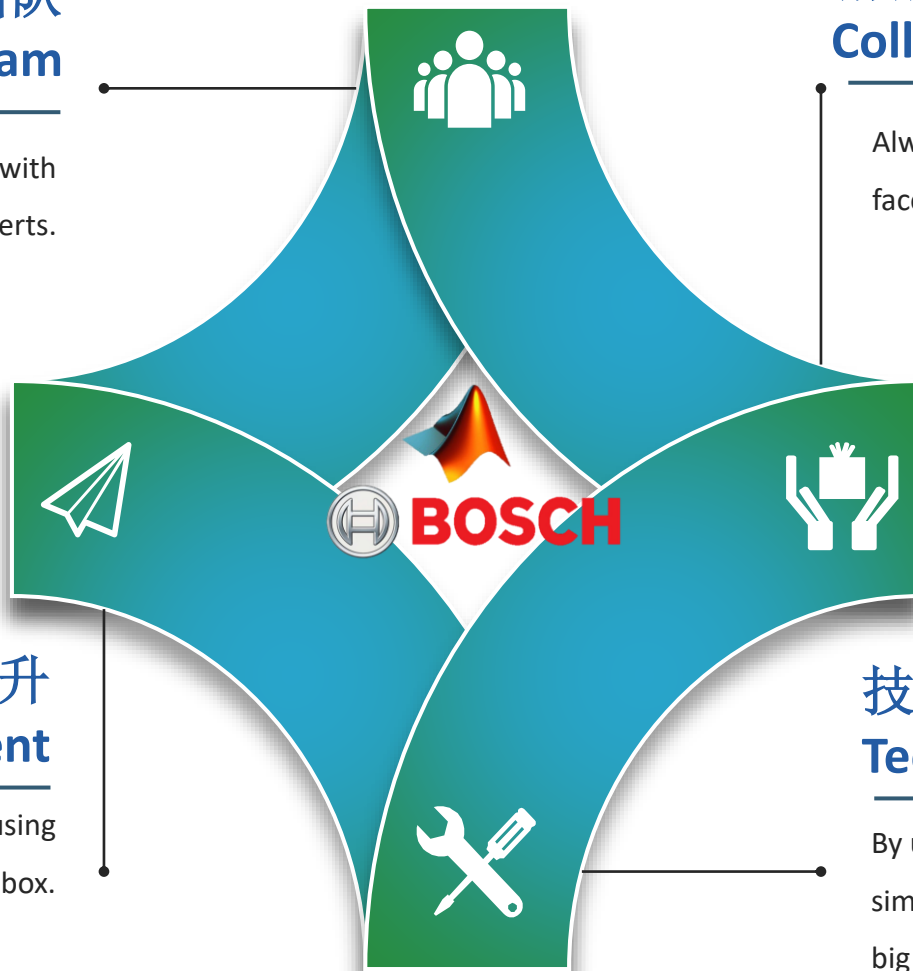
BOSCH
Fuel Cell Engine

专家团队 Expert Team

Engineer discussion involve with lots of MATLAB modelling experts.

精诚合作 Collaboration

Always keep communicating by face to face meeting and WebEx meeting.



能力提升 Capability Enhancement

Familiar with system modeling by using advanced MATLAB simulation toolbox.

技术进步 Technical Advancement

By using MATLAB simulation tool, the simulation technology of fuel cell move a big step.