2026年度　JPECフォーラム

【12】合成ガスの高効率製造技術の開発
～SOEC性能向上と劣化機構解明～

2026年5月12日

（国研）産業技術総合研究所

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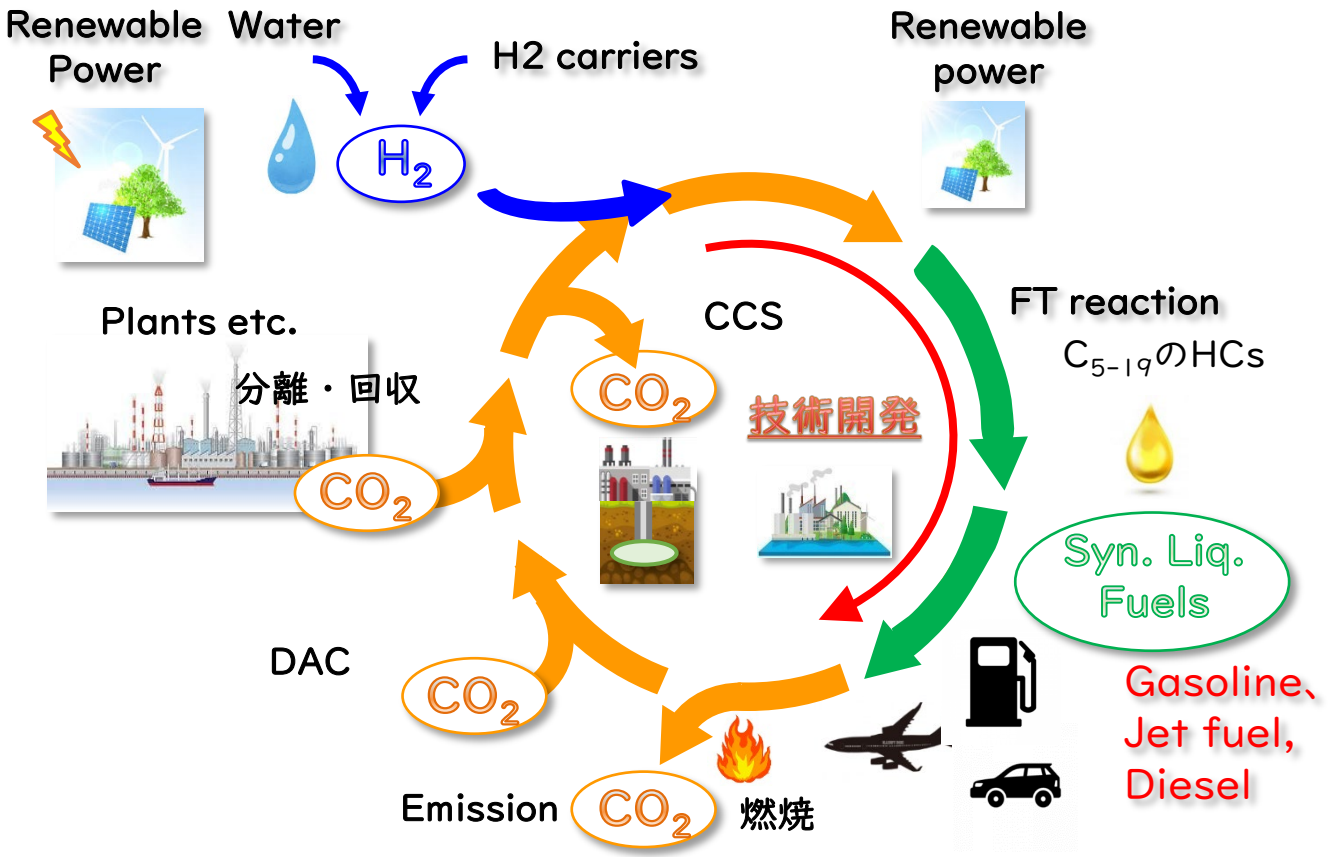
1st stage of an e-fuel project in Japan (2020-2024)

- Almost-4-year NEDO project has just finished.
- AIST contributed to SOEC stack evaluation, process development, Fischer-Tropsch synthesis (FTS), and 10 kW-class SOEC-FTS demonstration with the Japanese oil industry and other partners.



<Partners>

Seikei University
ENEOS
Nagoya Uni.
Yokohama Nation. Uni.
Idemitsu
COSMO oil
AIST
Japan Petroleum and Carbon Neutral Fuels Energy Center (JPEC)

<Period>
FY2020～2024

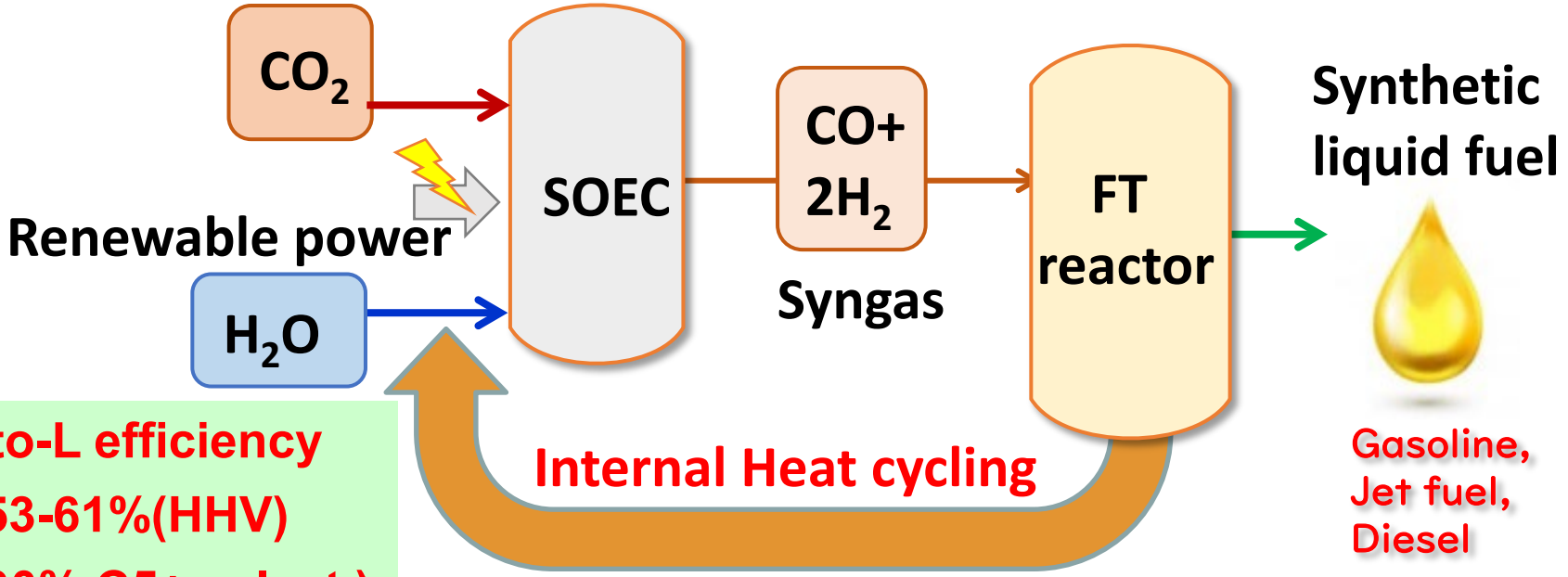
JPEC-AIST: SOEC co-electrolysis + FT rxn Process

Water evapo. : $2H_2O(l) \rightarrow 2H_2O(g)$

Co-electrolysis : $2H_2O + CO_2 \rightarrow 2H_2 + CO + 3/2O_2$; **+1.35 V**

FT synthesis : $2H_2 + CO \rightarrow -(1/n)(CH_2)_n- + H_2O$
(Fischer-Tropsch)

Overall: $H_2O(l) + CO_2 \rightarrow -(1/n)(CH_2)_n- + 3/2O_2$; +1.14 V



P-to-L efficiency
= 53-61%(HHV)
(100% C5+ select.)

Yohei Tanaka et al 2023 ECS Trans. 111 1947

Our roles

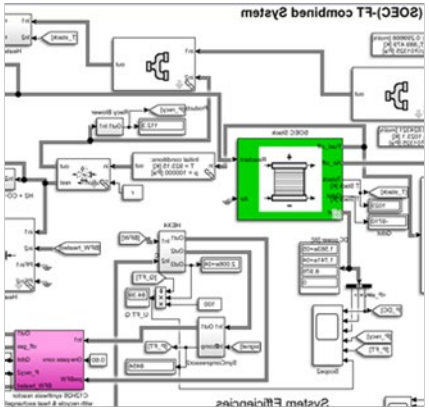
Basic R&D

1. To improve SOEC-FTS process (heat manage., hot gas recycling)

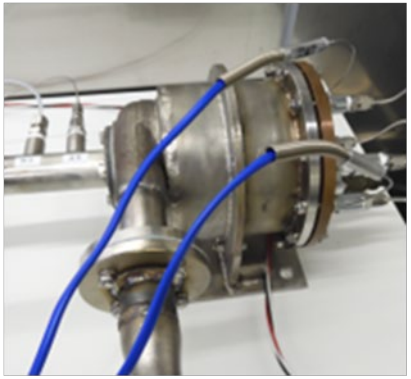
2. Single cell & stack (2 kW) evaluation and degradation phenomena

3. Co-electrolysis simulation for scale up

4. 10 kW-class SOEC-FT demonstration (2024)

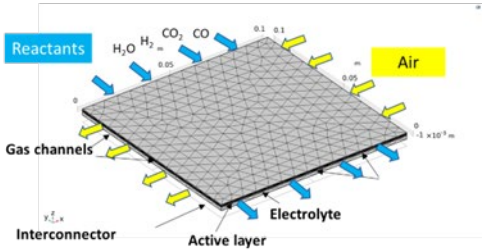


Dynamic process Simulator



HT Recycle blower

Cell & stack performance evaluation



Co-electrolysis cell & stack simulation

Cell & Stack Performance Evaluation

micro-GC

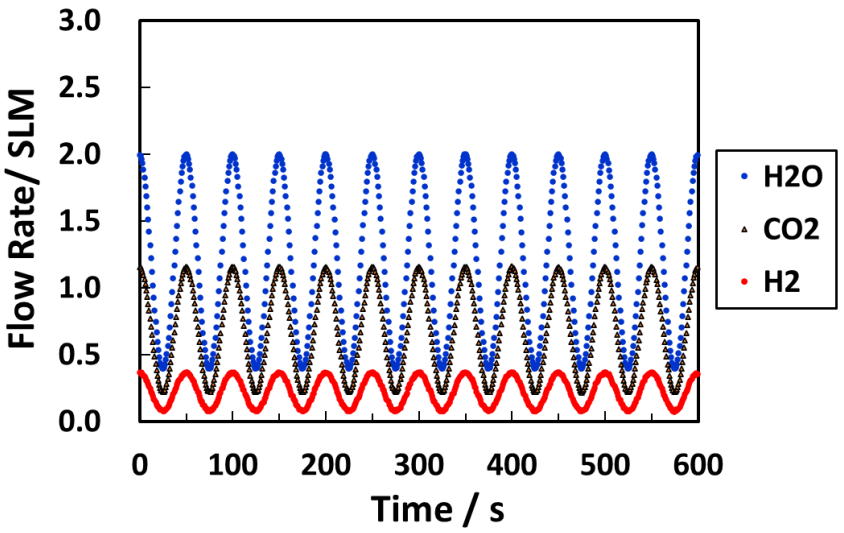
Flowmeter

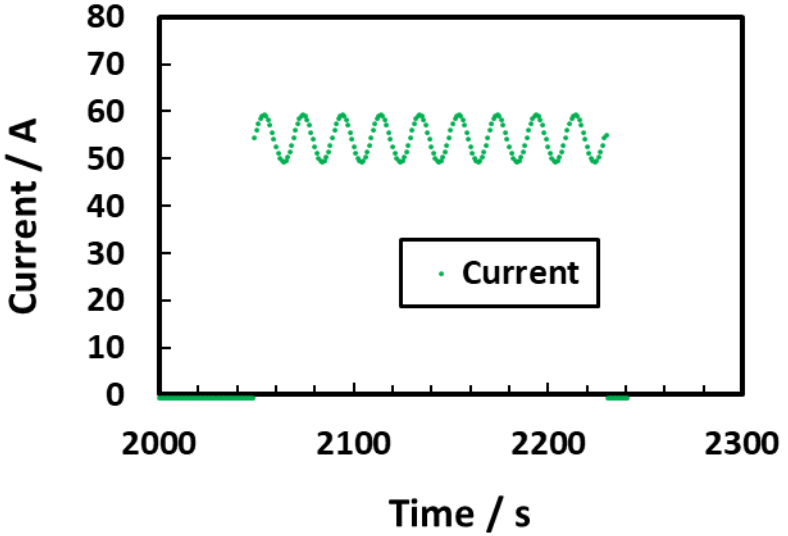
- Gas supply: steam 10 SLM, Air 50 SLM
  （H2O, CO2, H2, N2, Air/O2)
- H2O/CO2/H2 for Fuel electrode
- Flow rate precision: ±1% of setpoint
- DC input： ～ 4 kW
- I-V measurement: current step < 100 A
- AC Impedance meas. Of whole stack & each cell up to 30 cells (simultaneously)
- Output H2/CO analysis with GC and flowmeter including steam ⇒ C-H-O-N mass balance

SOEC stack test simulating RE Fluctuation

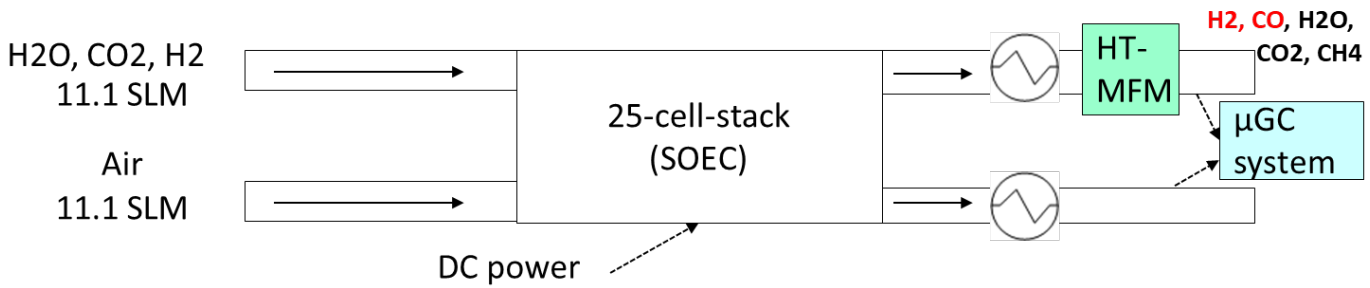
- Control of both gas flows and current to keep reactant utilizations constant (< 1 Hz)
- Waveform ：step, sine, ramp up or down, and triangle
- 6 cell-stack test finished in 2024

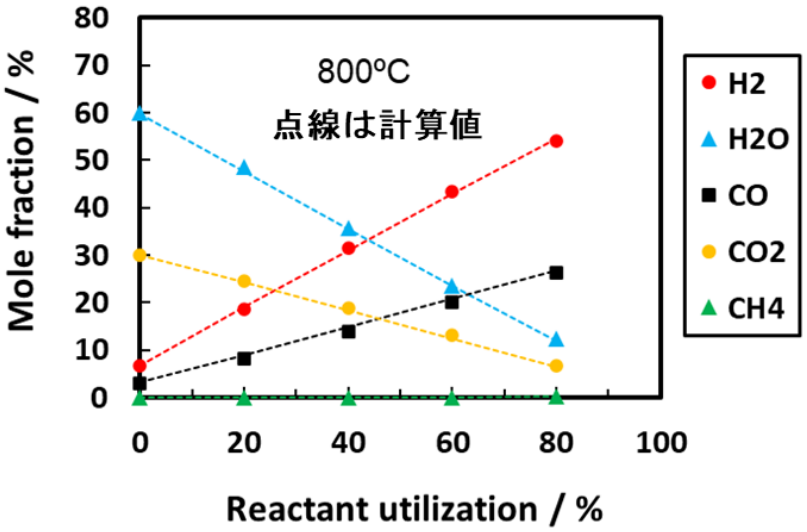
Gas-flow sine-wave control (10 mHz) with current





H2/CO gas measurement at the 25-cell-stack



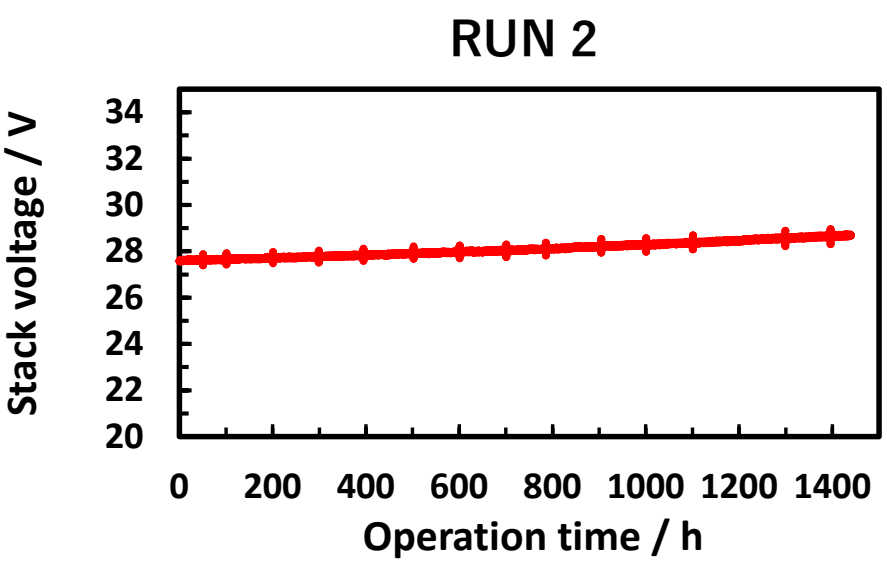


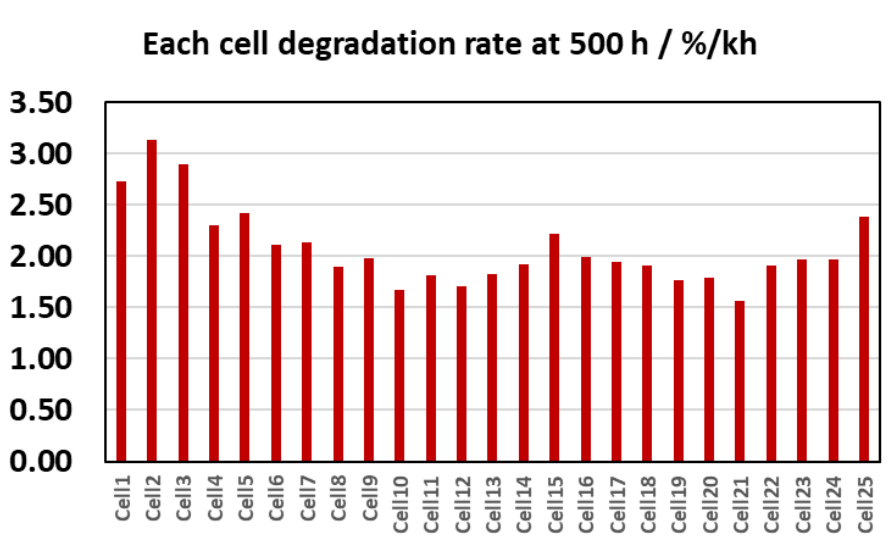
U (%)	Product flowrate (fuel side) (SLM) Meas.	Calc.	dev / %
0	10.98	11.11	-1.20
20	11.14	11.12	0.19
40	11.17	11.11	0.50
60	11.15	11.10	0.41
80	11.07	11.06	0.07

- Produced fuel gas composition agreed to equilibrium one by ±0.5%
- H2/CO ratio at *U* = 80% was 2.05 against 2.07 in calculation
- Faraday efficiency was estimated as 99.8% at 800℃

25-cell-stack test results at 825 °C

- 825℃, H2/C= 2, *U* = 70%, 0.6 A/cm^2
- Gas analysis revealed 99.8% Faraday efficiency
- Test stopped in weekends to room T ⇒ Thermal cycles did not affect performance





- Degradation rate reduced to 2.0-2.6%/kh (repeatability)
- 10 kW demonstration operation at 825℃, 0.6 A/cm^2, U= 70%

Co-electrolysis degradation summary

- **Degradation rates**

  25 cell-stack 2.0-2.6%/kh < single cell 3.7%/kh < 6-cell 7.2%/kh

  (825℃) (800℃) (850℃)

Temp. (°C)	Current density J (A/cm2)	Degradation rate (%/kh)	Observation	Electrolyte phase transition
800	0.6	3.7	Carbon (C) deposition and Ni migration	Yes
825	0.6	2.0-2.6	Partial Ni migration	Yes
850	0.6	7.2	No C deposition or Ni migration	Yes

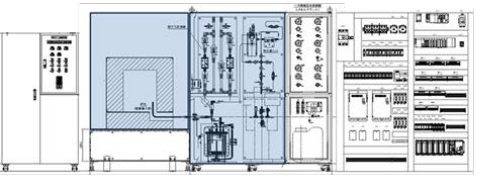
- **Steal electrolysis resulted in Ni depletion at fuel-electrode inlet,**
- **At co-electrolysis, carbon deposition will promote Ni migration**
- **Proposed SOEC design: lower overvoltage at the fuel electrode and operation near the thermoneutral voltage (1.35 V)**

10 kW-class SOEC-FTS demonstration in 2024

- 10 kW-class SOEC-FTS demonstration unit installed in AIST Tsukuba
- **Synthetic crude oil (5 L/day)** was successfully produced in FY2024

Synthetic crude oil

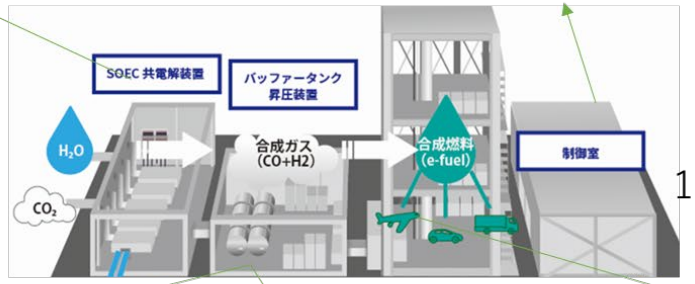
SOEC co-electrolysis unit



Reaction condition of SOEC unit
- Number of Stack : 2~4
- Reaction Temp. : ~900°C
- Feedstock supply
  H_2O : ~13.75NL/min
  CO_2 : ~6.75NL/min
- Synthesis gas production capacity : ~1500L/h

Operating room

Reaction condition of FT unit
- Reaction tube heating system: heat transfer oil circulation system
- Reaction pressure : < 0.9MPaG
- Catalyst bed length : 3m×2
- Catalyst bed volume : ~1800cc
- FT oil production capacity : ~200cc/h



Buffer tank, Compressor

FT bench unit

Summary

- A static and dynamic SOEC stack testing method was developed to simulate Renewable Power Fluctuation (constant reactant utilization).
- SoA SOFC stack showed 2.0-2.6 %/kh degradation rate at 825℃. 10 times higher than in FC mode
- SOEC degradation was mainly due to increase in ohmic resistance and activation polarization.
- JPEC and AIST successfully implemented 10 kW SOEC-FT synthesis demonstration in 2024.
- From FY2025, we will improve SOEC performance and durability.

Acknowledgement

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