



# Hydrogen and Fuel Cells for the Future Sustainable Growth

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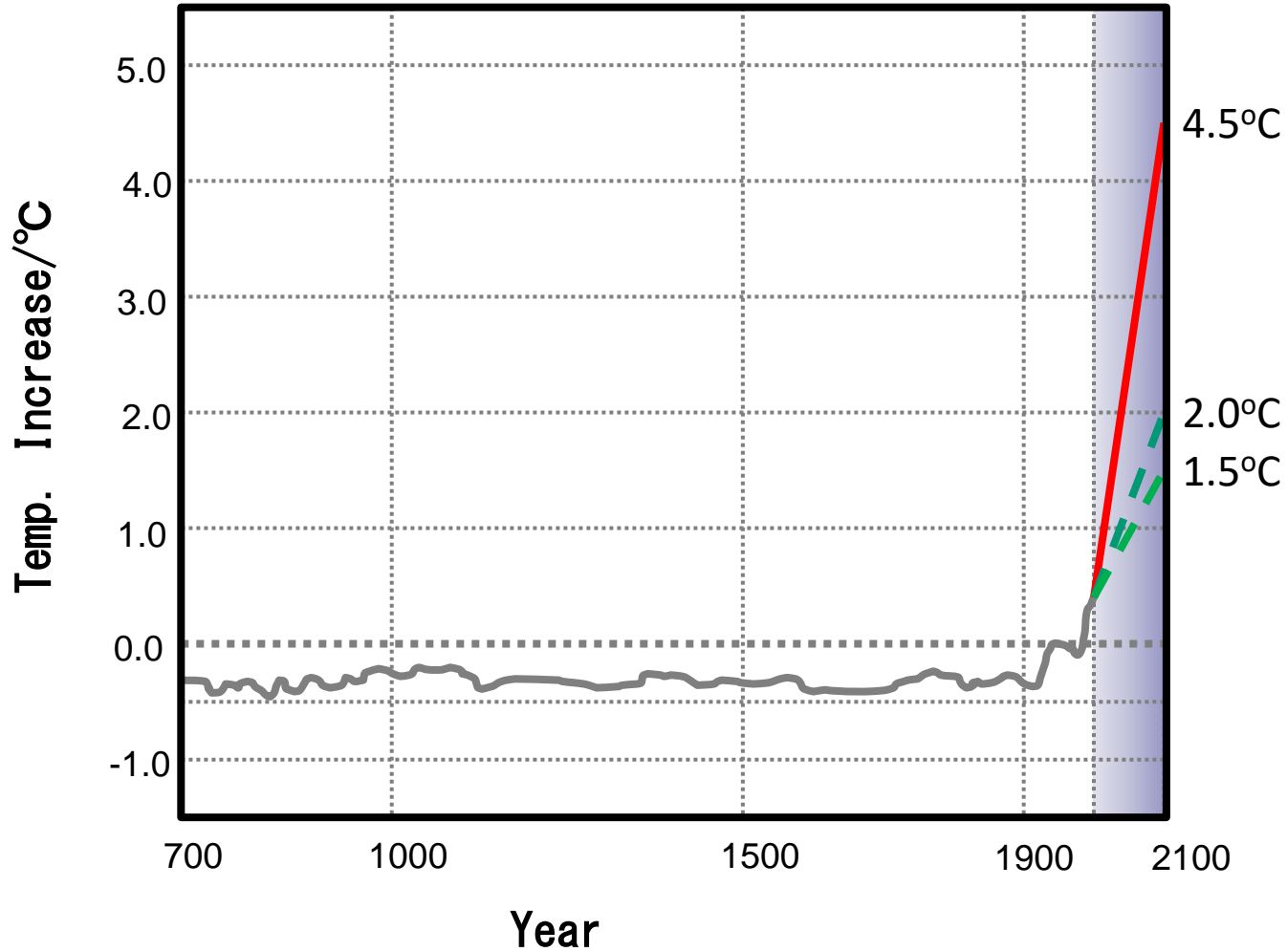
**Green Hydrogen Research Center**

**Yokohama National University, JAPAN**

IPHE Forum Yokohama, May 8<sup>th</sup>, 2018,  
Yokohama Grand Intercontinental Hotel, Yokohama, Japan

# Rapid Global Warming on the Earth

Green Hydrogen Research Center, Y.N.U.



(by IPCC 4<sup>th</sup> Report(2007))

# Global entropy flow for sustainable growth

Green Hydrogen Research Center, YNU



The earth is a closed system.

Human society

Materials circulation

Entropy production by the activity of human beings

Resources to the human society

Wastes of the human society

Solar energy  
Low entropy

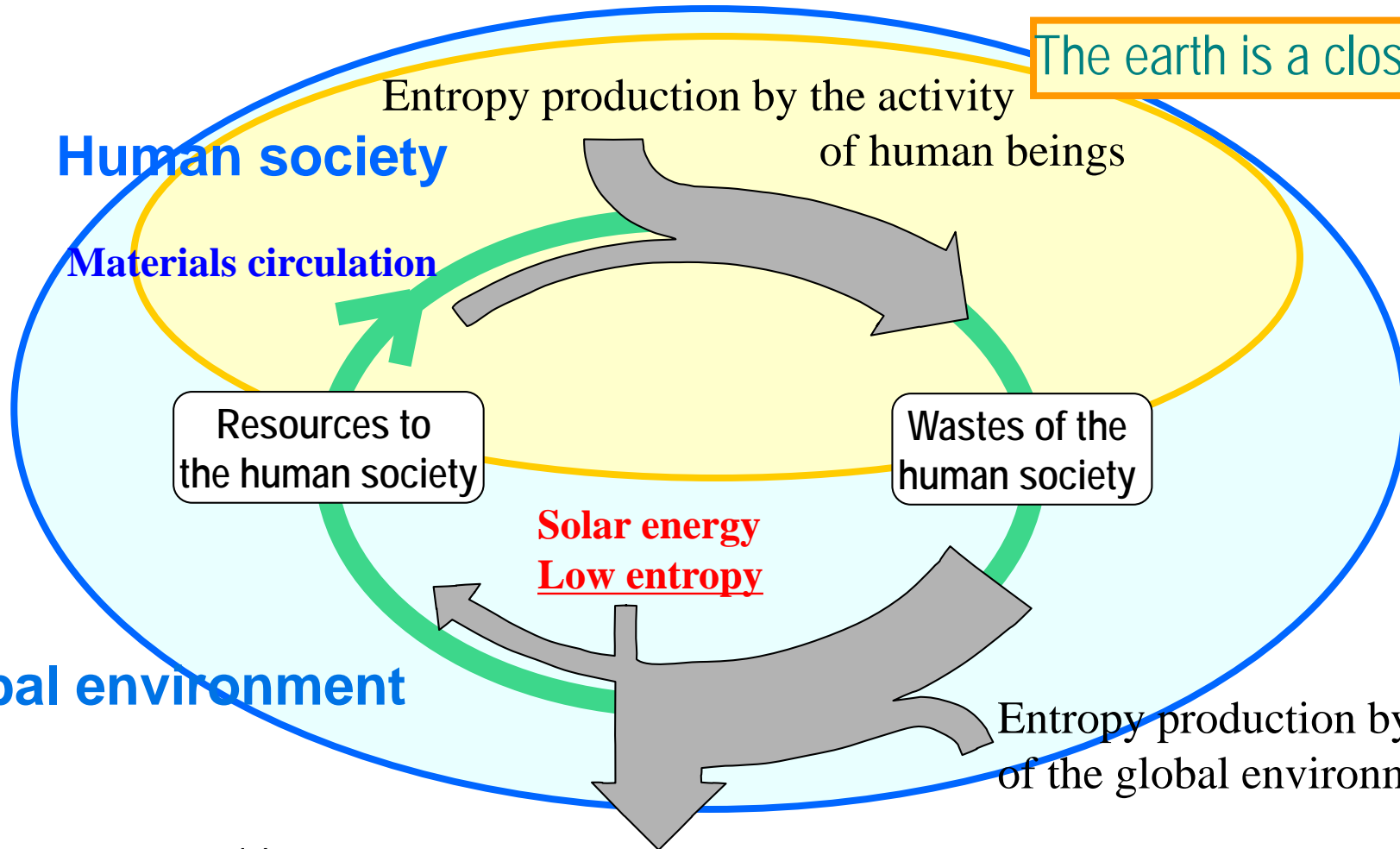
Global environment

Entropy production by the activity of the global environment

Heat radiation to the space  
High entropy

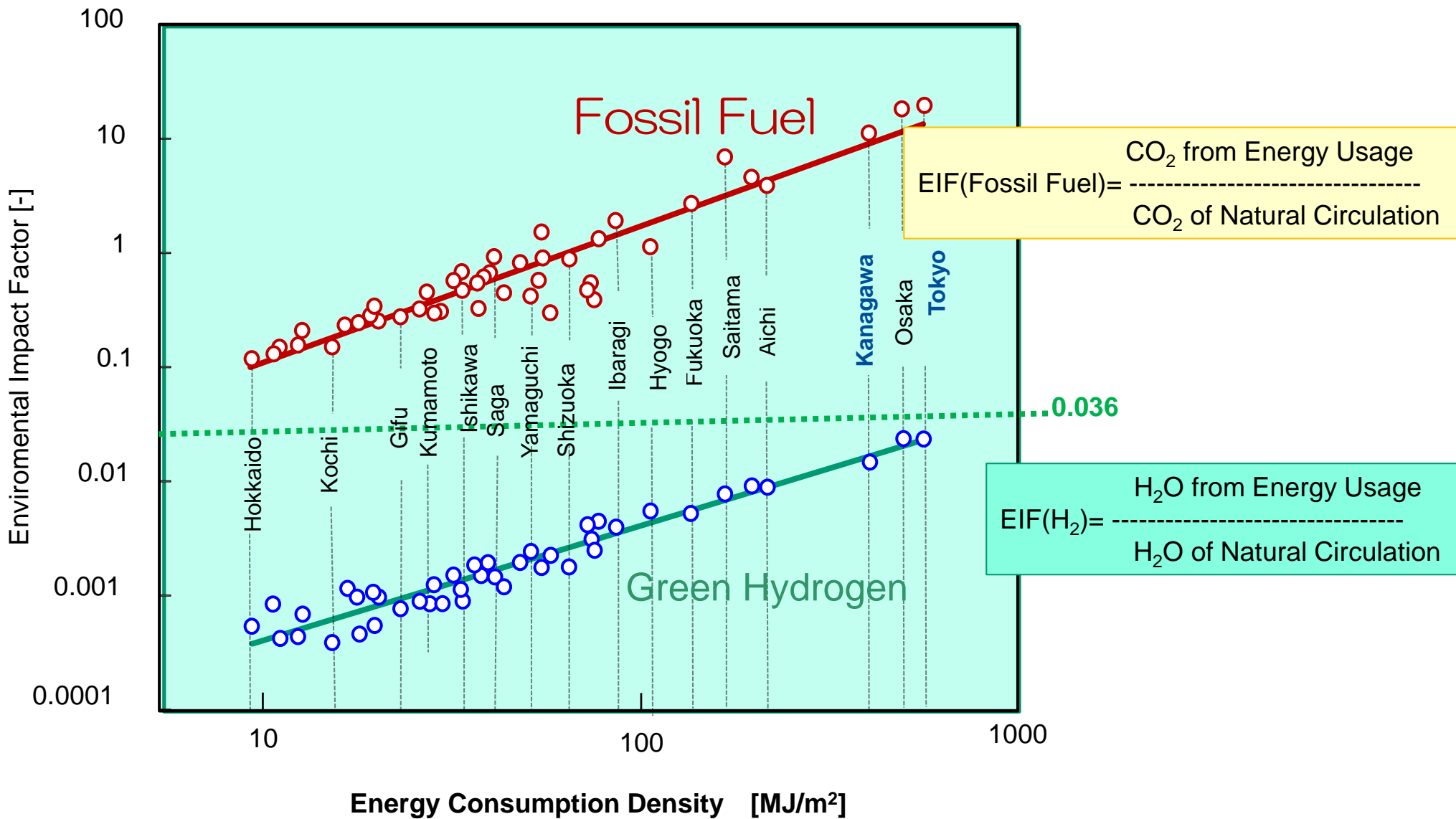
$$Q: 1.2 \times 10^{14} \text{ kW}$$

$$\Delta S = 4.7 \times 10^{11} \text{ kJ/K} \cdot \text{s}$$



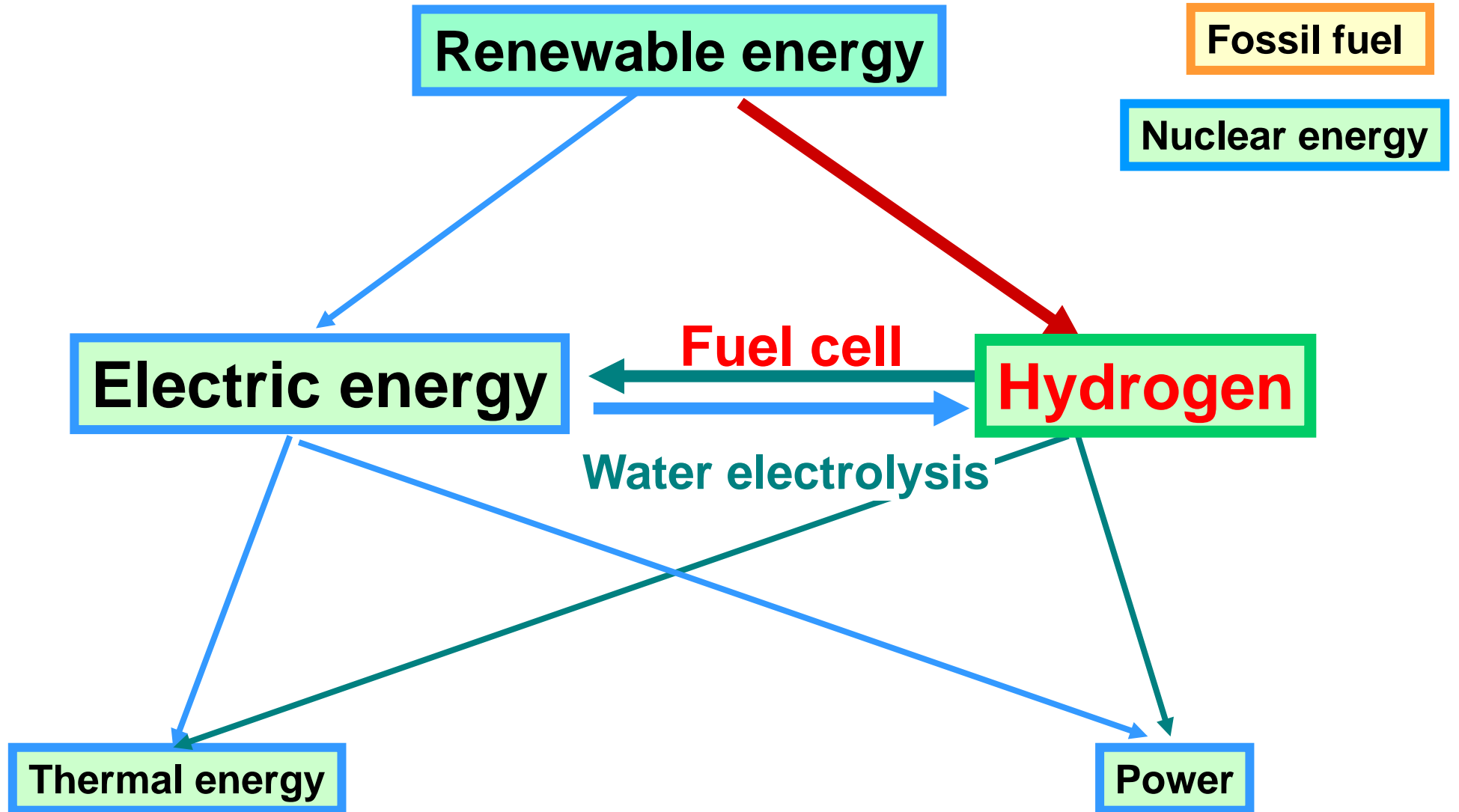
# Dependence of EIF on Consumption Density (2005-2014)

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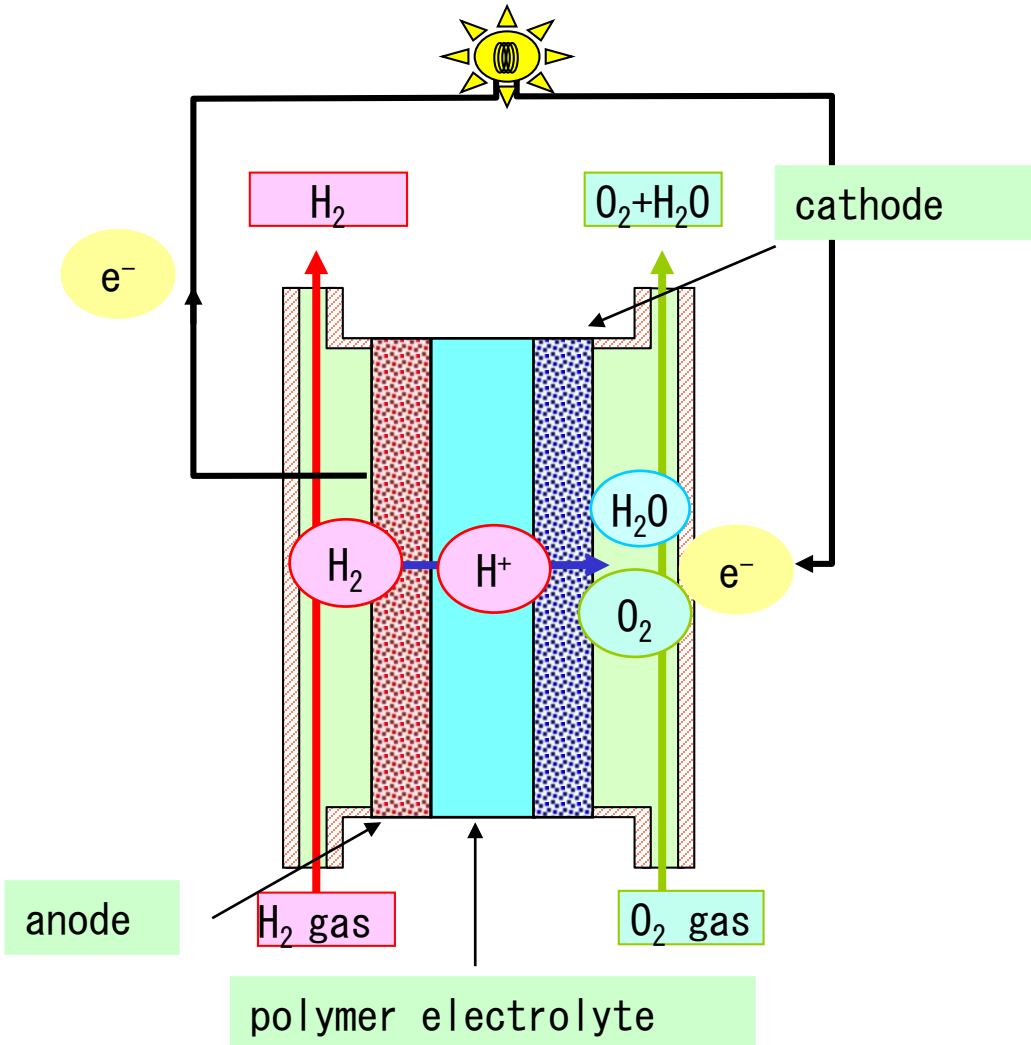


# Green Hydrogen Energy System

Green Hydrogen Research Center, YNU



Green Hydrogen: Hydrogen from water using renewable energy.



## Characteristics

- High power density
- Low operation temperature

## Applications

- Co-generation system (CHP)
- Fuel Cell Vehicle
- Mobile power source

## Major technical issues

- Cost down
- Improvement of performance

# 1 kW PEFC at my home

(2005.7.09 - )



Green Hydrogen Research Center YNU



## 1 kW home cogeneration system

The commercialization started in 2009.

Over 220,000 units are operating in Japan.

### Capacity

1 kW – 700 W

Hot water (60°C, 200 L)

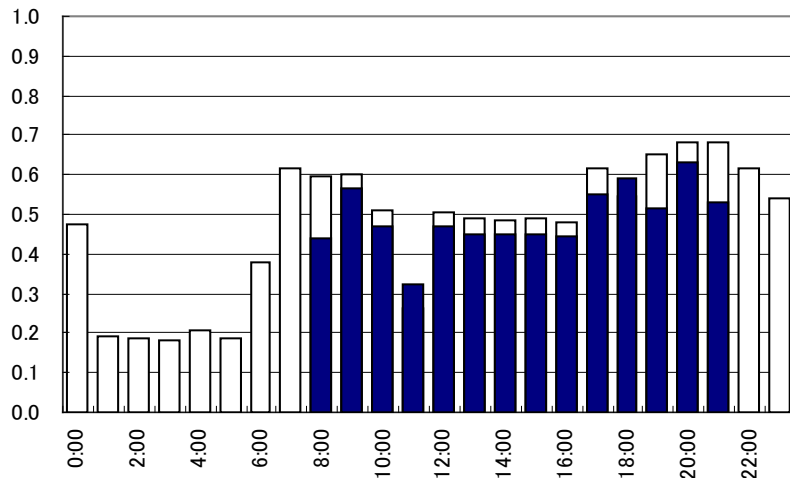
Daily Start and Stop

without N<sub>2</sub> purge

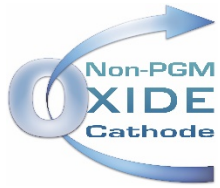
(Hot water oriented mode)

Life > 10 years

**The cost target: 7,000 US\$/unit in 2020.**



Month	CO <sub>2</sub> Reduction kg-CO <sub>2</sub>	CO <sub>2</sub> Reduction %
Jan	17.5	11.5
Feb	38.3	21.6
Mar	41.8	21.9



# FCVs in Japan

Green Hydrogen Research Center YNU



Compressed H<sub>2</sub> gas ( 70 MPa)  
Driving Range > 650 km  
Life > 10 years (5000 h)

Cold start at - 30°C

Output Power: 3 – 3.5 kW/L

➔ **NEDO's new target is 9 kW/L  
in 2040.**

**Commercialization has started in 2014.**

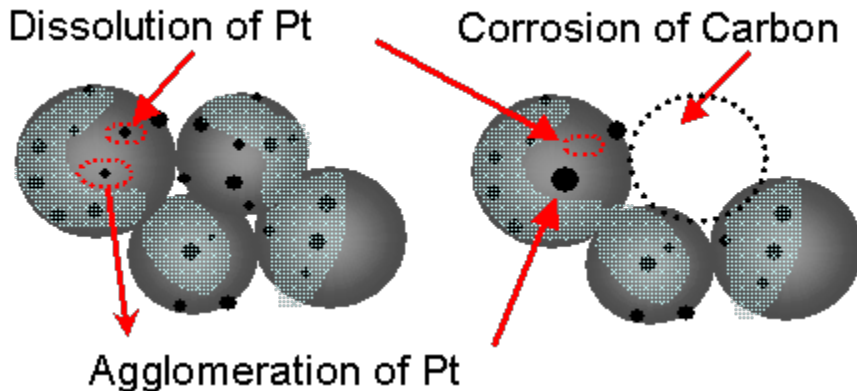
**Target 200,000 FCVs with 320 H<sub>2</sub> Stations  
in 2025.**



## Problems of cathode catalyst

Resources of Pt  
High cost and limited !!

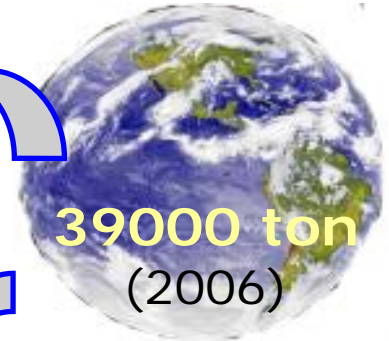
Instability of Pt cathode  
Limit of reduction for Pt usage!



## Pt resources

100 kW FCV

→ 50 g Pt !!

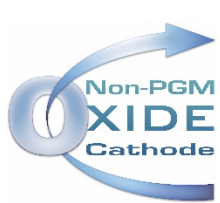


800 million



Number of motor vehicles (2009)

965 million  
(in the world)



# Concept of Non Pt Cathode for PEFCs

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**High stability**



**Combined**

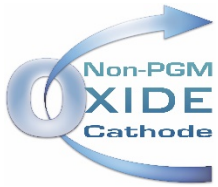
**High catalytic activity**



Group 4 and 5 metal oxides are stable in acid and  $O_2$  .



**Development of innovative materials.**

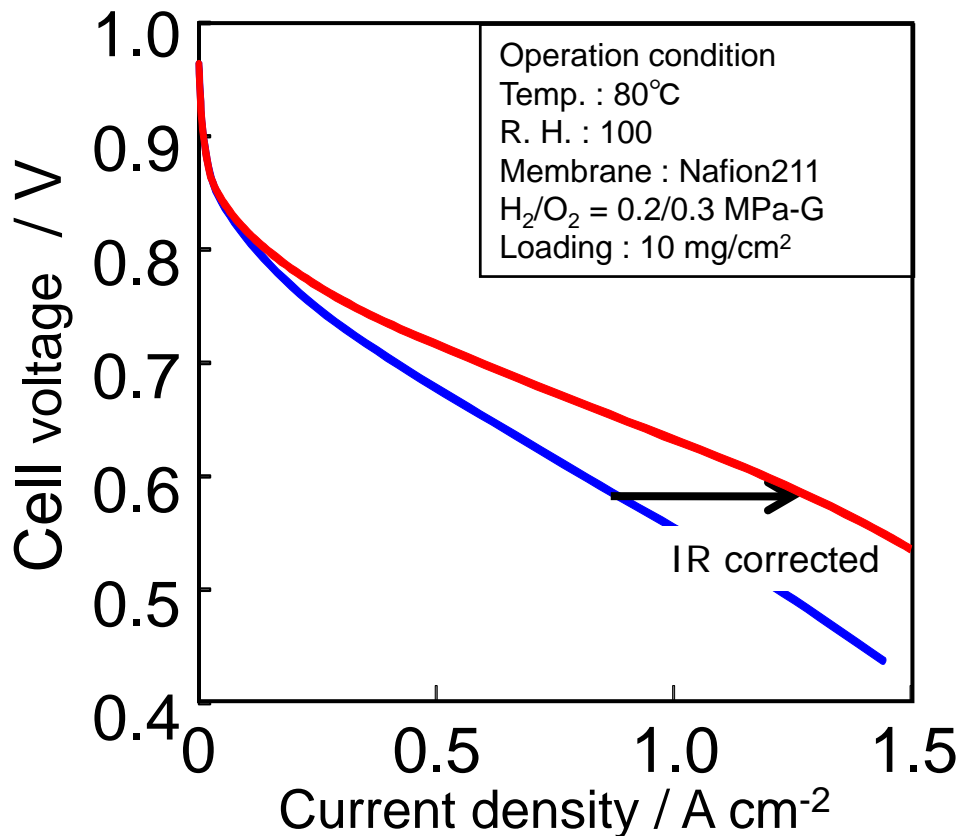


# Single cell performance

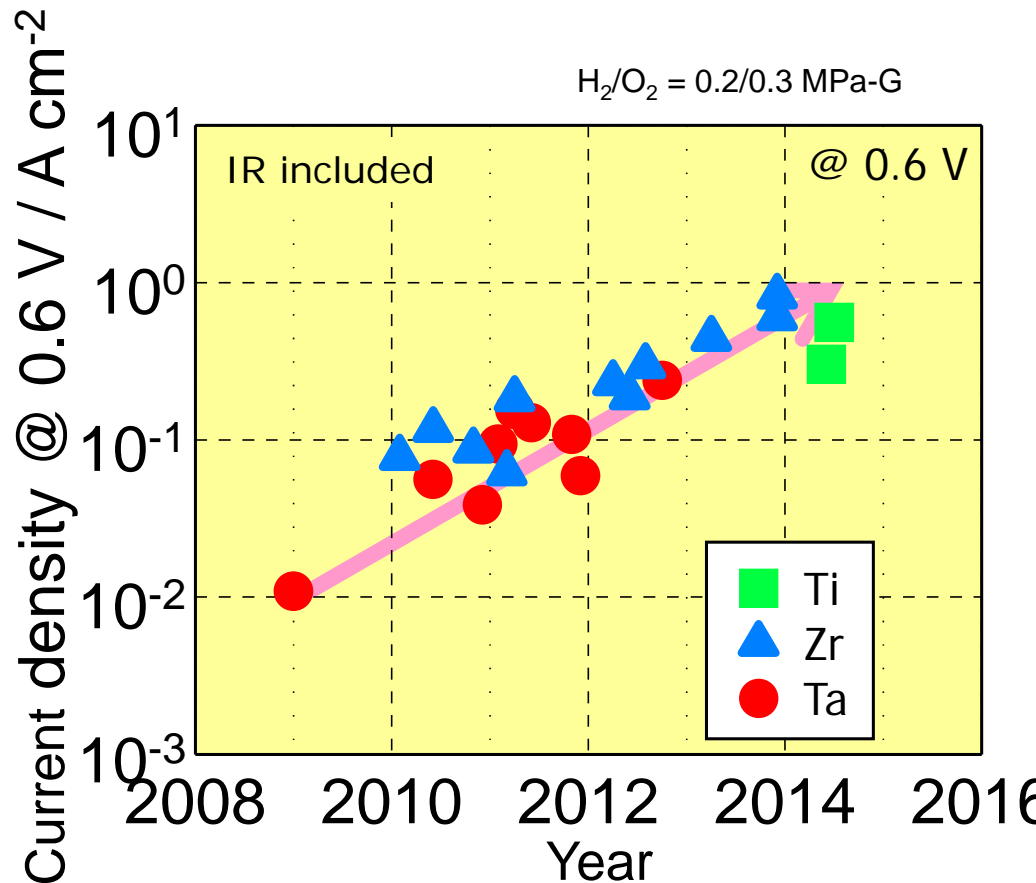
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## Zr oxide-based cathode



1.2 A cm<sup>-2</sup> @ 0.6 V (IR corrected)



Cell performance increased drastically.

## PEFC for Future Generation

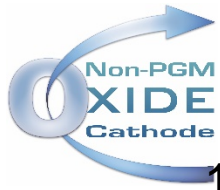
- More Stable Fuel Cell
- More Efficient Fuel Cell

Operating voltage: ~ 0.9 V

Energy Efficiency: ~ 60 %(HHV)

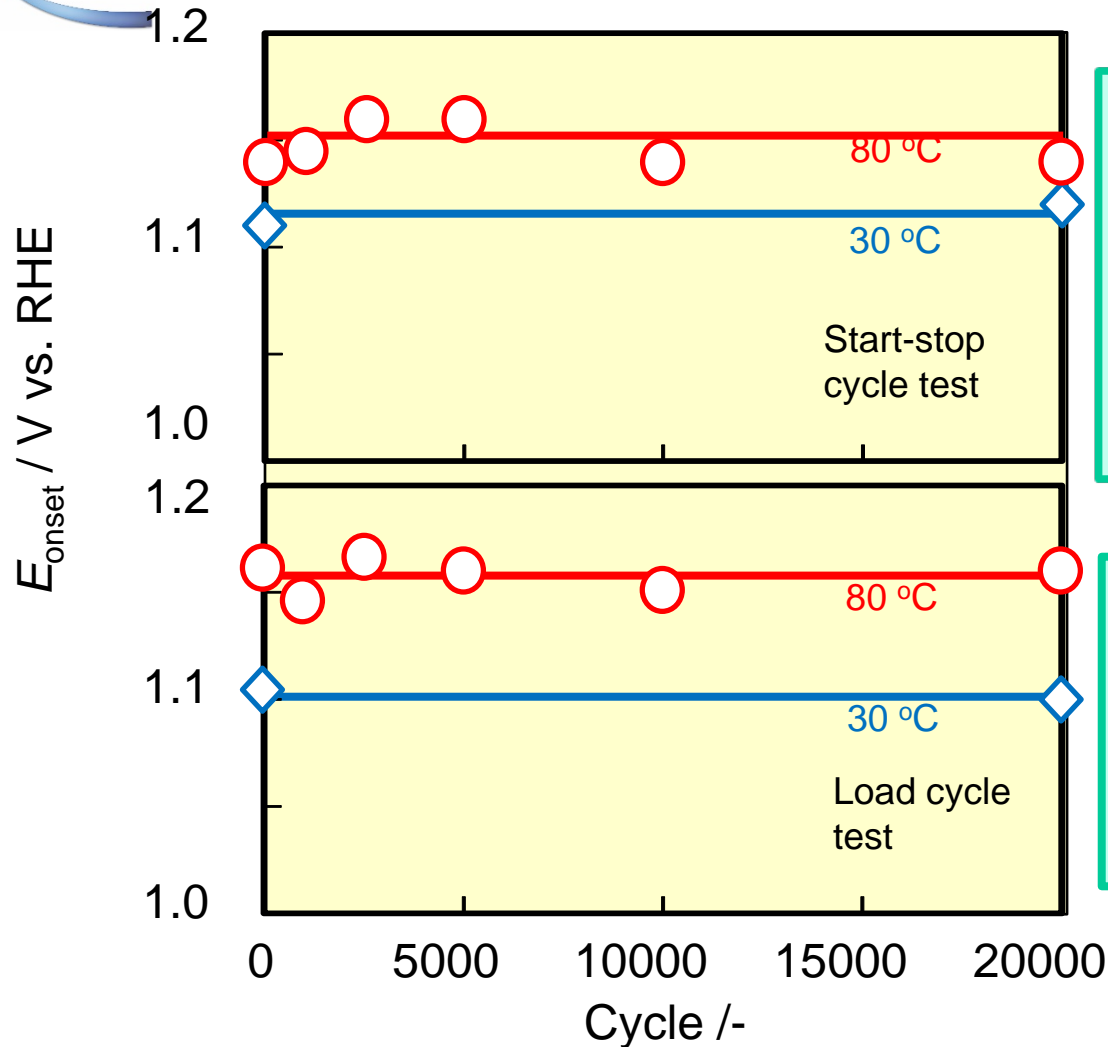
Operating temperature : 120 °C or higher

**Our target: NPGM Catalyst without Carbon.**



# Onset Potential during the potential Cycle

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High onset potential



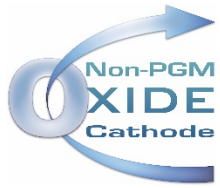
High quality of active point.  
More than Pt ?

No change during cycles.



Active points are stable.

Fig. Onset potentials of  $\text{Ti}_x\text{Nb}_x\text{O}_z$  supported by  $\text{Ti}_4\text{O}_7$ .  
 $E_{\text{onset}} \sim -20 \text{ nA/cm}^2$ , Ti:Nb = 85:15



# Acknowledgment

*Green Hydrogen Research Center, YNU*



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