

# Overview of HTR and Nuclear Hydrogen Development in Korea

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- **Why hydrogen**
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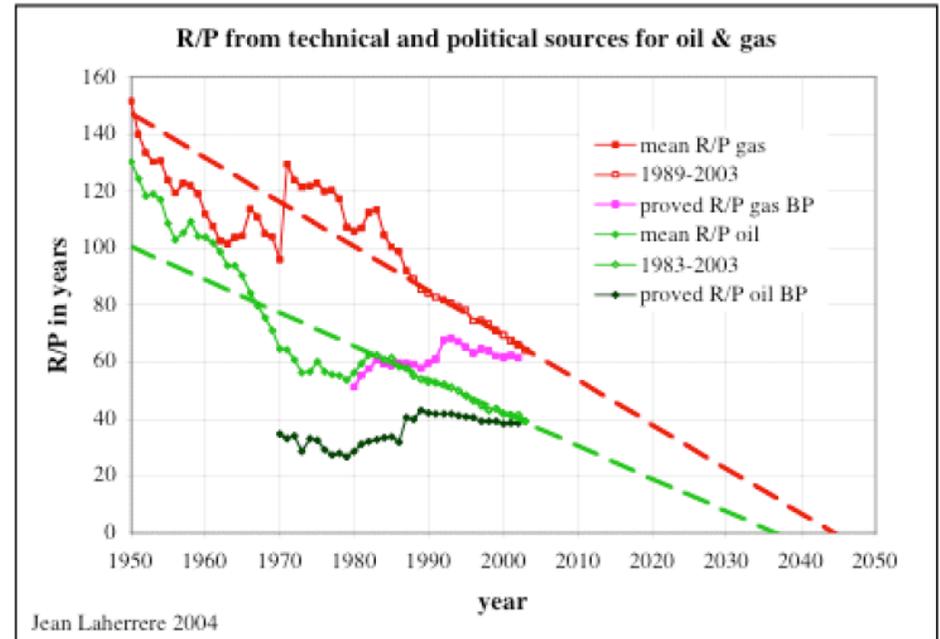
# Background of Hydrogen Economy

## ■ Global warming and Climate change

- Fossil fuel emits CO<sub>2</sub>

## ■ Crude oil and natural gas Resource Limit

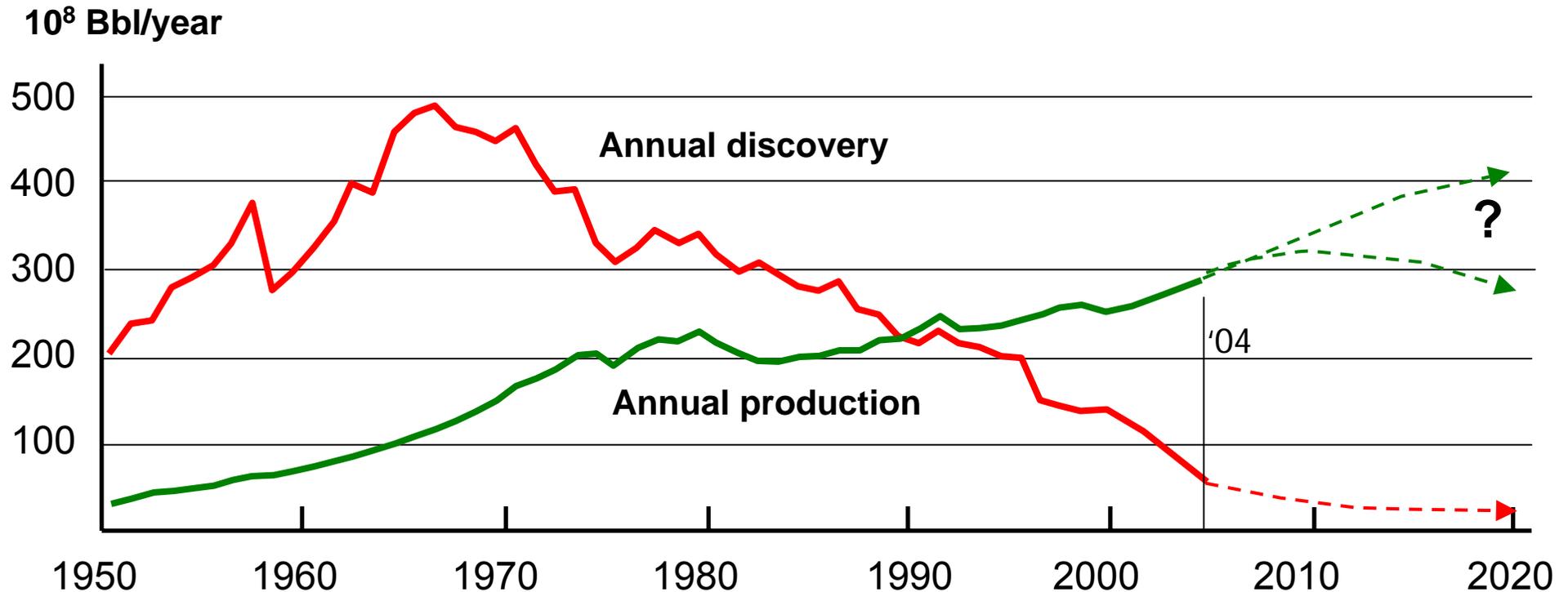
- within 2 generation
- demand growth in developing country



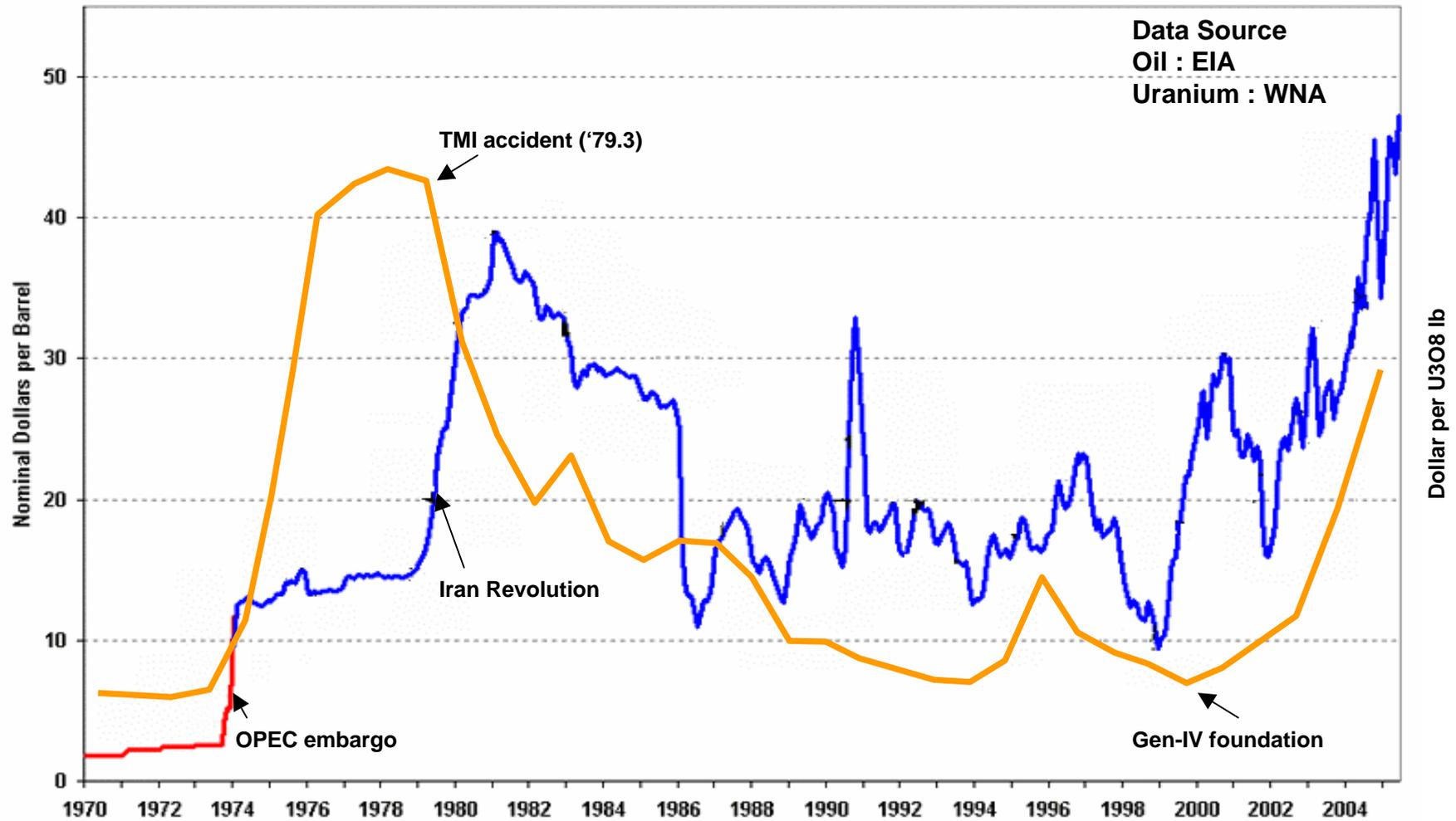
# Crud oil production in world

## ■ Production rate overruns Discovery rate

- Price raise is seen and occurring !
- End of cheap oil. Too expensive to burn.



# Primary energy price



# Fuel Efficiency of Hydrogen Vehicle

- Fuel efficiency is twice by using Fuel Cell.
- No air pollution and GHG emission.

Ref : Hyundai Motor (2003)

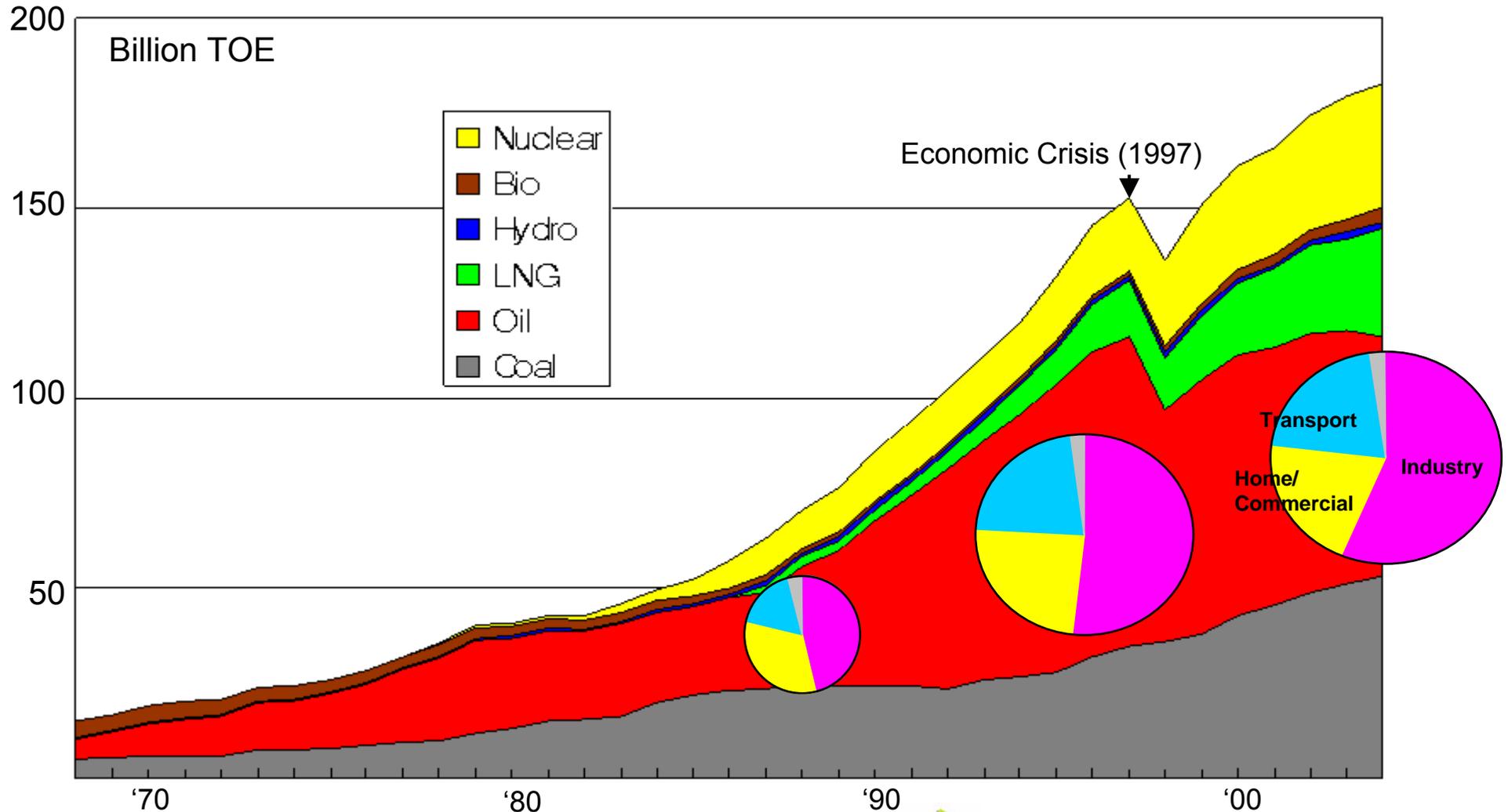
Santa-Fe	Well-to-Tank(%)	Tank-to-Wheel(%)	Overall Eff.(%)
Gasoline Car	88	18	16
Diesel Car	89	22	20
Electric Car	26	80	21
Fuel Cell Vehicle	75 (H2 from Natural Gas)	48	36 (Target: 43)

# Energy situation in Korea

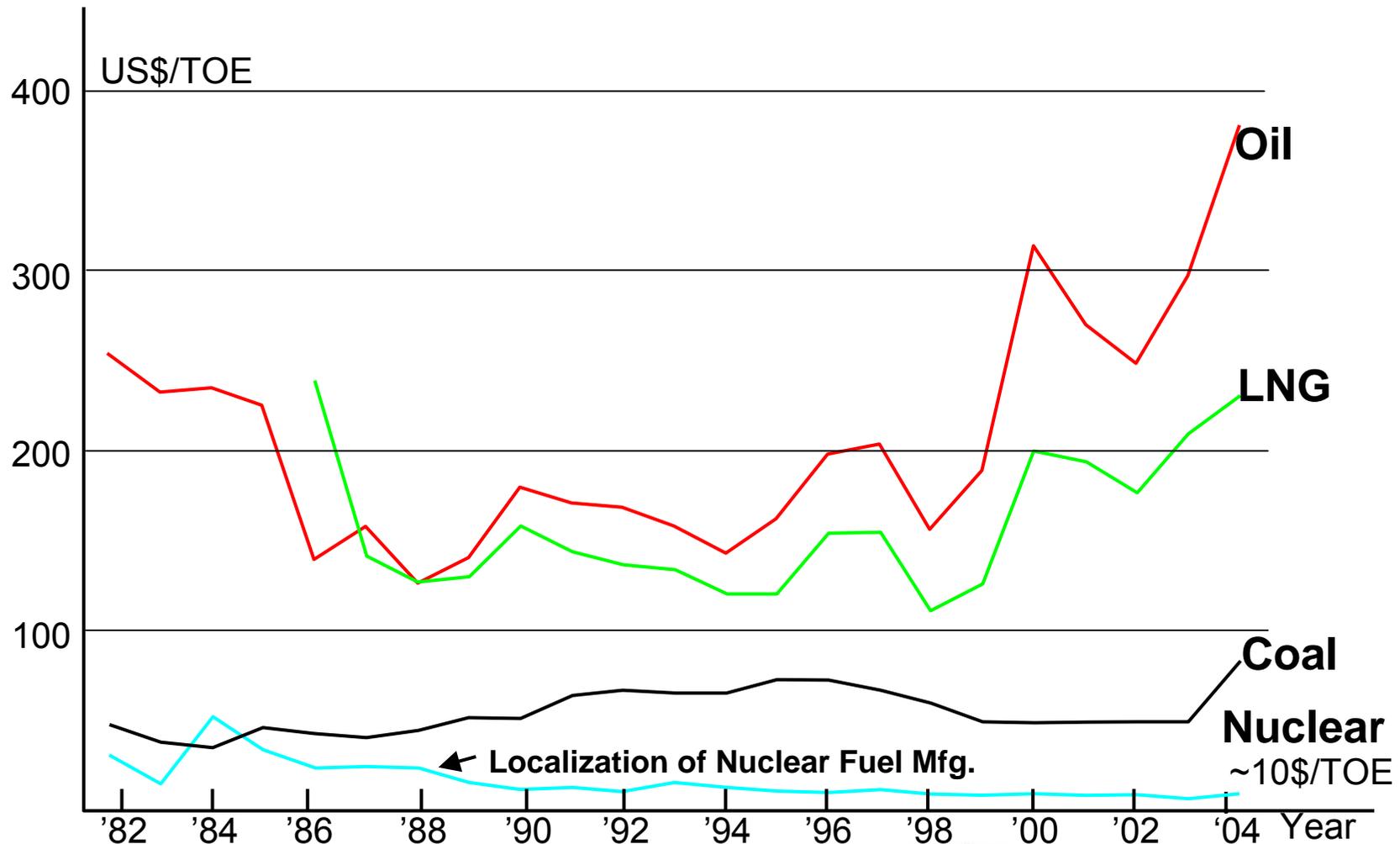
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- **Korea do not have domestic energy resources.**
  - domestic energy supply is less than 2.5%. (hydro, waste and biomass)
- **Energy consumption is expanded with development in Economy.**
  - 3.4% growth for 4.7% GDP growth (during '00-'05)
- **Nuclear electricity was proved as a stabilizer during the economic crisis in 1997.**

# Energy Usage and Consumption in Korea



# Energy Import Price in Korea



# Nuclear Energy in Korea

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- **Produce 40 % of Electricity**
- **Pay less than 5% of Fuel import for electricity**
- **Nuclear energy is technology leading energy.**
  - Enriched uranium cost is less than 5 % in generation cost.
  - Uranium ore cost is less than 1.5%.
- **Fuel price variation is mild**
  - Long term storage is easy (1 kg of uranium produces energy of 10,000 barrel oil.)
  - Uranium mine is found in every continent on earth.

❖ World uranium reserve is sufficient for next 200 ~ 300 years of PWR need. Fast reactor can recycle the spent fuel for next 10,000 years. Ref: OECD/NEA News, 2002, 2006.

# **Nuclear Energy in Korea**

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- **Nuclear Energy is regarded as indigenous.**
  - **Good infrastructure for development.**
  - **Less land for “renewables” (or high population density)**
- ▶ **Hydrogen production using Nuclear energy is necessary in future.**

# Limit of Renewable Energy

Ref) Energy in Japan, METI, 2003.

## ■ Solar

- on Roof of every building
- 770 km<sup>2</sup> , 700 B\$ investment  
equiv. 11 plants (1000MWe)**

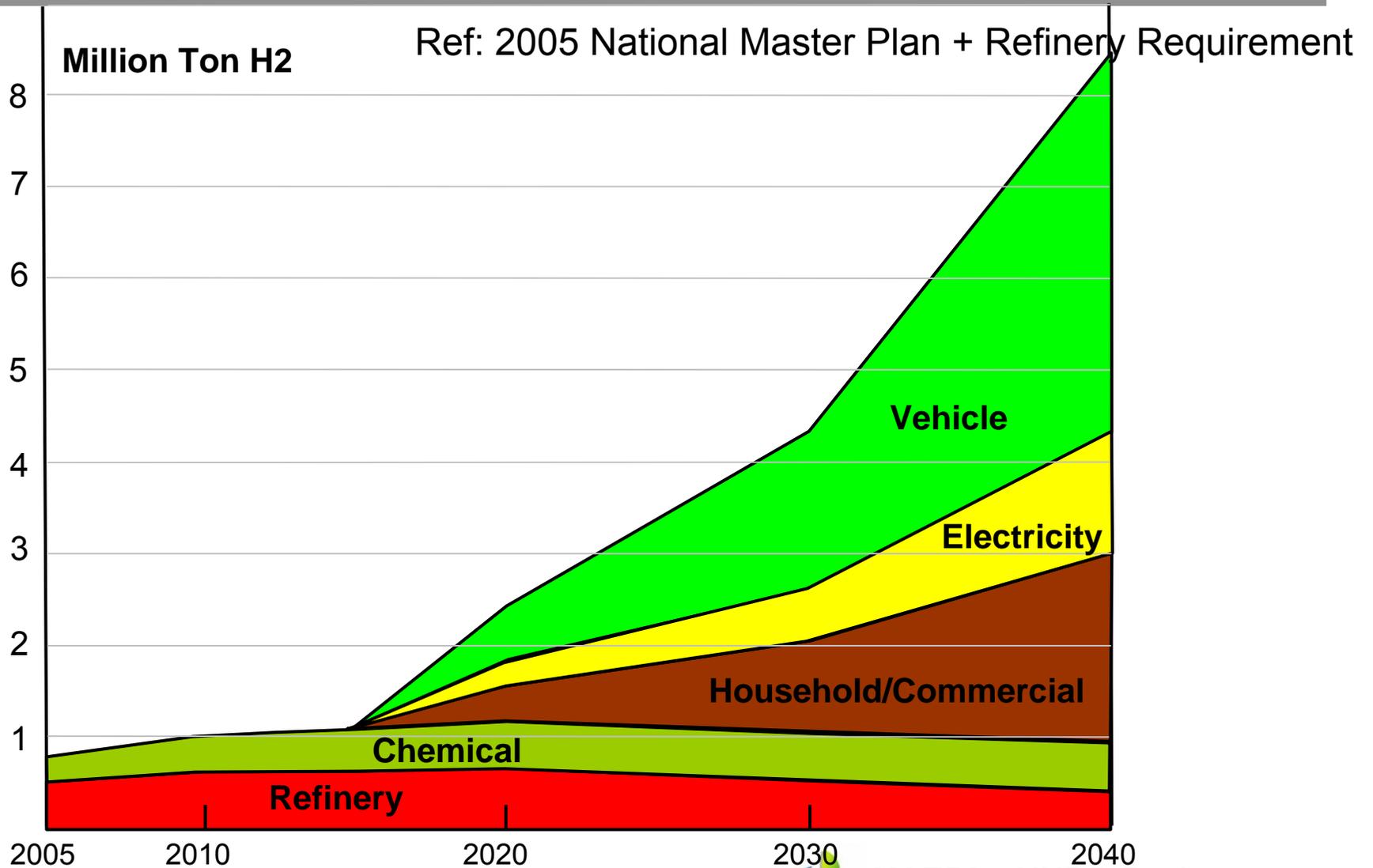
## ■ Wind

- on No-plant land
- 1,500 km<sup>2</sup> , 60 B\$ investment  
(except land price)  
equiv. 6 plants (1000 MWe)**

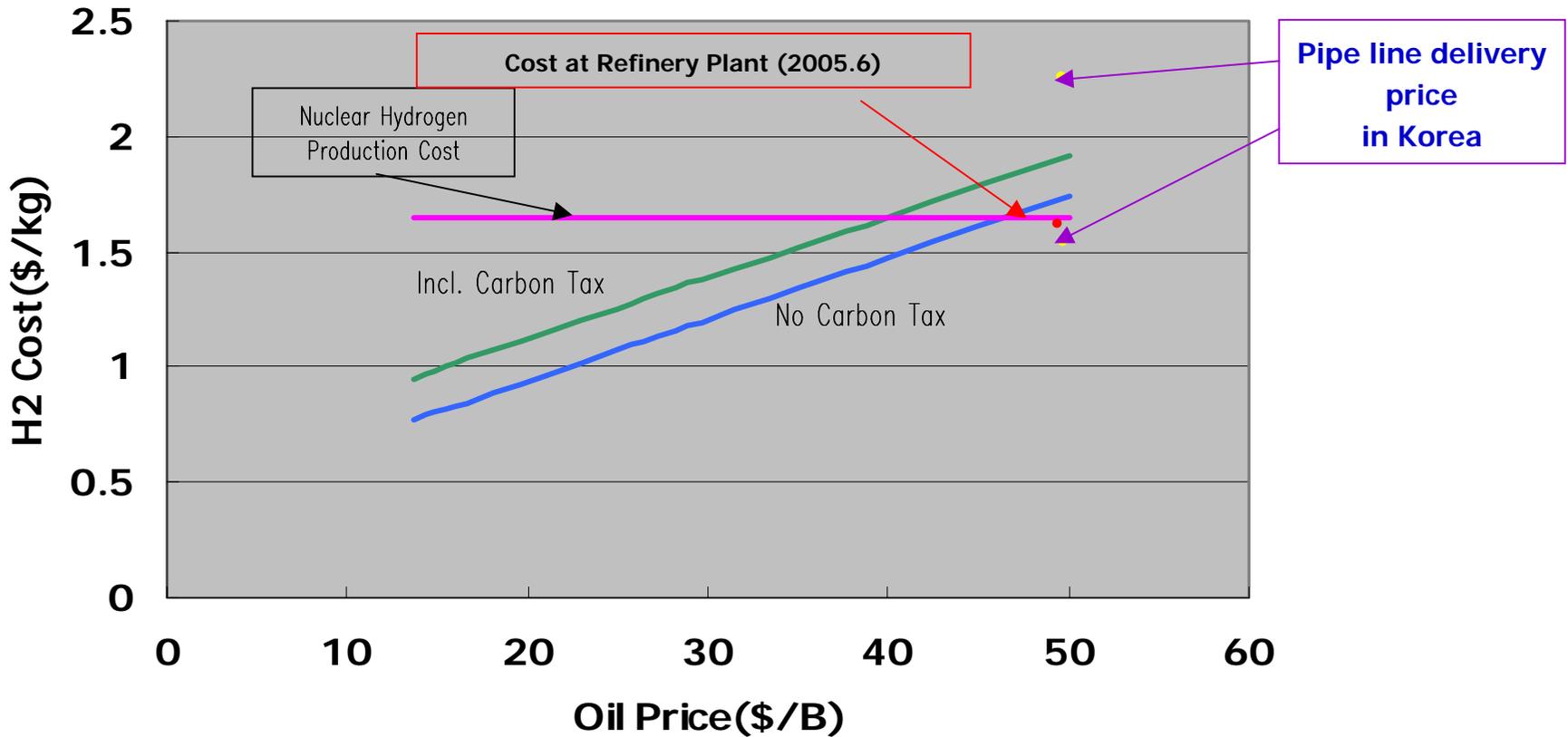
- ✓ Korea can have 17 plants  
after 760B\$ investment !

	Nuclear power generation	Solar power generation		Wind power generation
		For business use	For household use	
Capacity per power plant	1 million kW	300kW	3.5kW	1,000kW
Load factor	80%	12%	12%	20%
Annual power generation per plant	7 billion kWh	320,000 kWh	3,700 kWh	1.75 million kWh
Investment per plant	360 billion yen	300 million yen	3 million yen	250 million yen
Number of power generating units required to generate equivalent electricity to one block of a 1 million kW nuclear power plant	1 unit	21,875 units	1.9 million units	4,000 units
(For reference) Necessary investment	360 billion yen	7 trillion yen	6 trillion yen	1 trillion yen
Required site area (•Solar power generation: 10 m <sup>2</sup> /kW •Wind power generation: 0.062 km <sup>2</sup> /generating unit )		Approx. 67 km <sup>2</sup> ( Almost equivalent to 1,500 Tokyo Domes )		Approx. 248 km <sup>2</sup> ( Almost equivalent to 5,550 Tokyo Domes )
Generating cost	5.9 yen/kWh	Mean price (Household use): 66 yen/kWh (Lowest price (Household use): 46 yen/kWh)		Large-scale: 9-14 yen/kWh
(For reference) Comparison with the costs of the competing energies listed below		Approx. 2-3 times		Approx. 1.2-2 times
Assumed costs of competing energies		Unit price of household power: 23.3 yen/kWh		Unit cost of thermal power generation: 7.3yen/kWh

# Hydrogen Demand in Korea



# Hydrogen Production Cost

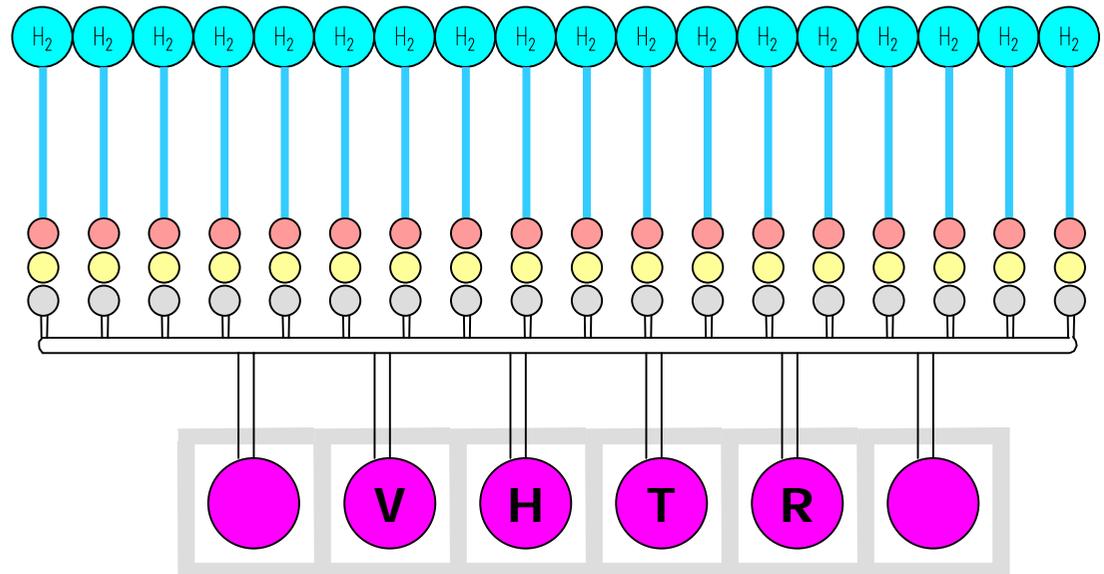


✓ Nuclear Hydrogen is cheap when crud oil price is more than 40~45\$/bbl.

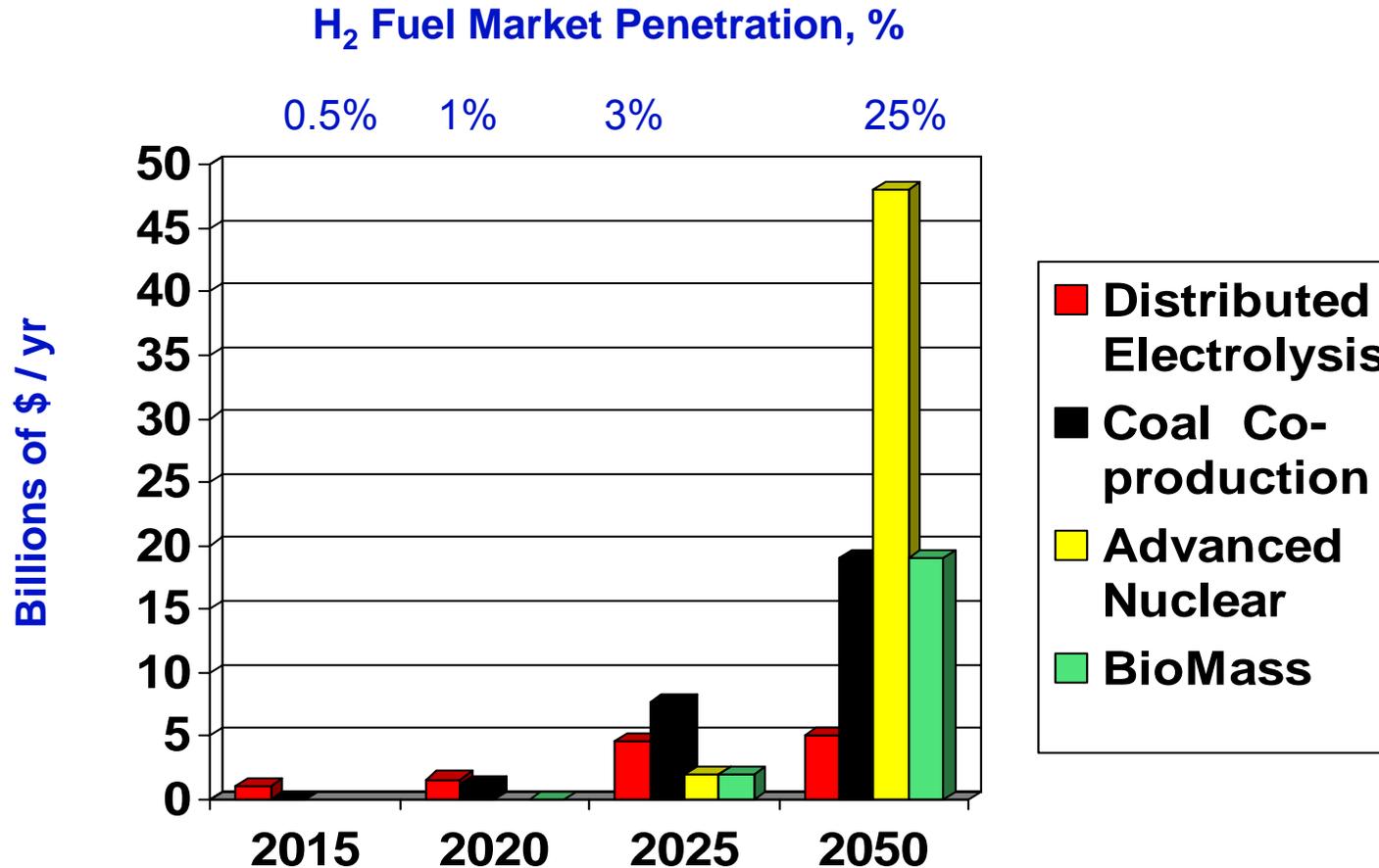
# Vision of Nuclear Hydrogen in Korea

Profile	2040		Modules (600MW)	Const/yr
	Share	H2-ton/yr		
Low	15%	1,130,000	19	1.1
Medium	20%	1,500,000	25	1.7
High	50%	3,800,000	63	5.5

- Construction : 2020 ~ 2040
- Dedicated H-2 producer



# Estimated Annual Revenues Billions of dollars per year

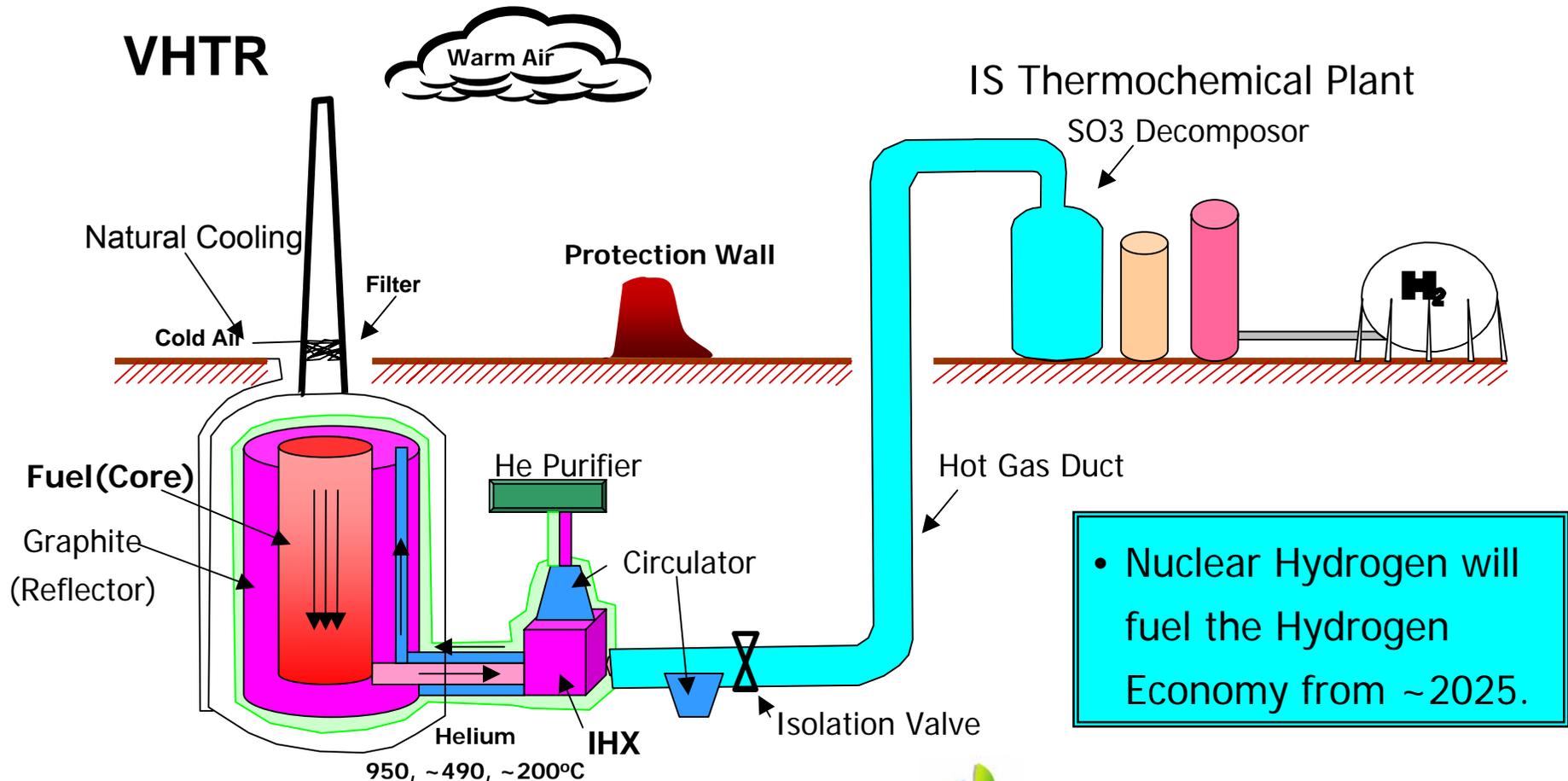


Assumptions: Revenue from electrolysis at 3 cents per kWh;

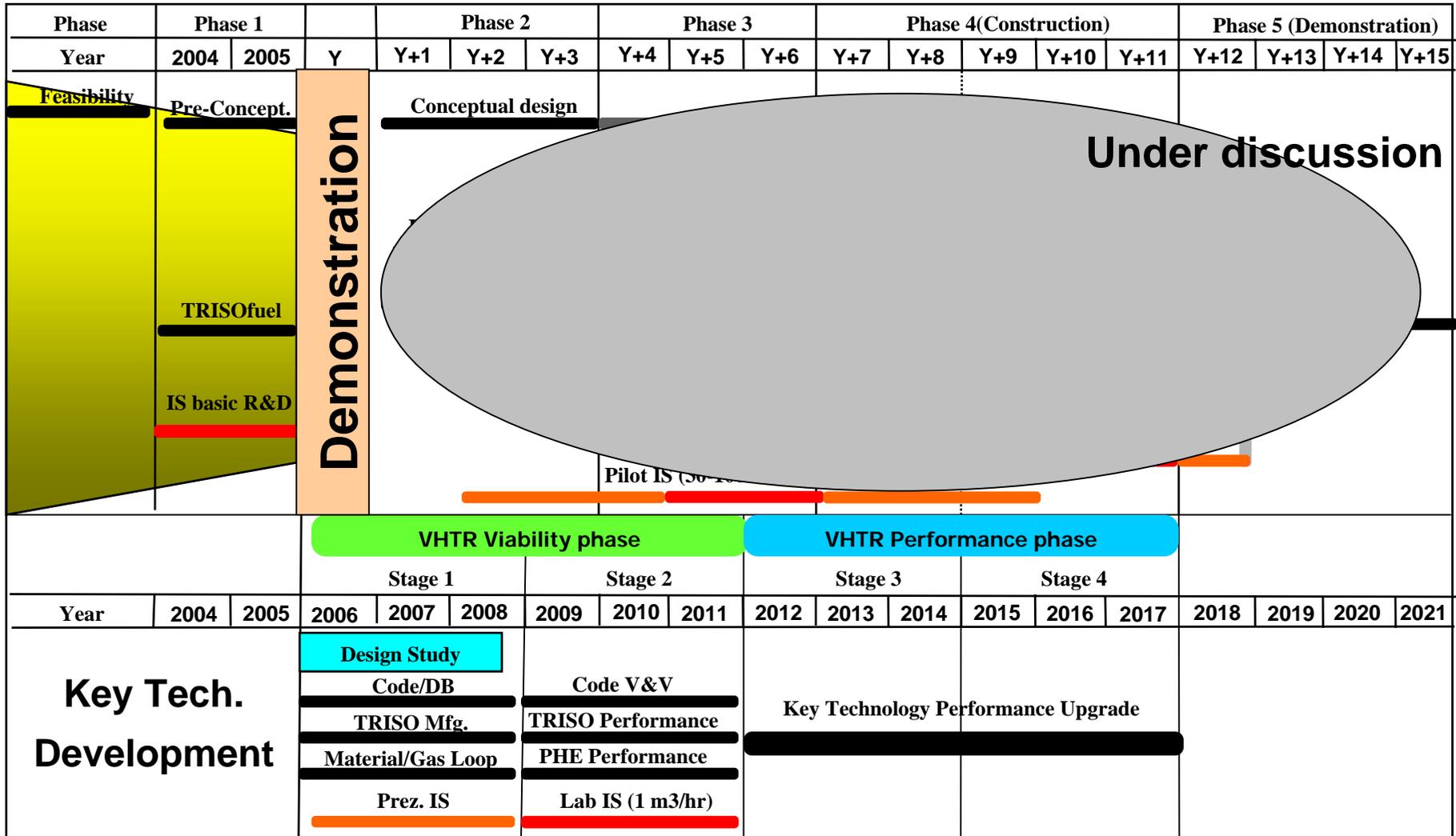
Revenue from sale of hydrogen fuel from coal, biomass and nuclear at \$ 3 per kg

# Nuclear Hydrogen Production Development and Demonstration (NHDD)

- Complete the development and demonstration of the nuclear based hydrogen production technology until early 2020.



# NHDD Project Status



# Important Issue for Reactor Development

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## ■ Outlet temperature of 950 °C

- Code and Standard of materials
  - ◆ No ASME Code exists
- Maximum fuel temperature during accident
  - ◆ More accurate core physics and thermo-fluid models are required

## ■ Quality of TRISO fuel

- ~Billion TRISO in a core with  $10^{-5}$  failure prob.

# Important Issue for Hydrogen Production

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## ■ Demonstration of pilot scale hydrogen production

- IS cycle at 2 - 4 MPa
- Efficiency better than 40 % to be competitive with distributed electrolysis system.

## ■ Material and Components

- High T corrosion resistive material
- Leak tight seal

# Important Issue for Reactor Coupling

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## ■ Process Heat Exchanger

- Highly corrosive (SO<sub>3</sub>, O<sub>2</sub>, Steam, etc.)
- High temperature
- High pressure differences

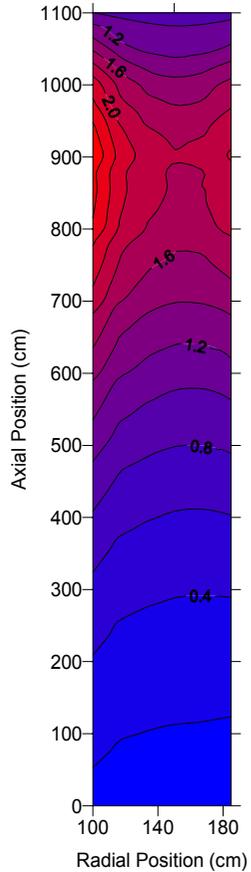
## ■ Tritium (and F.P.) contamination

- Higher leak rate in elevated fuel temperature
- Role of graphite

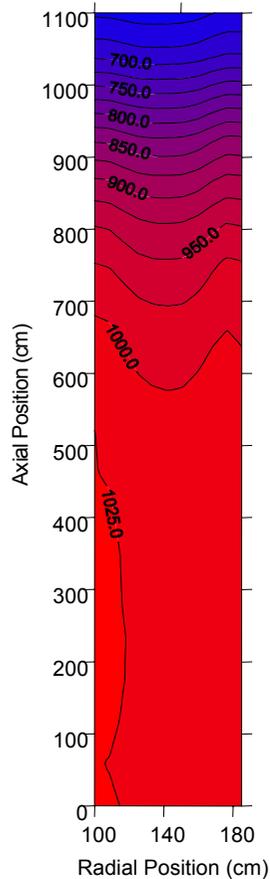
## ■ Separation distance

# Core Analysis

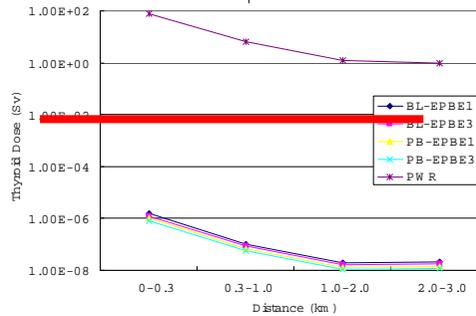
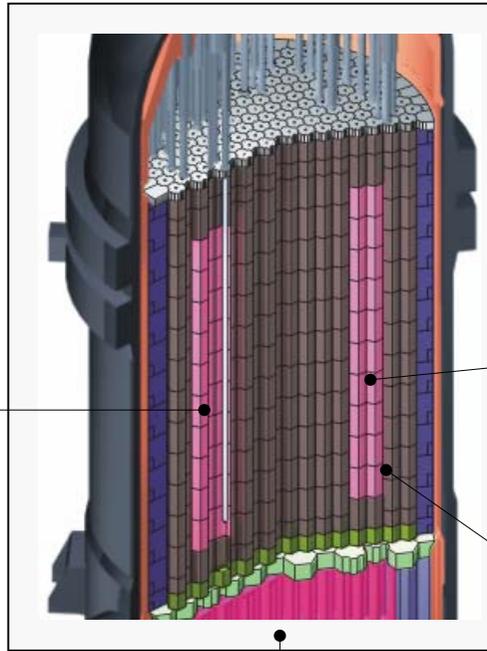
## Steady State Analysis



Power

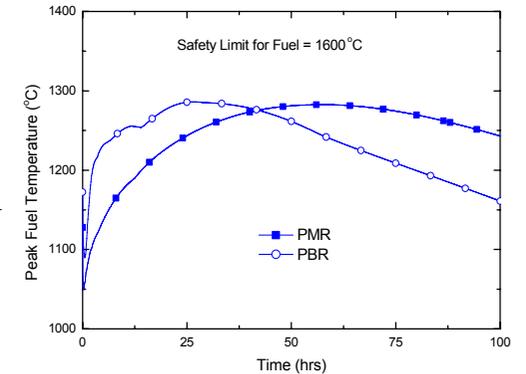


Temperature

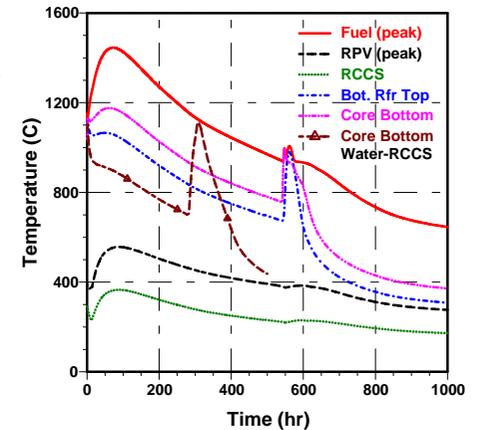


Public Dose rate

## Accident State Analysis



Loss of Flow accident



Duct rupture and Air ingress

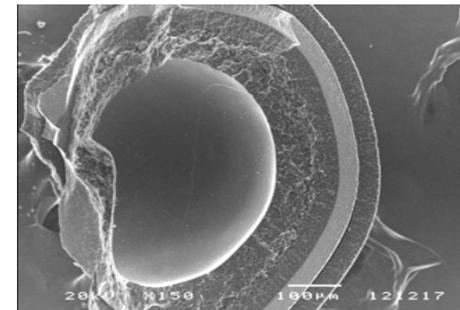


# Coated Nuclear Fuel (TRISO)

## Kernel fabrication

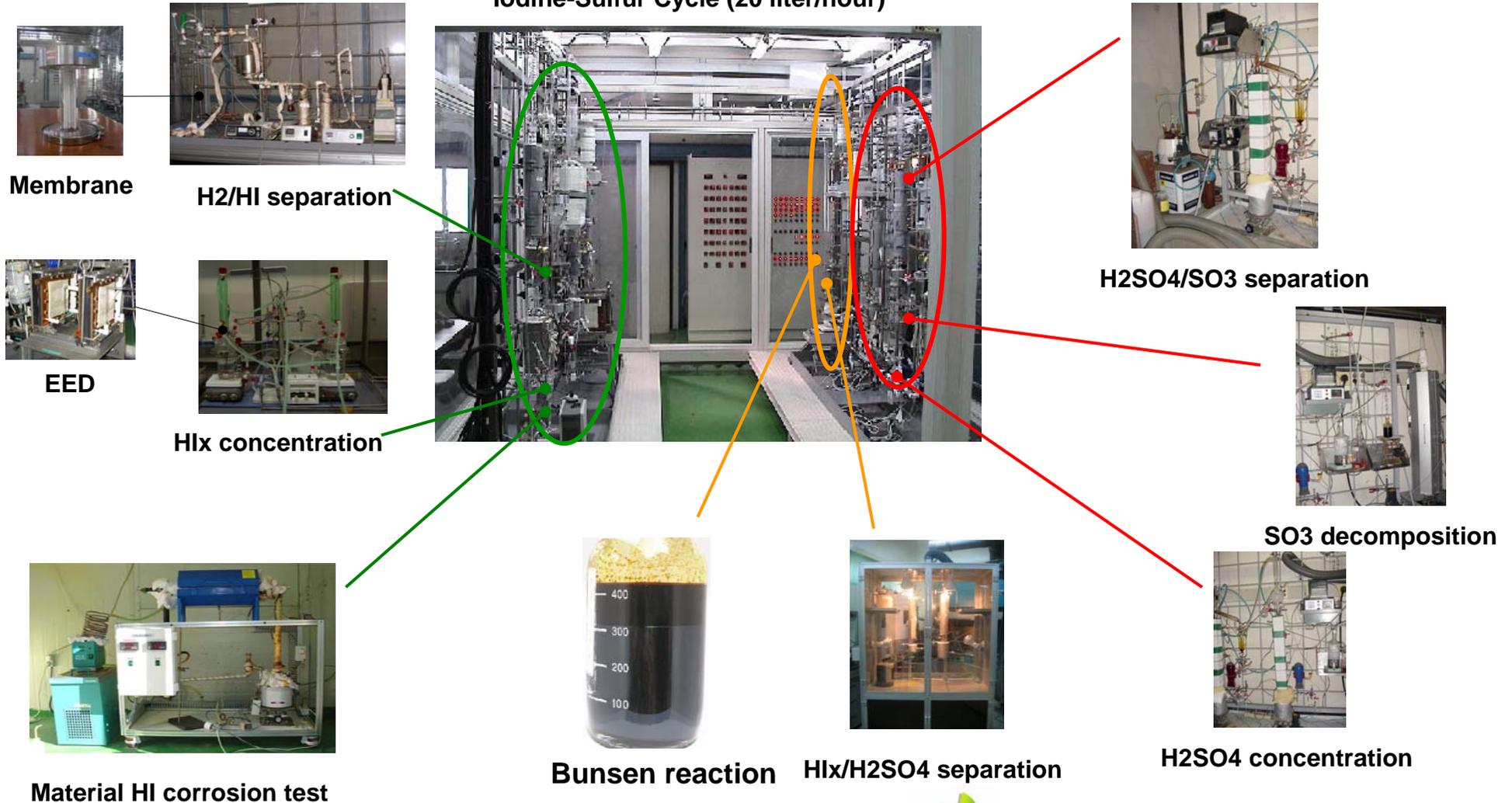


## Fuel Coating



# Thermochemical Hydrogen Production

Iodine-Sulfur Cycle (20 liter/hour)



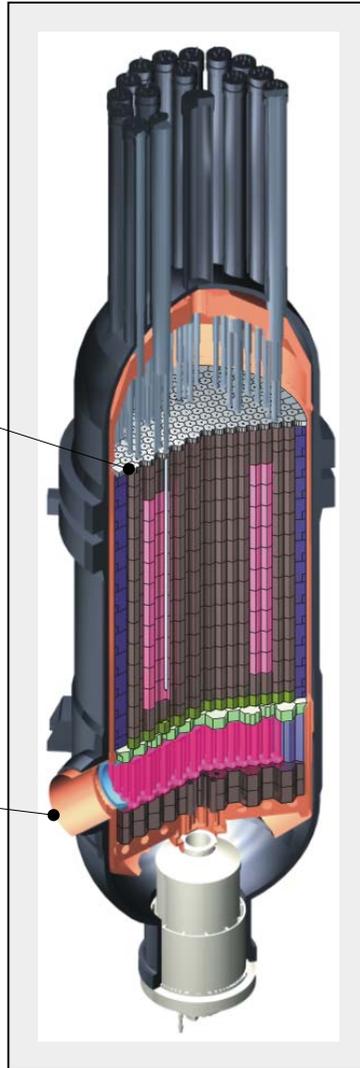
# Material Assessment and Improvement



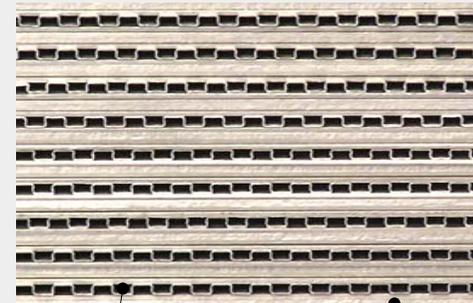
Graphite



Superalloy



Process Heat Exchanger

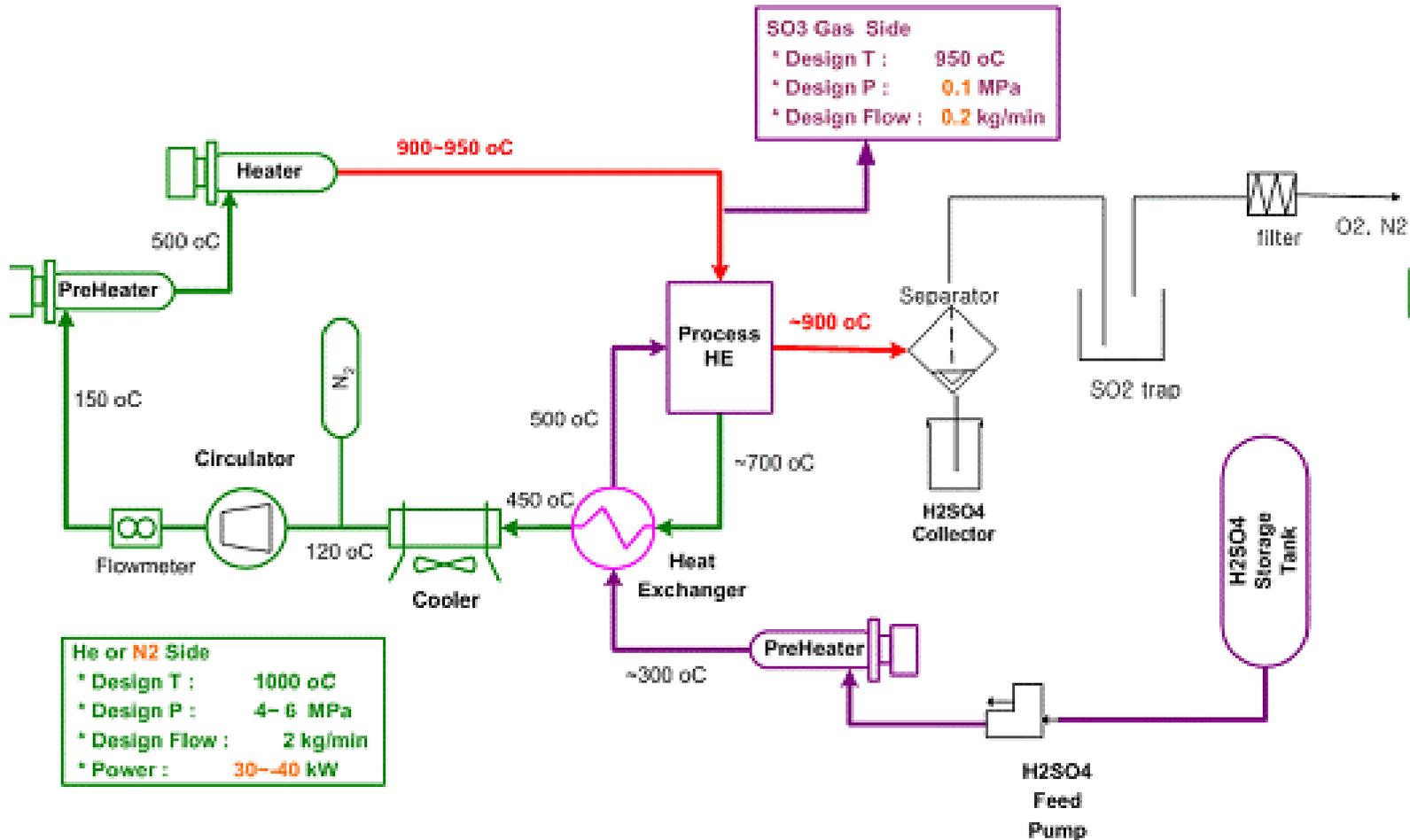


Coating



Corrosion

# Small Gas Loop for integral test of PHE



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# Thank you for Listening !

