



The 2nd U.S.-China CO<sub>2</sub> Emissions Control  
Science & Technology Symposium, Hangzhou, China

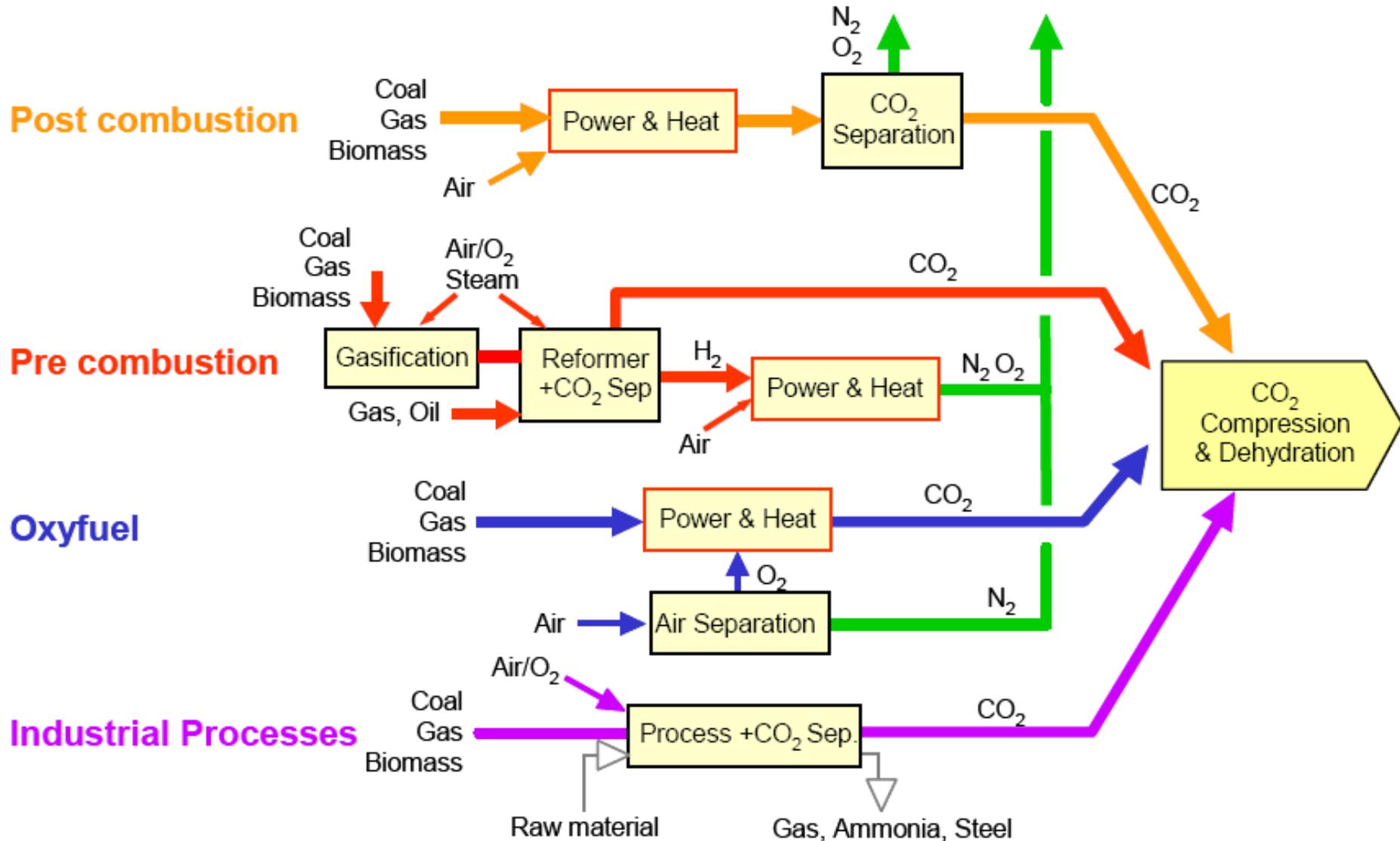
# Development of CCS Technologies and Scenario Suitable for China

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# CO<sub>2</sub> Capture and Storage (CCS)



# Main Obstacles in CCS

Is it technical *ready* of CCS for China?

Due to low concentration, large quantity of CO<sub>2</sub> gas,

Unacceptable energy penalty (7-15% points);

Resulting into additional 20% energy input,

Leading to energy problem more serious;

Not yet find suitable solutions from demonstrations *using the existing technologies*

*Real understanding of innovative CCS technology?*

# Special issues of China for CCS

*What is special issue in China?*

- Huge amount of energy consumption;
- Rapid increasing of energy consumption;
- Heavily relying on coal (with high carbon)

If we adopt current CCS technologies,

Nearly **billions of tce.** per year will be paid for CCS  
and thousands of Billions USD will be required for CCS.

Is it a sustainable development for China?

***Real understanding of special issue of China!***

# Breakthrough in CCS

**Innovative** Energy Systems,

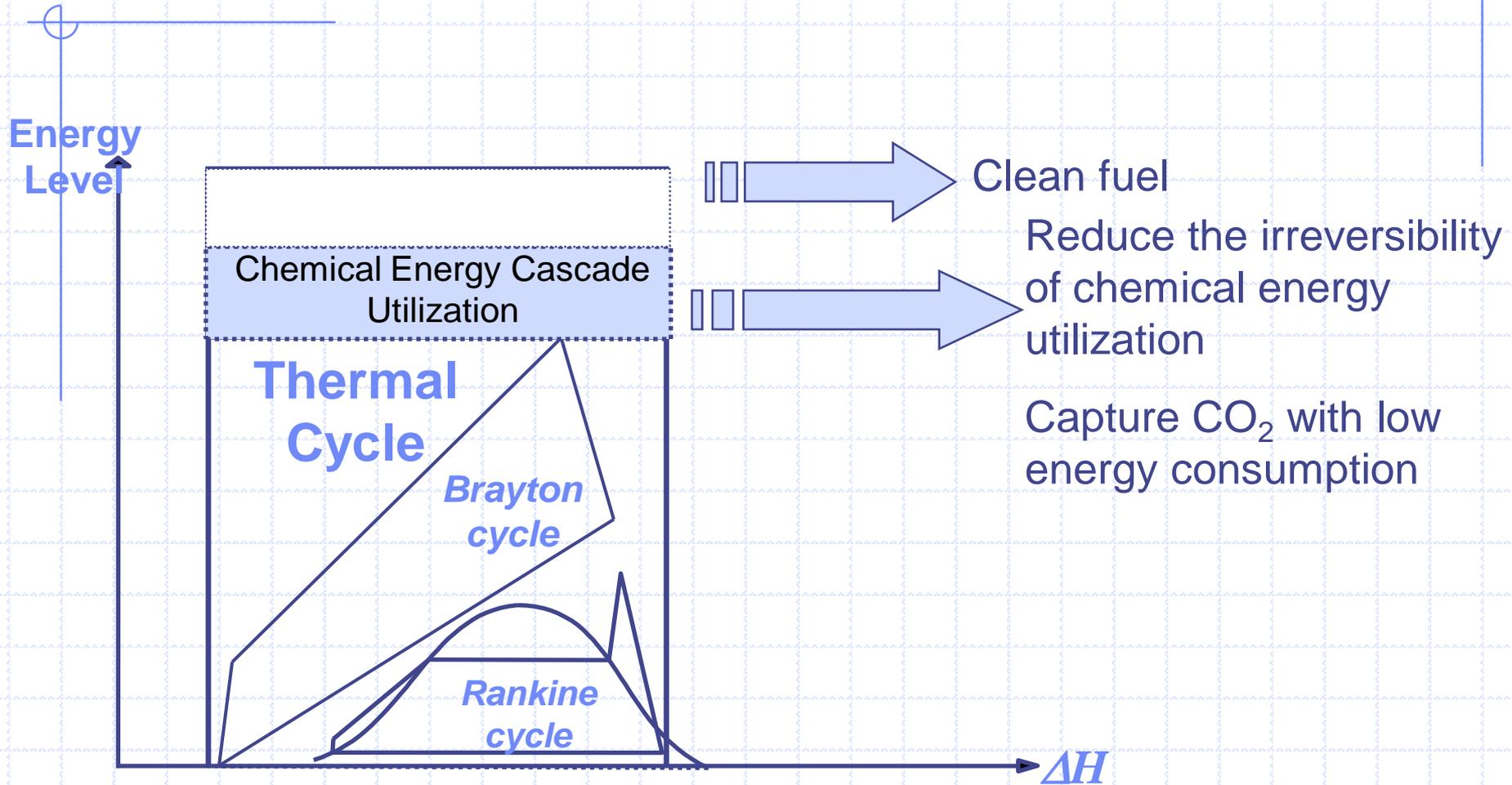
Instead of simple extension of the existing technologies

Focus on low even **zero energy penalty**,

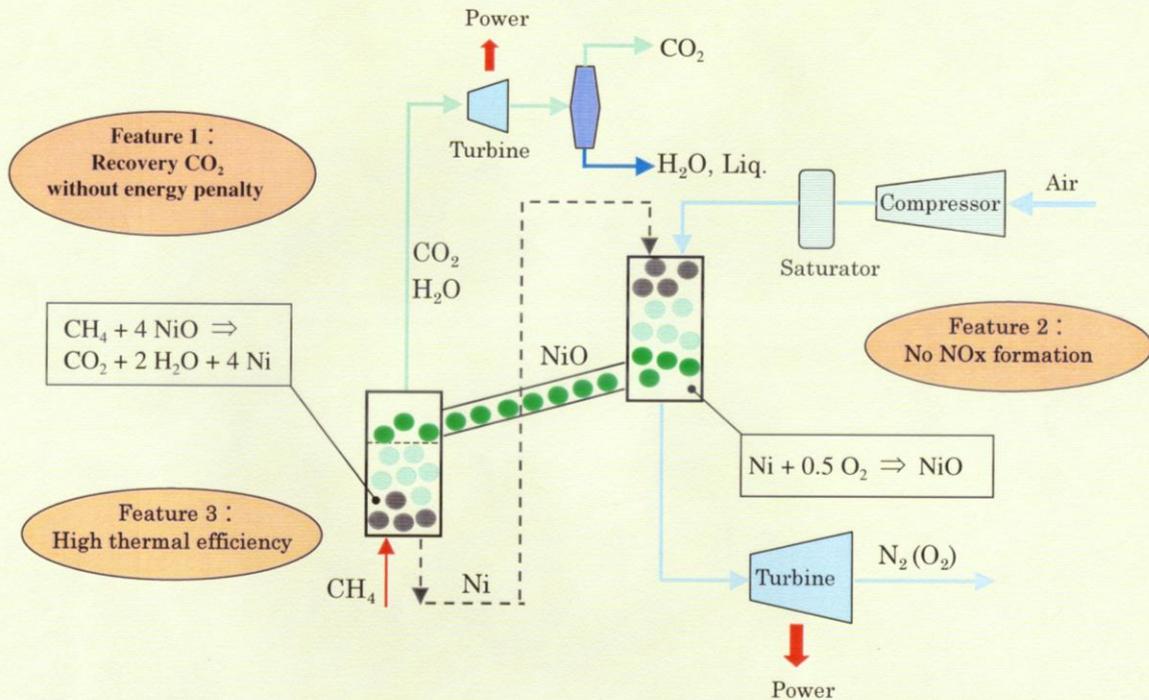
Instead of zero emission with high penalty

Toward to resolving both energy and environments

# To integrate chemical energy utilization with CO<sub>2</sub> capture



# Novel Cycle with Chemical Looping Combustion



United States Patent [19]  
Ishida et al.

[11] Patent Number: 5,447,024  
[45] Date of Patent: Sep. 5, 1995

[54] CHEMICAL-LOOPING COMBUSTION POWER GENERATION PLANT SYSTEM  
[19] Inventors: Masaru Ishida, Yoshitaka Hongo, Jun, Machida, Toshio of Japan  
[73] Assignee: Tokyo Electric Power Co., Inc., Japan  
[21] Appl. No.: 336,092

OTHER PUBLICATIONS  
"Energy", vol. 12, No. 2, pp. 147-154, 1987.  
1993 Tokyo International Gas Turbine Congress, pp. 297-303, Most et al.  
Primary Examiner—Richard A. Bertsch  
Assistant Examiner—William Wicker  
Attorney, Agent, or Firm—Lenczner & Lund  
[57] ABSTRACT

The United States of America

專利

U. S. Pat. No. 5, 447,024, 1995  
特願平 4-142363, 日本, 1992

Therefore, this United States Patent

Grants to the person or persons having title to this patent the right to exclude others from making, using or selling the invention throughout the United States of America for the term of seventeen years from the date of this patent, subject to the payment of maintenance fees as provided by law.



Bruce Lehman  
Commissioner of Patents and Trademarks  
Kannaly Cooper  
Attent

Patent by U.S.A and Japan

“Most Advanced Research” projects supported by NEDO

“The Excellent Research” of RITE

## System Synthesis

CO<sub>2</sub> Capture with No energy Penalty  
Up to New-generation Efficiency

## Greenhouse Gases Control

CO<sub>2</sub> Capture with New Combustion  
No NO<sub>x</sub> Formation

**Energy**

**Environment**

**A Novel Power Plant  
With CO<sub>2</sub> Capture**

**Material**

**Reactor**

## Solid Looping Material

Addition of binder  
Particle Preparation Method  
New Materials  
(NiCoO<sub>2</sub>/YSZ, NiO/NiAl<sub>2</sub>O<sub>4</sub>)

## Reactor Tests

Control of Carbon Deposition  
Regenerability of Looping Materials  
Fixed Bed Reactor  
Fluidized Bed Reactors

# The principle of integration for polygeneration system

cascade conversion of material according to composition

for chemical production

for power generation

Fuel

Light Fraction

Pollutant

Fresh Gas Preparation Subsystem

Fresh Gas  $A_{ch}$

Liquid Fuel

Synthesis Subsystem

Fuel  $A_{cm}$

Unconverted  $A_{cl}$

$A_{tl}$

$A_{tm}$

GT

Electricity

HRSG&ST

Heat/Cold

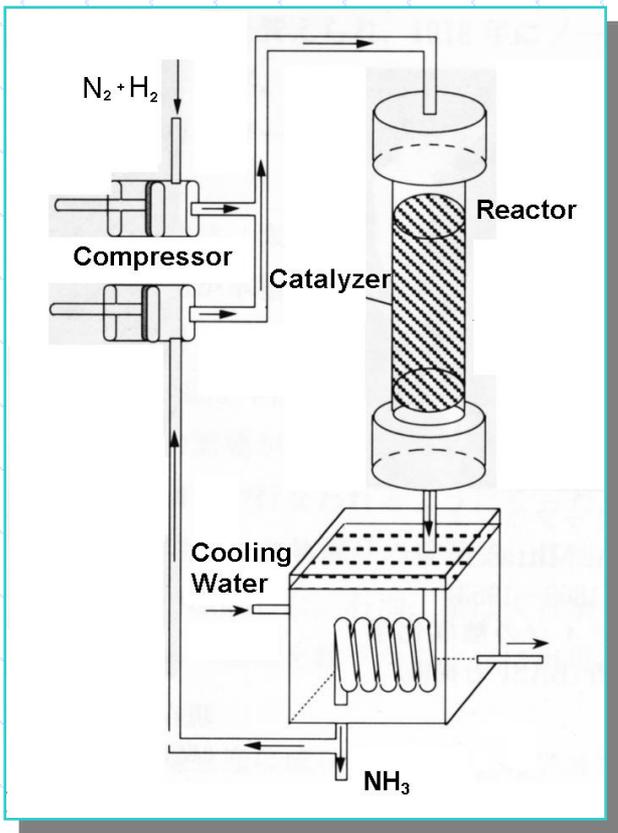
Chemical Energy

cascade utilization of energy according to energy level

High Temp

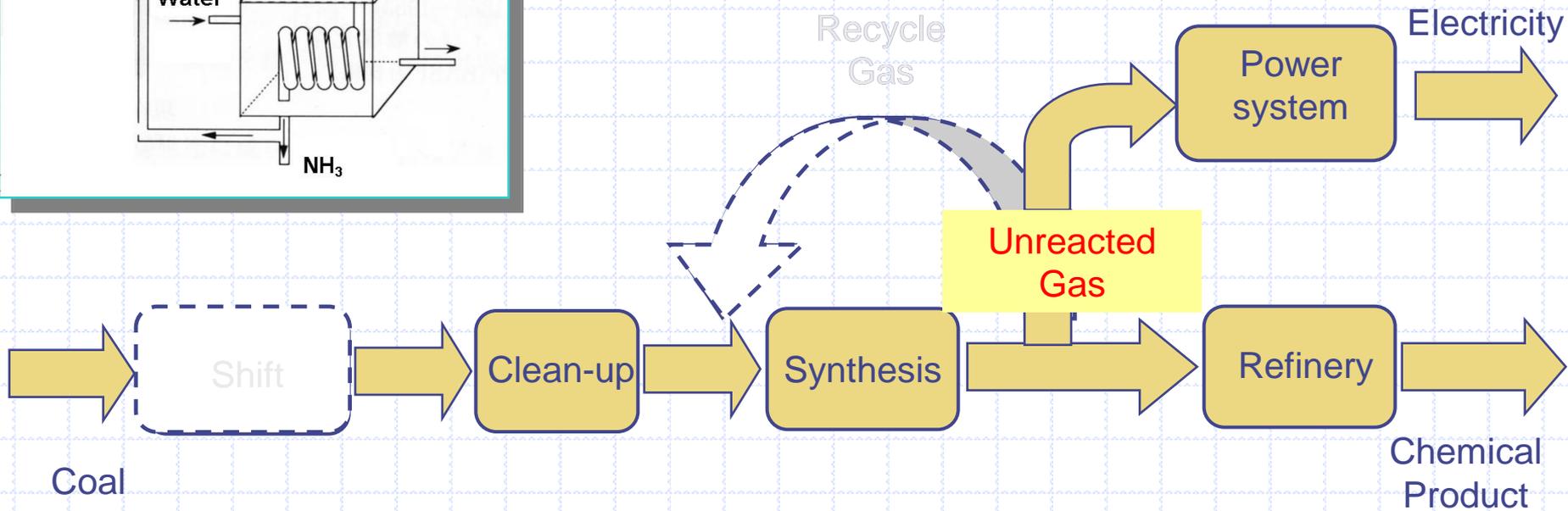
Middle and Low Temp

integration of clean fuel production and pollutants control

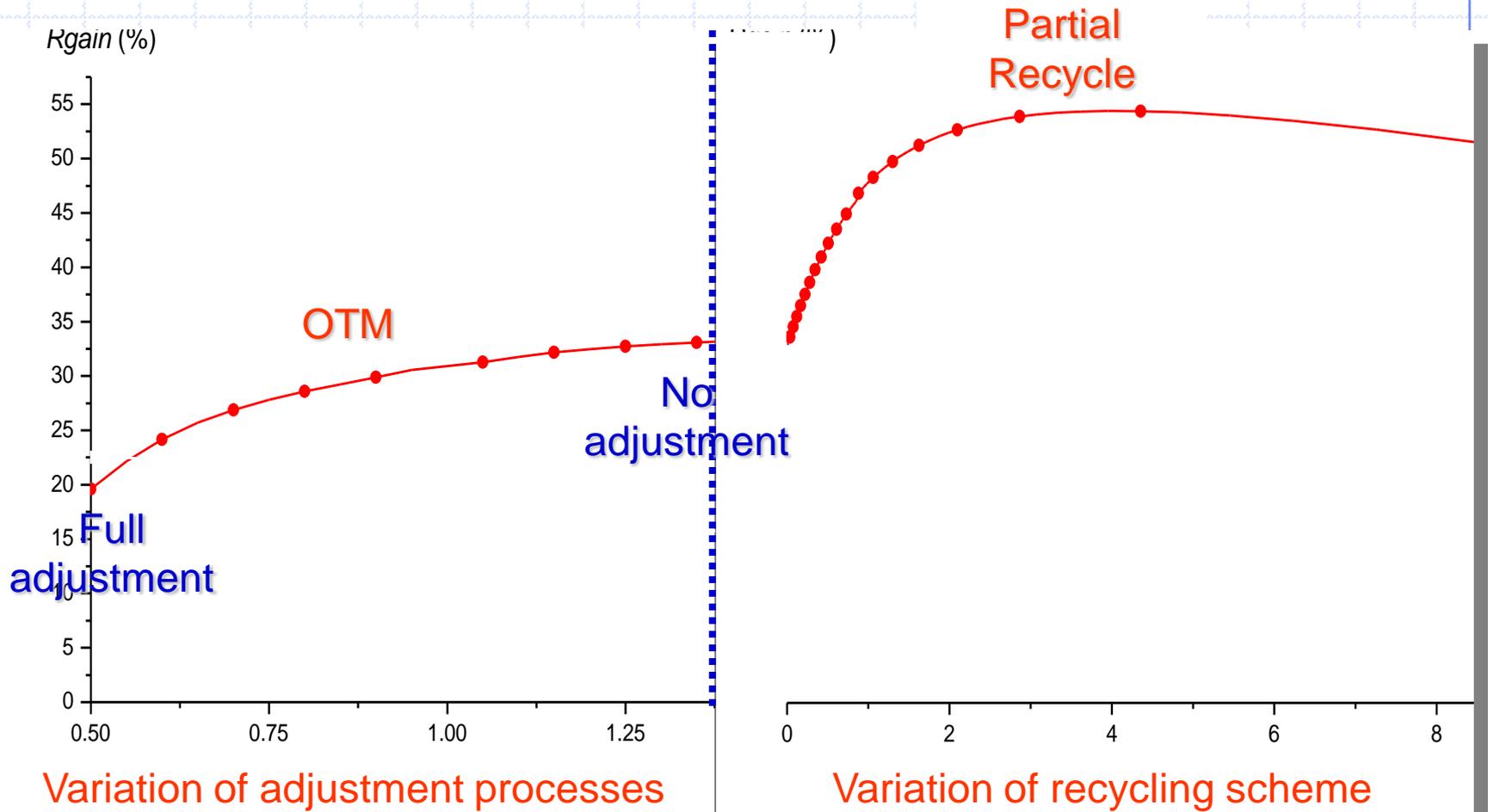


**Professor F. Haber**  
**Recycle the unreacted gas.**  
**Highly improve the conversion ratio.**  
**Main contribution on chemical production.**

**Optimal for chemical production!**  
**Also suitable for polygeneration system?**



**New approach for polygeneration systems**



Synergetic integration of adjustment processes and cycling scheme

→ reach chemical energy cascade utilization

# Performance comparison between three sequential polygeneration systems

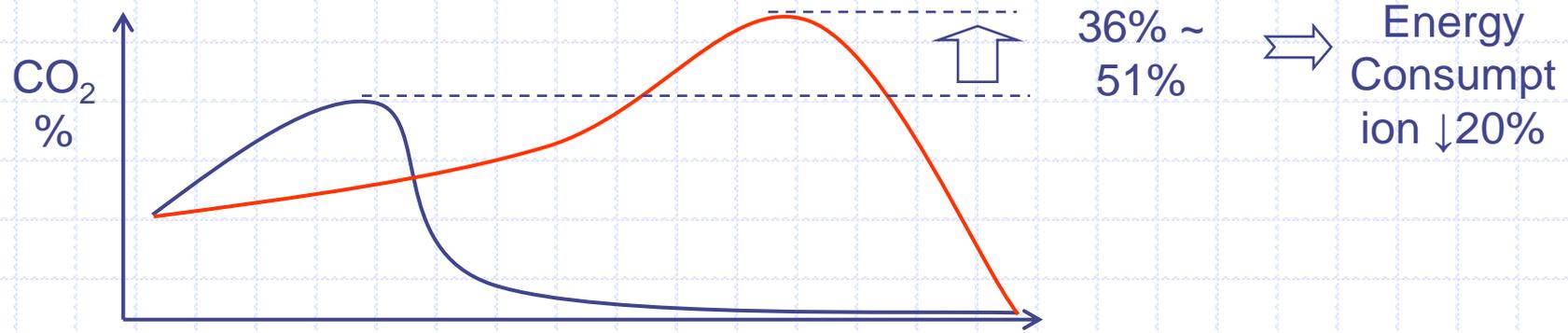
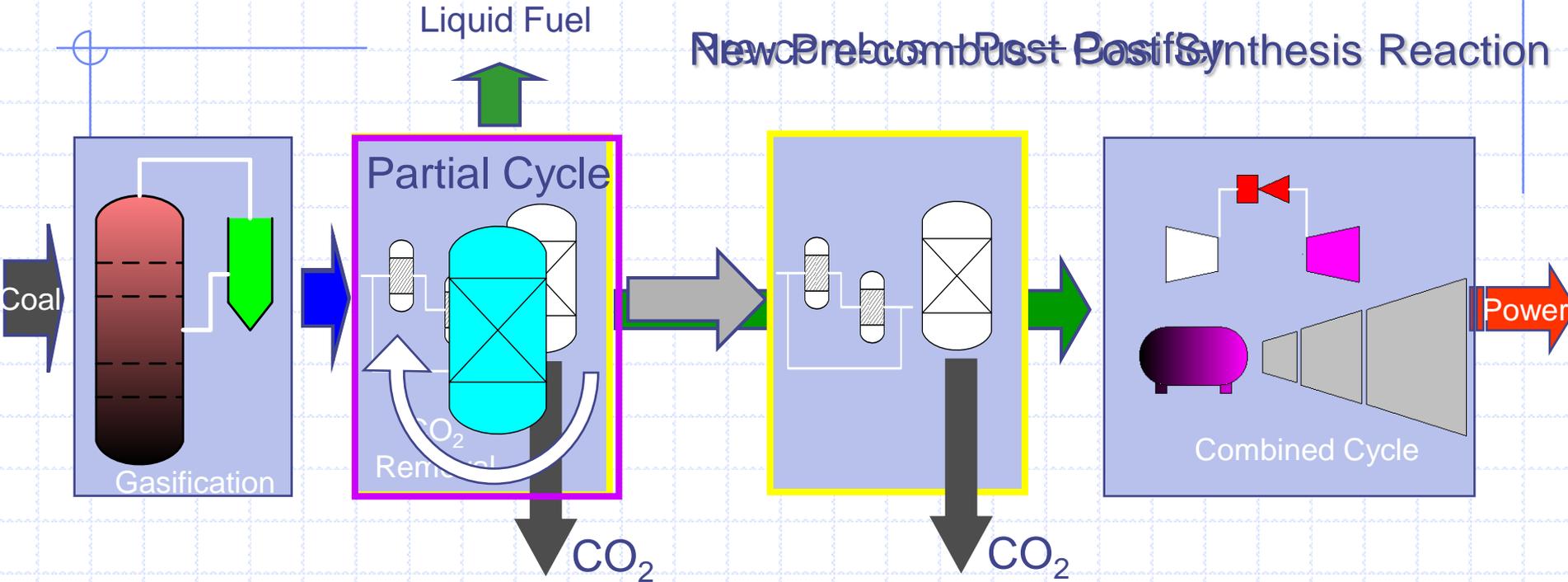
Performance Comparison						
	Accounted	NA/PC	Accounted	FA/OTM	Accounted	NA/OTM
Fuel Consumption	31415 (18148/13267)	26710	28190 (13561/14629)	26710	29077 (9576/19501)	26710
Work Output (kJ)	5824	5824	6422	6422	8561	8561
Methanol Production (kg)	0.3978	0.3978	0.2974	0.2974	0.2095	0.2095
Capacity Ratio		1.54		1.04		0.55
Efficiency(LHV, %)	43.9	68	43.9	48.9	43.9	49.9
Energy Consumption (LHV, GJ/t)	45.6	33.8	45.6	40.6	45.6	34.4
Conversion Efficiency (LHV, %)	43.6	58.9	43.6	49	43.6	58
Energy Saving Ratio (%)		<b>15</b>		<b>5.3</b>		<b>8.1</b>

Attractive performance improvement in new system

# Novel polygeneration system with CO<sub>2</sub> recovery

-Patent in Application

New Pre-combustion Basis Synthesis Reaction



# Improvement both in energy utilization and CO<sub>2</sub> recovery

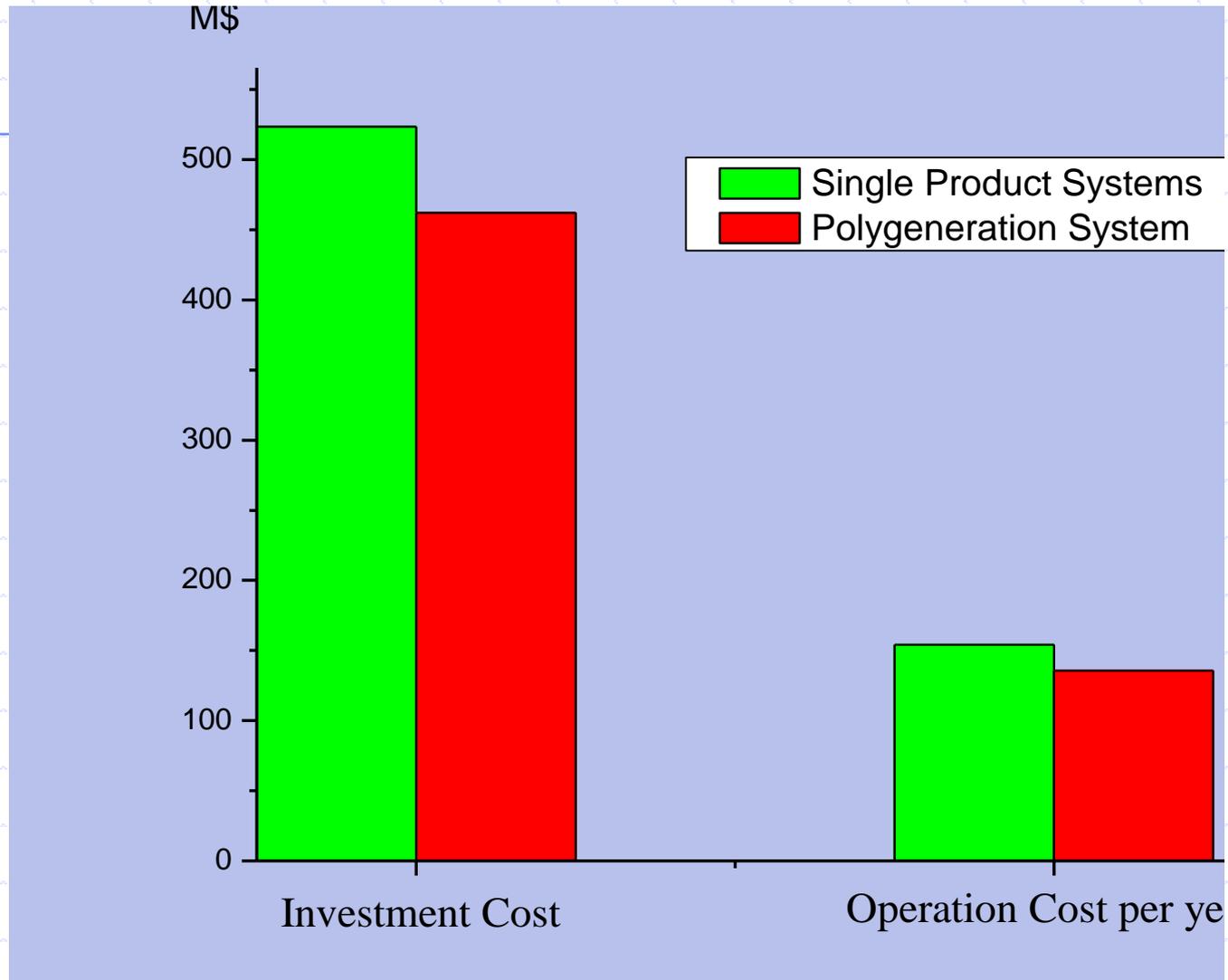
Comparison of performance for single product processes and polygeneration system

Items	Single Product Systems			Polygeneration System with CO <sub>2</sub> Capture
	IGCC		Single Methanol Product Process	
	No Capture	With Capture		
Fuel input (LHV kJ/kg-fuel)	26710			
Network output (kJ/kg-fuel)	11718	9396		4694
Methanol production (kg/ kg-fuel)			0.586	0.368
CO <sub>2</sub> product (kg/kg-fuel)		1.89		1.79
CO <sub>2</sub> emission (kg/kg-fuel)	2.485	0.59		0.183
CO <sub>2</sub> emission rate (kg/kWh)	0.763	0.226		<b>0.14</b>
Recovery ratio (%)		76.2		72.1
Energy penalty for CO <sub>2</sub> recovery (kWh/kg-CO <sub>2</sub> )		0.341		None
Thermal efficiency (%)	43.9	35.2		<b>47.3</b>
Energy Consumption for Methanol (GJ/t)			45.61	
Energy Saving Ratio (%)				<b>12.8</b>

Instead of paying energy penalty

new system achieve better performance with CO<sub>2</sub> capture.

# Qualitative economic assessment



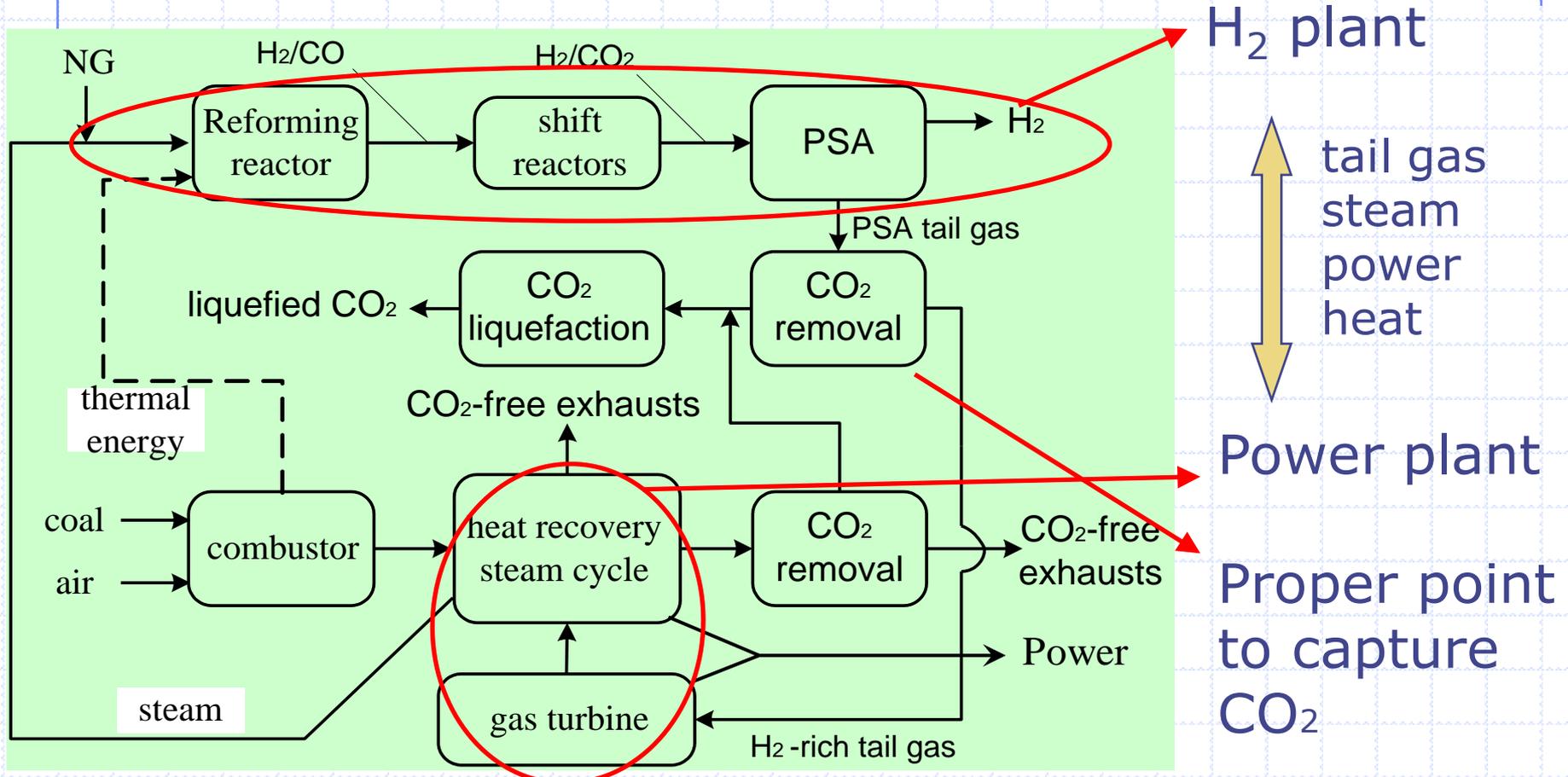
*200MW electricity output and 0.4Mt methanol production per year*

# Conceptual design of the MES system

Two specific features of the MES system

Integration of H<sub>2</sub> plant and power plant

Synthetic use of NG and coal



# Synthetic use of coal and NG

## Reaction of methane/steam reforming



Strong endothermic reaction



Reforming process in conventional H<sub>2</sub> plant

Steam generation in conventional power plant

# Synthetic use of coal and NG

## Reaction of methane/steam reforming



Strong endothermic reaction



# Synthetic use of coal and NG

## Reaction of methane/steam reforming



Strong endothermic reaction

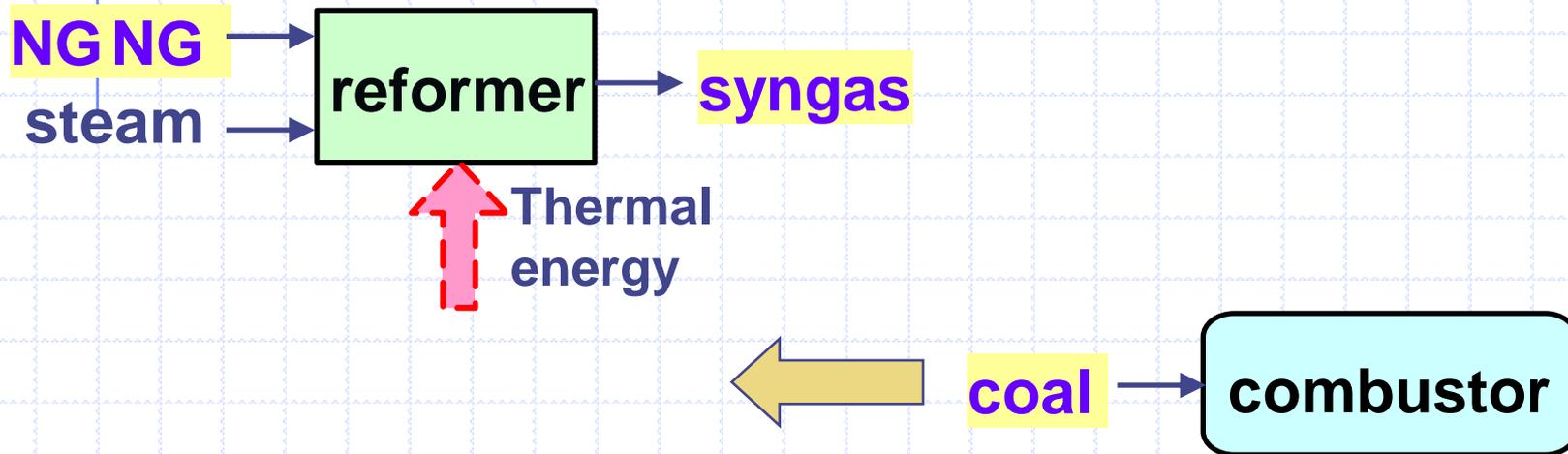


# Synthetic use of coal and NG

## Reaction of methane/steam reforming



Strong endothermic reaction

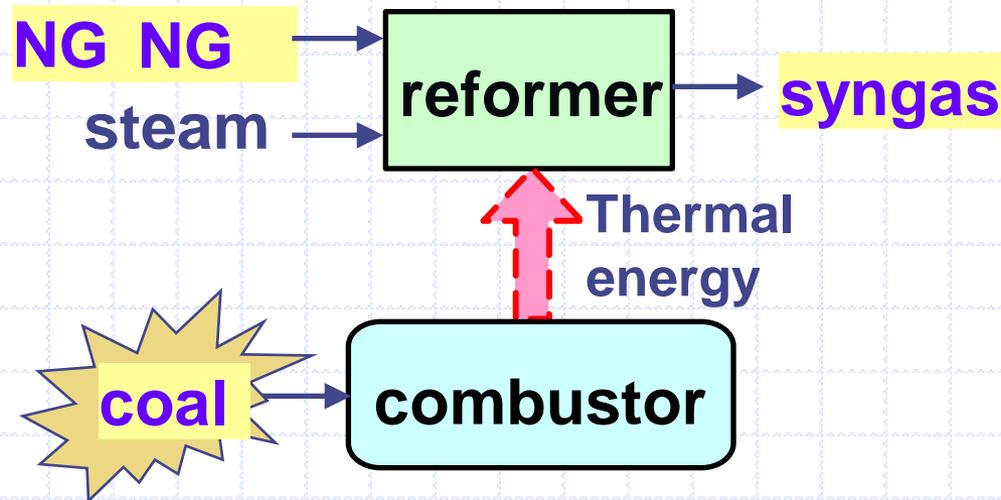


# Synthetic use of coal and NG

## Reaction of methane/steam reforming



Strong endothermic reaction



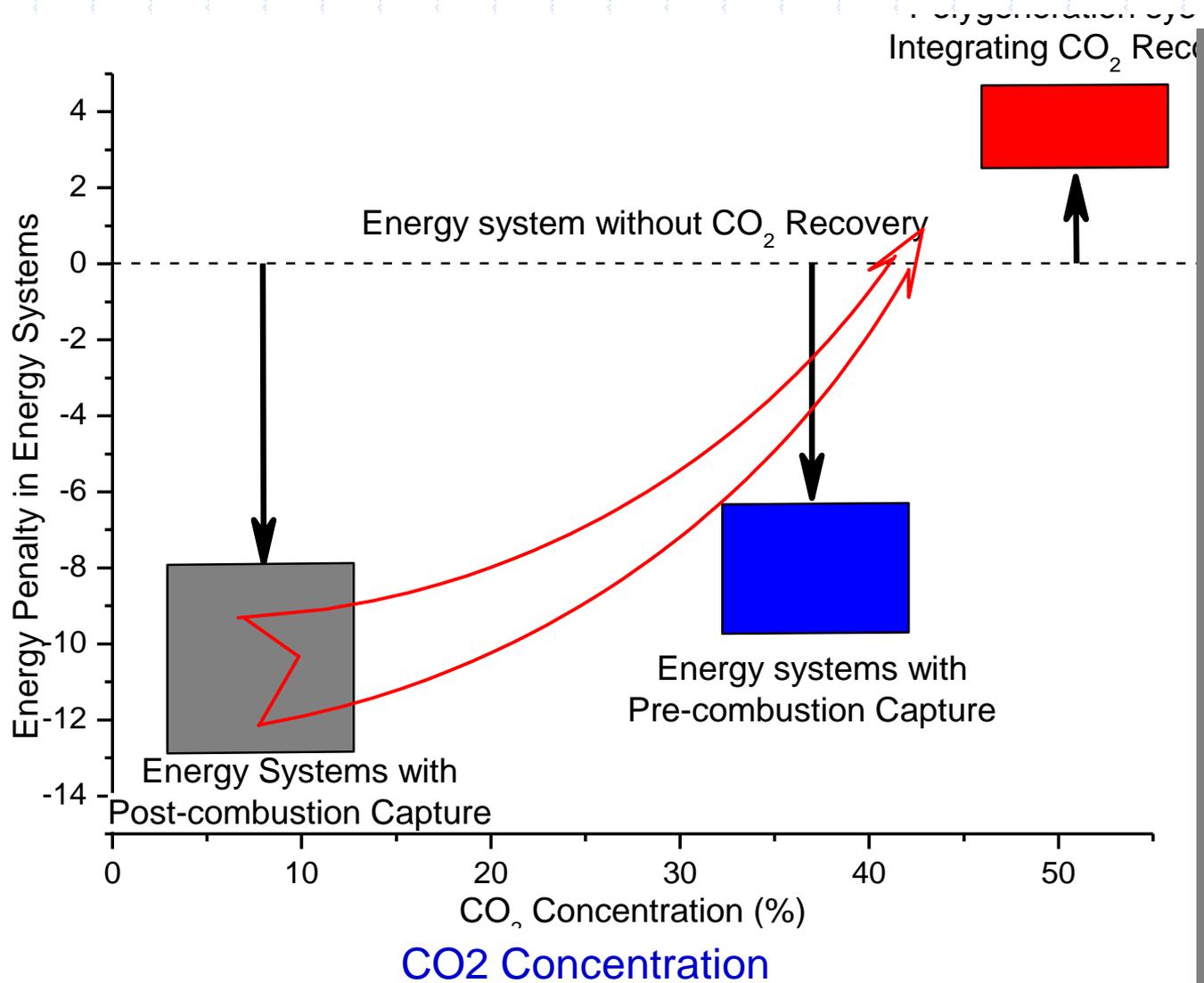
Dual fuel reforming process in MES system

# Results and Discussion

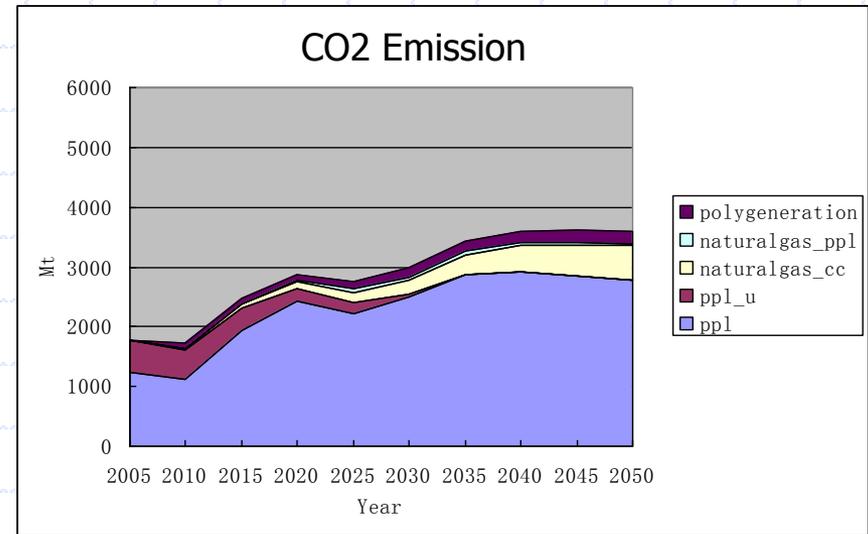
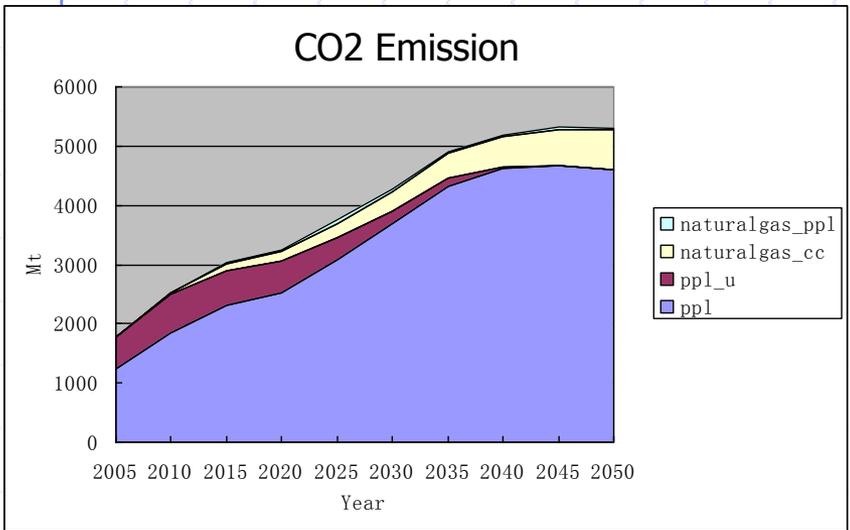
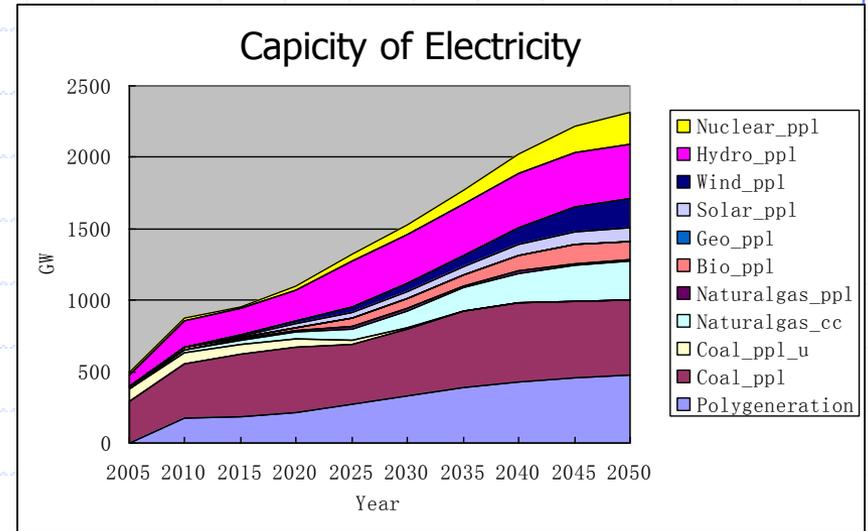
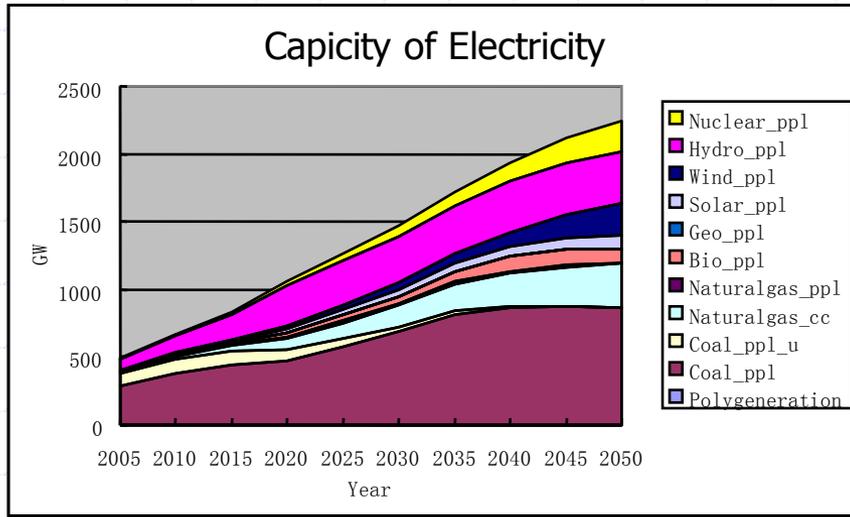
System Items	Ref. without CO <sub>2</sub> removal	MES system	Ref. with CO <sub>2</sub> removal
Natural gas input	427.5	427.5	427.5
Coal input	214.6	214.6	214.6
Hydrogen output	304.0	344.0	304.0
Power output from NG	17.6	-	0.9
Power output from coal	82.8	-	44.8
Net power output	100.4	63.7	45.7
Power to physical abs.	-	3.8	-
Heat to chemical abs.	-	78.4	163.1
Power for CO <sub>2</sub> liq.	-	13.4	16.7
CO <sub>2</sub> removal rate, %	-	90.1	90.1
Overall efficiency, %	63.0	63.2	54.5

**MES system has zero energy penalty for CO<sub>2</sub> removal!**

# Breakthrough in CCS technology



# Scenario for Different Technical Routes



Scenario with Traditional Technologies

Scenario with New Technologies

# Innovative technology for CO2 capture

- ◆ **Integration of energy use and CO2 capture**
- ◆ **Breakthrough in principle and energy system**
- ◆ **Super low energy penalty, low cost technology**
- ◆ **Scenario suitable for Chinese development**



**Thanks for your Attention**

# Effect foresee of new CCS technologies

