Development of CCS Technologies and Scenario Suitable for China

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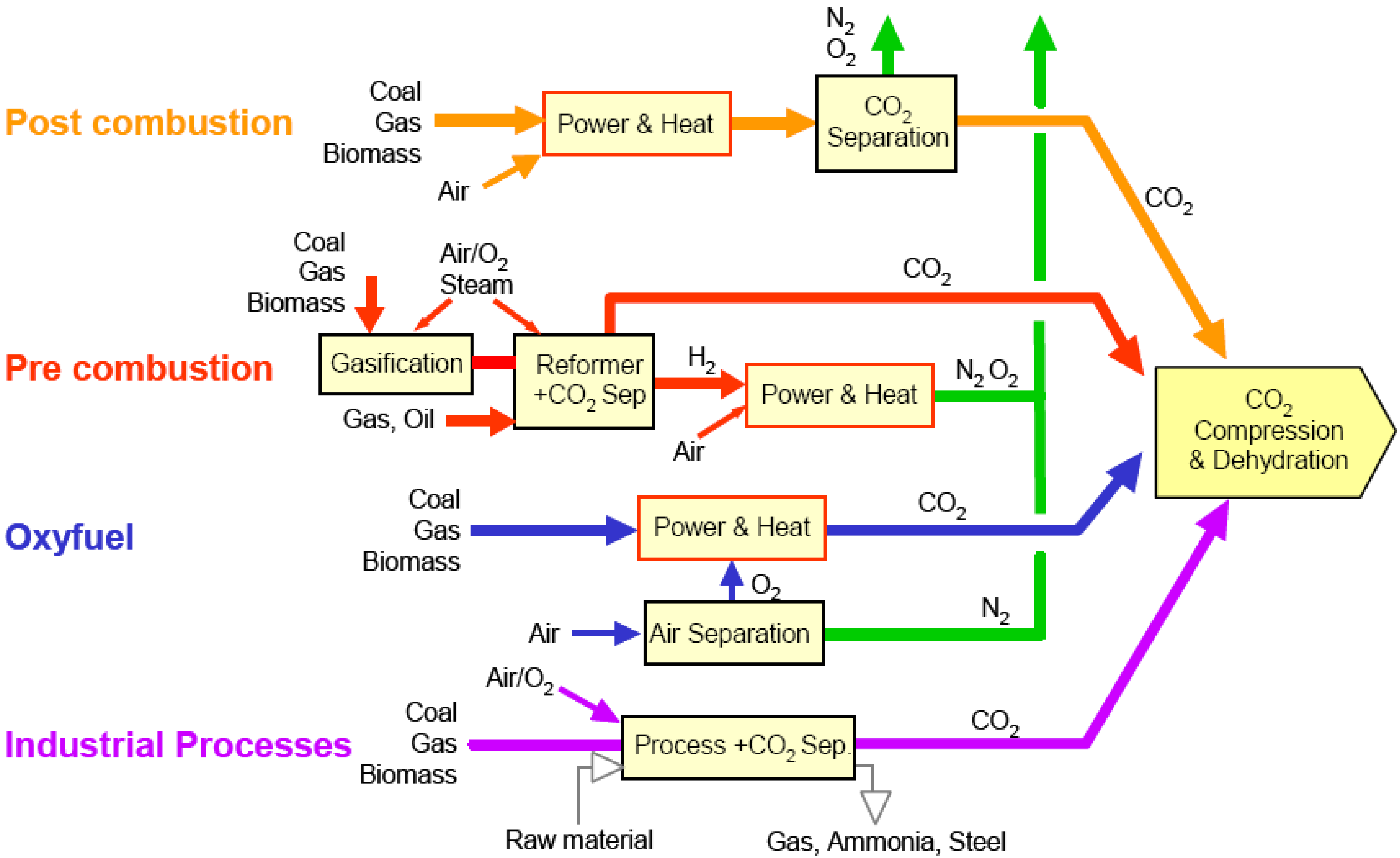
29 May, 2008

CO2 Capture and Storage (CCS)



Main Obstacles in CCS

Is it technical ready of CCS for China?

Due to low concentration, large quantity of CO2 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 speical 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,

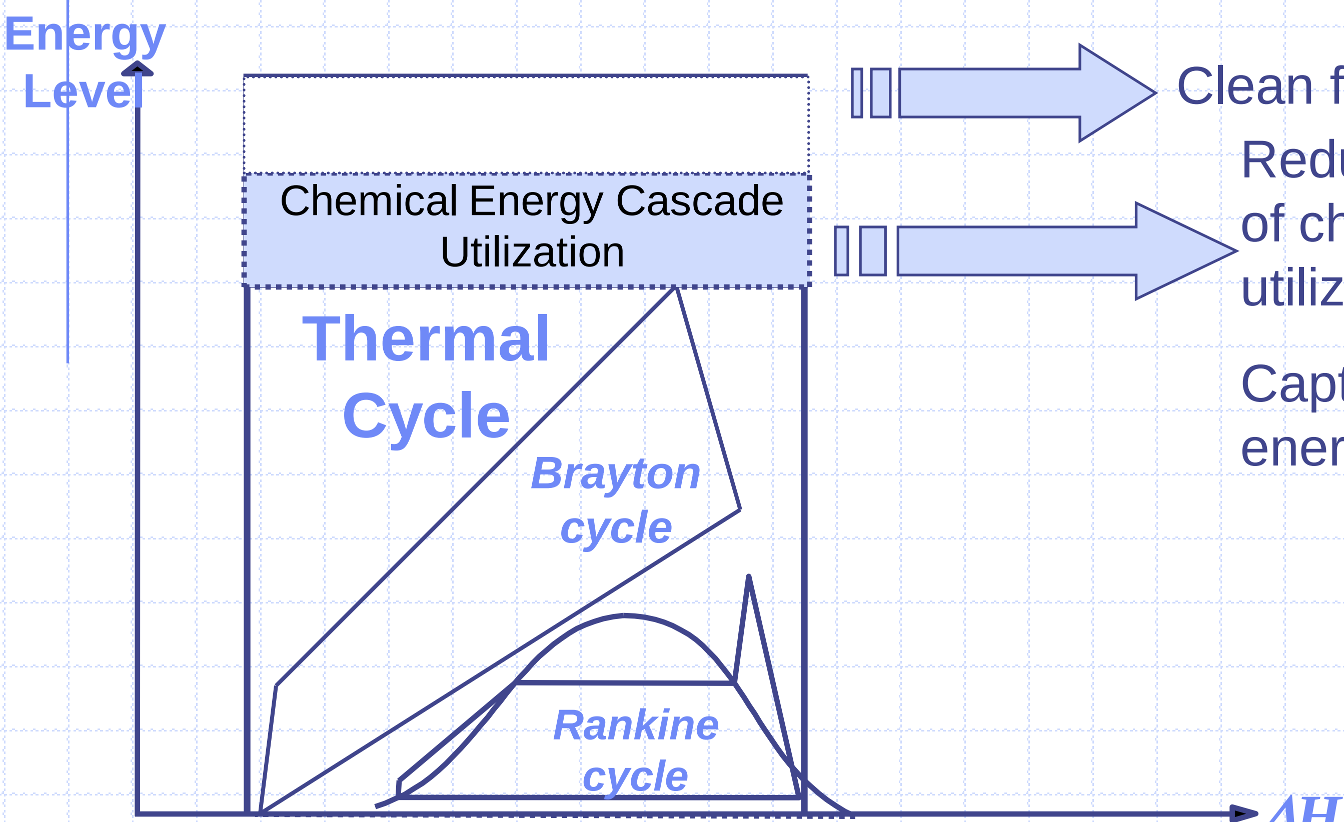
Instead of simple extension of the existing technologies

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_2 capture

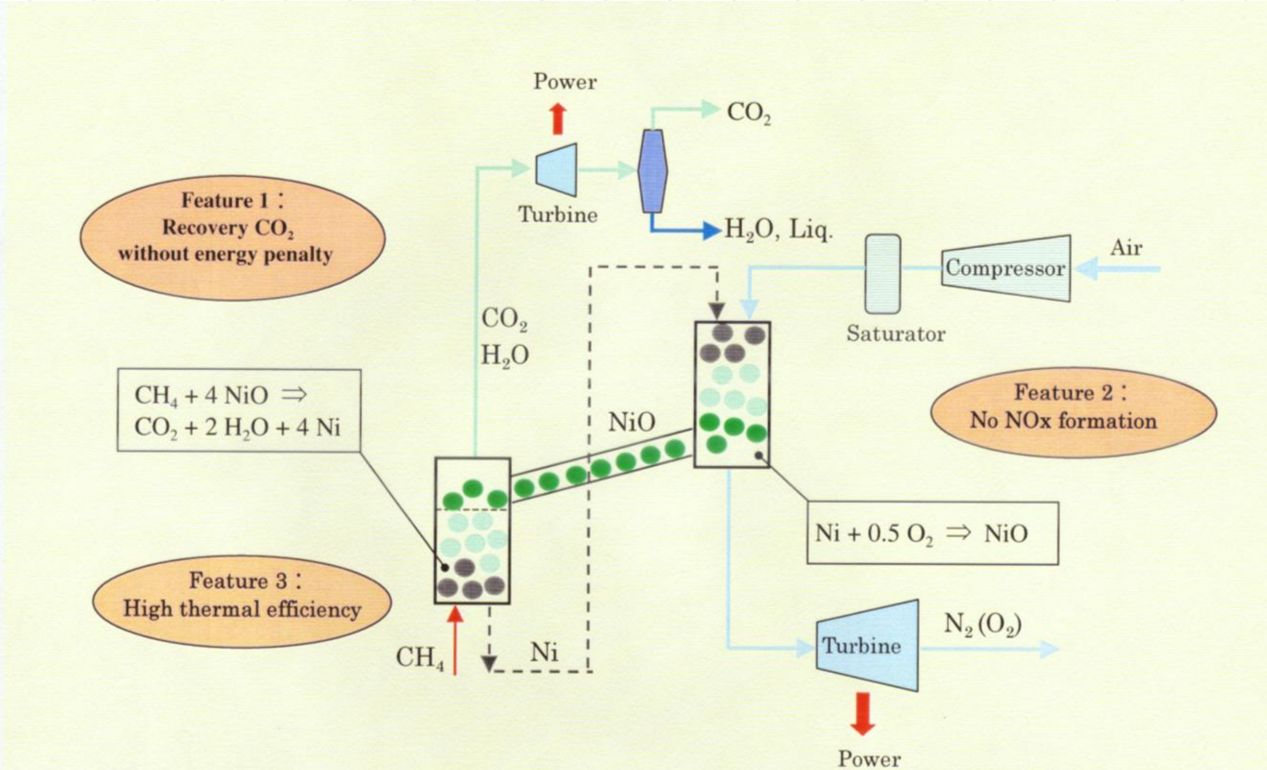


Clean fuel

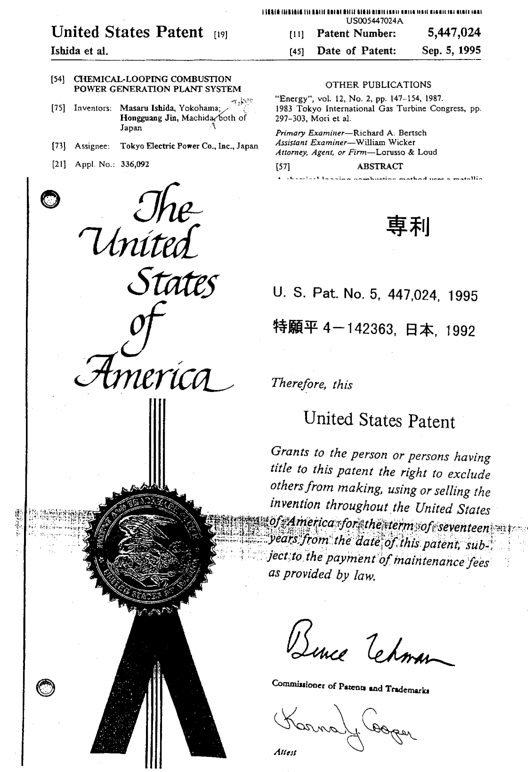
Reduce the irreversibility of chemical energy utilization

Capture CO_2 with low energy consumption

Novel Cycle with Chemical Looping Combustion



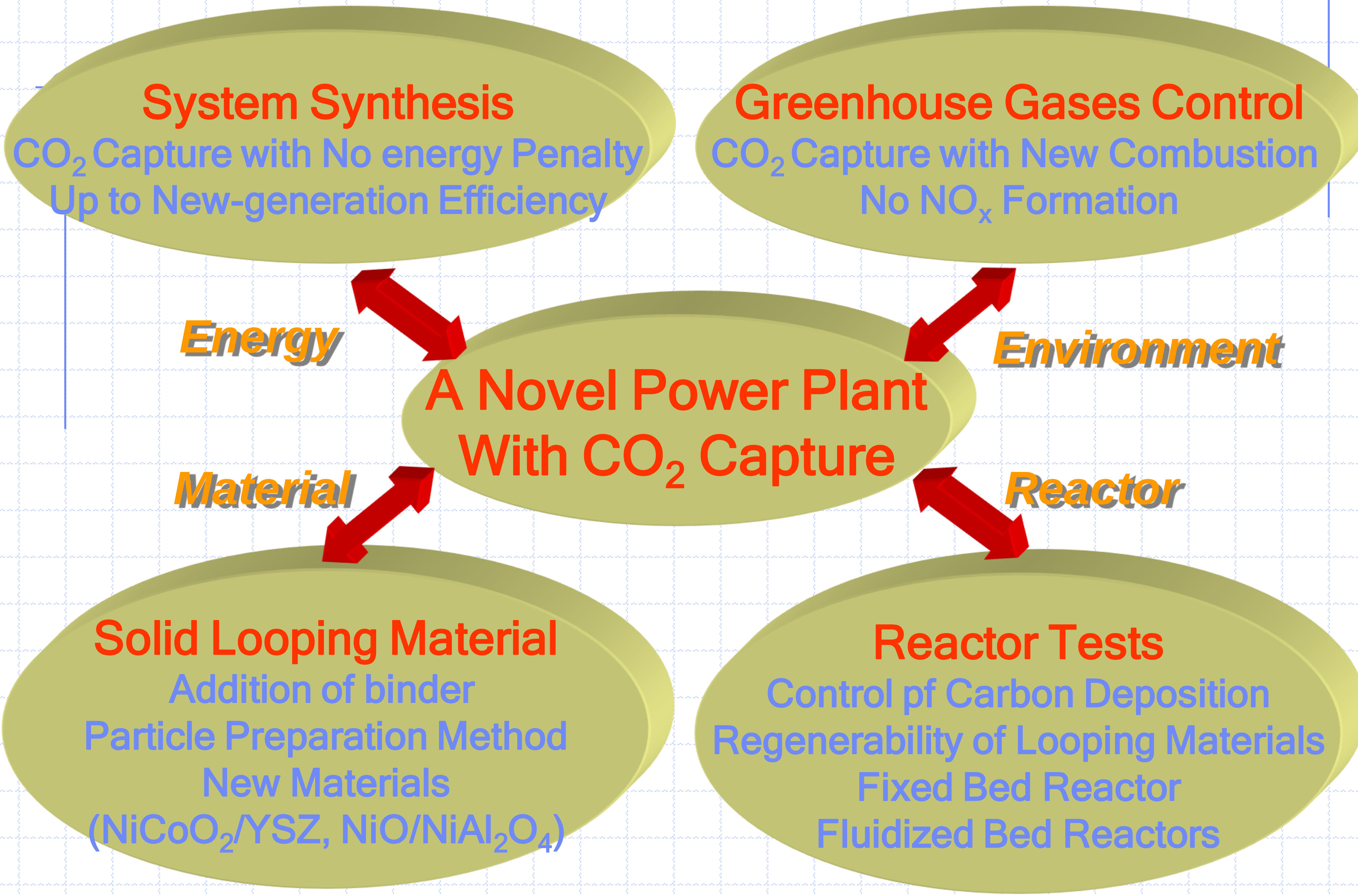
Concept diagram of a gas turbine cycle with chemical looping combustion



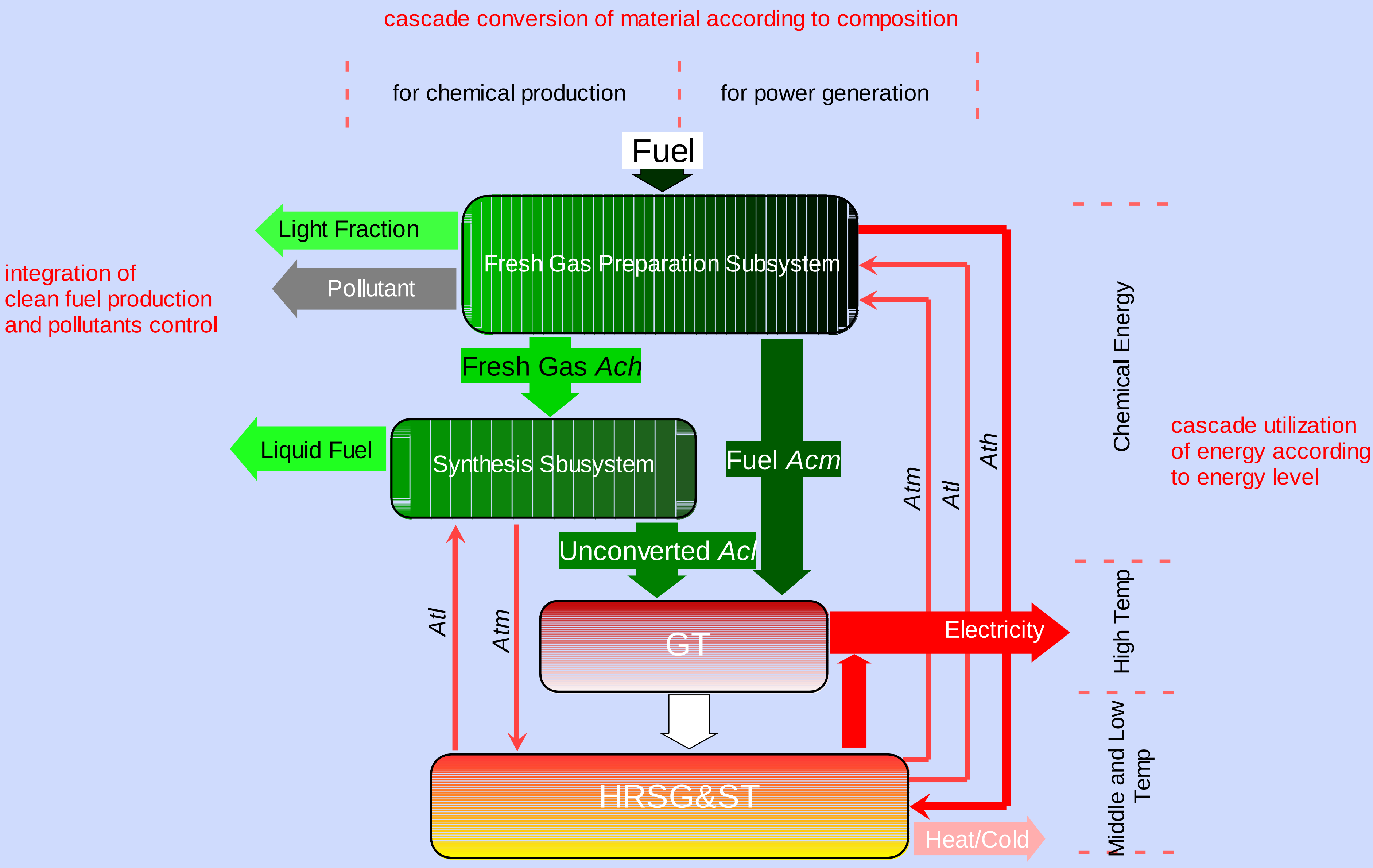
Patent by U.S.A and Japan

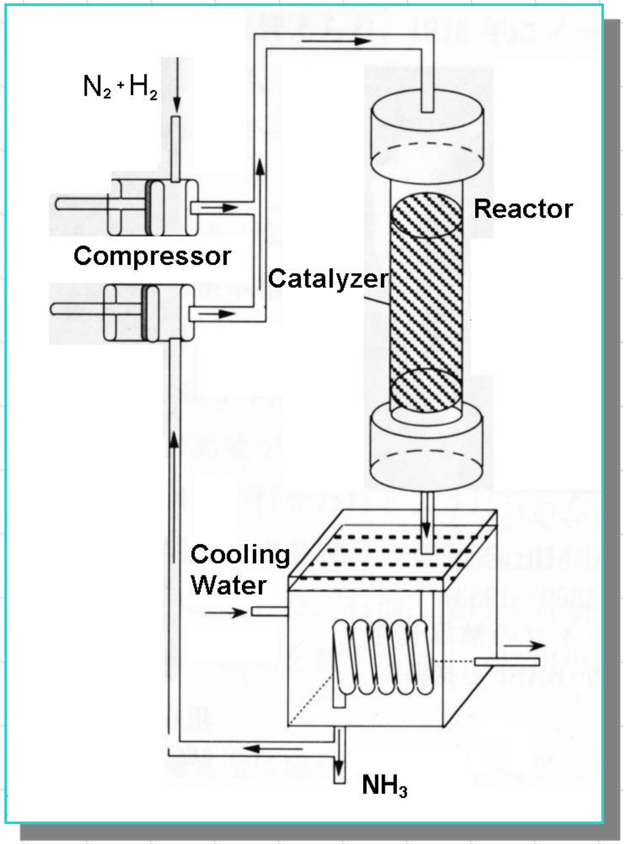
“Most Advanced Research” projects supported by NEDO

“The Excellent Research” of RITE


System Synthesis
CO_2 Capture with No energy Penalty
Up to New-generation Efficiency
Greenhouse Gases Control
CO_2 Capture with New Combustion
No NO_x Formation
Energy
Environment
A Novel Power Plant
With CO_2 Capture
Material
Reactor
Solid Looping Material
Addition of binder
Particle Preparation Method
New Materials
($NiCoO_2$/YSZ, NiO/$NiAl_2O_4$)
Reactor Tests
Control pf Carbon Deposition
Regenerability of Looping Materials
Fixed Bed Reactor
Fluidized Bed Reactors

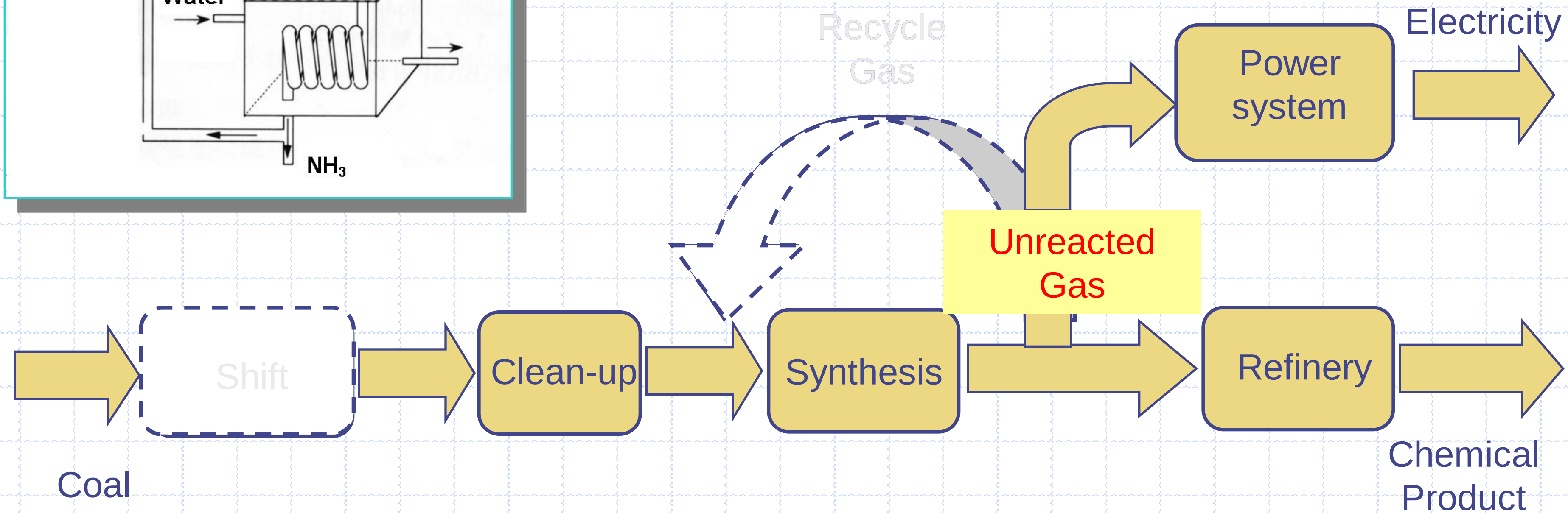
The principle of integration for polygeneration system



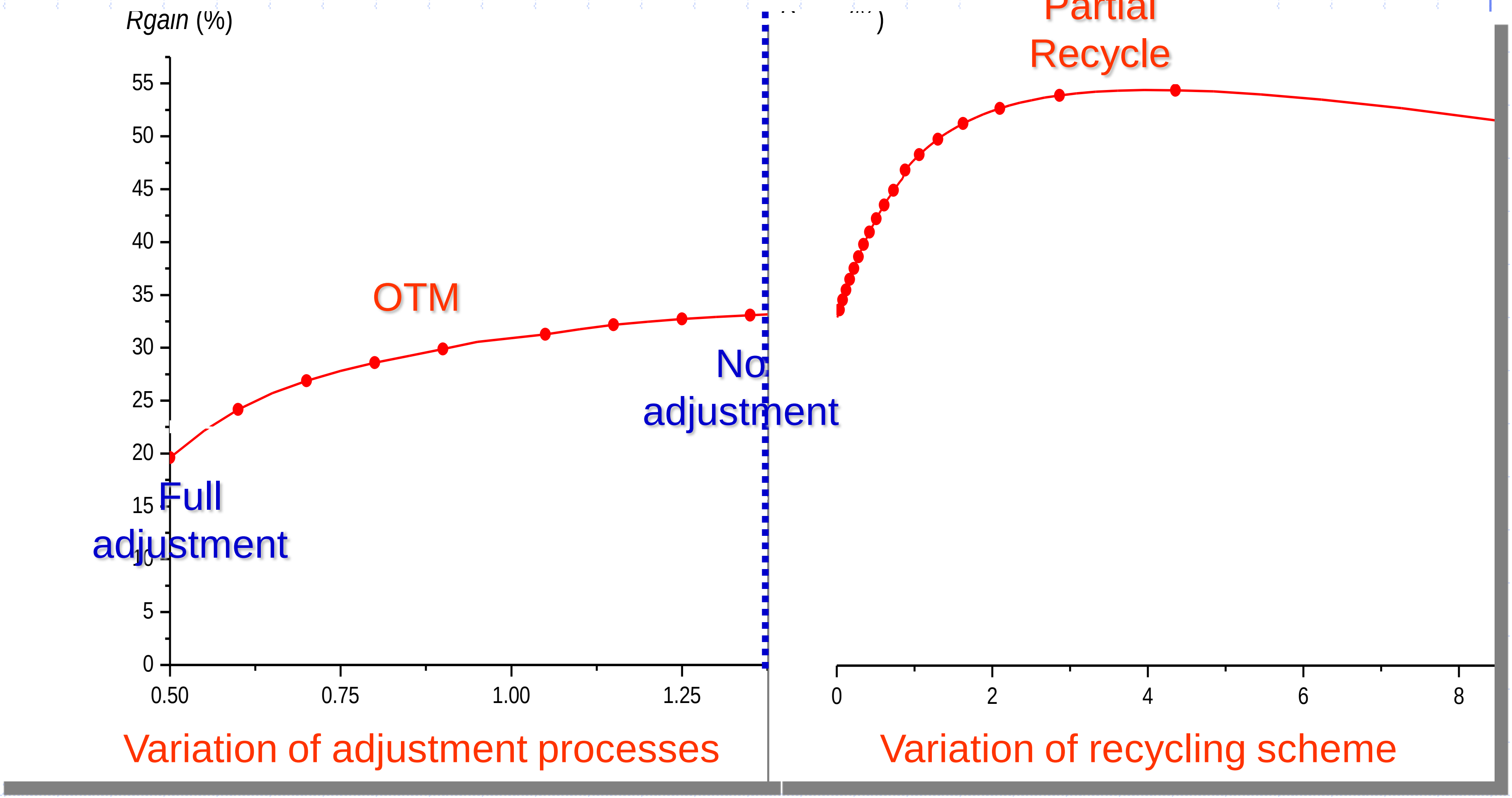


Professor F. Haber
Recycle the unreacted gas.
Highly improve the conversion ratio.
Main contribution on chemical production.

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

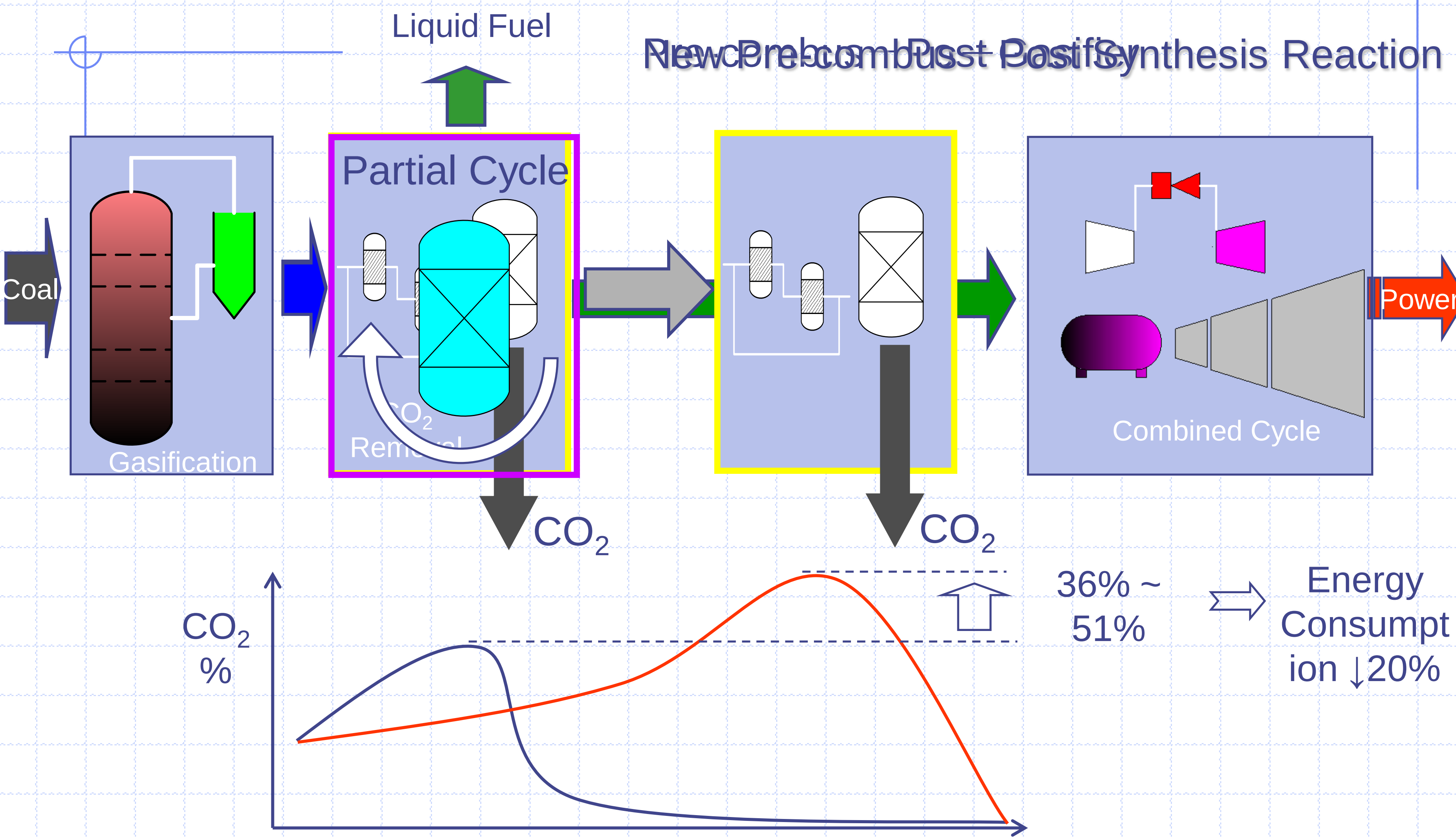
Performance comparison between three sequential polygeneration systems

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 (%)		***15***		***5.3***		***8.1***

Attractive performance improvement in new system

Novel polygeneration system with CO_2 recovery

-Patent in Application



Improvement both in energy utilization and CO_2 recovery

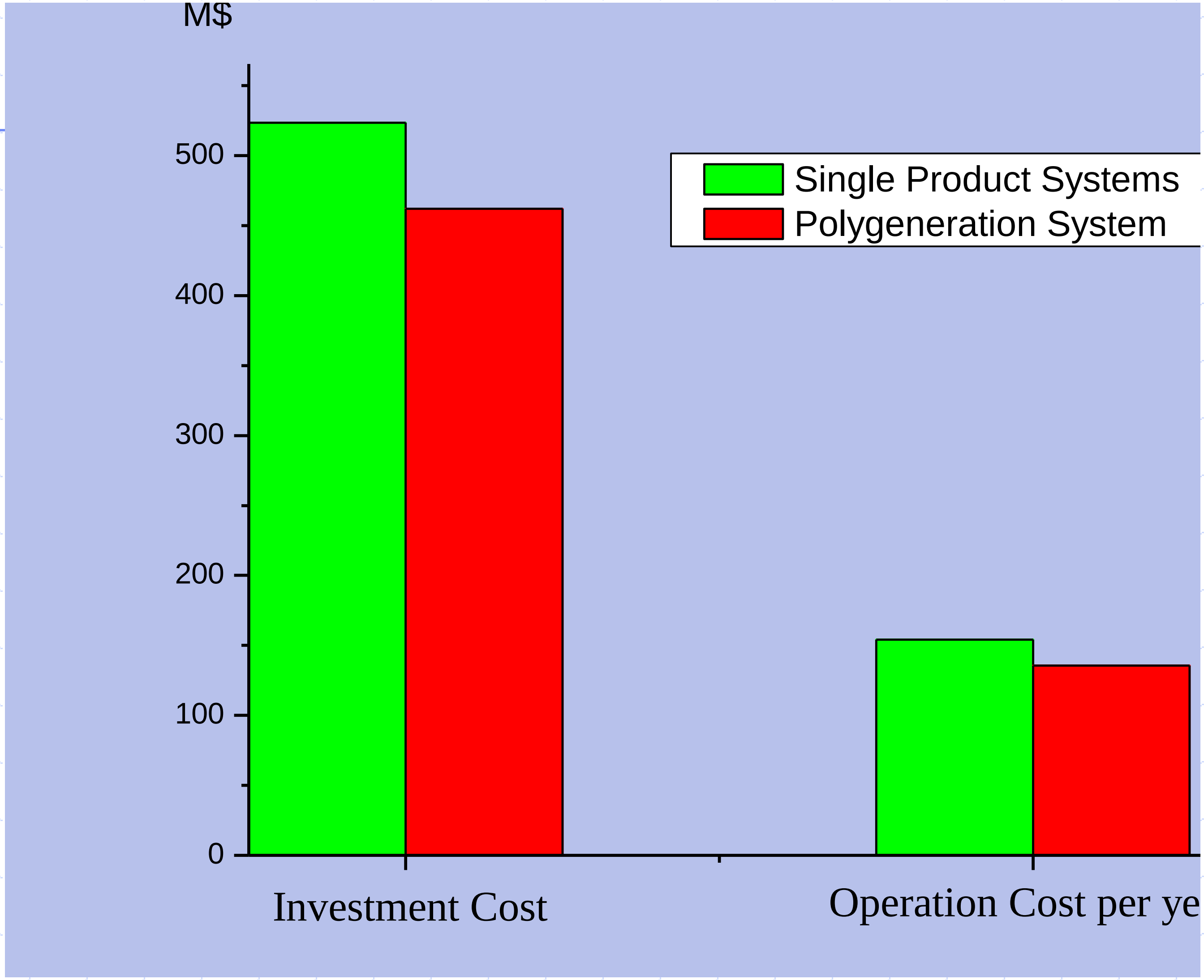
Comparison of performance for single product processes and polygeneration system

Items	Single Product Systems: IGCC – No Capture	Single Product Systems: IGCC – With Capture	Single Product Systems: Single Methanol Product Process	Polygeneration System with CO_2 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_2 product (kg/kg-fuel)		1.89		1.79
CO_2 emission (kg/kg-fuel)	2.485	0.59		0.183
CO_2 emission rate (kg/kWh)	0.763	0.226		***0.14***
Recovery ratio (%)		76.2		72.1
Energy penalty for CO_2 recovery (kWh/kg-CO_2)		0.341		None
Thermal efficiency (%)	43.9	35.2		***47.3***
Energy Consumption for Methanol (GJ/t)			45.61	
Energy Saving Ratio (%)				***12.8***

Instead of paying energy penalty

new system achieve better performance with CO_2 capture.

Qualitative economic assessment

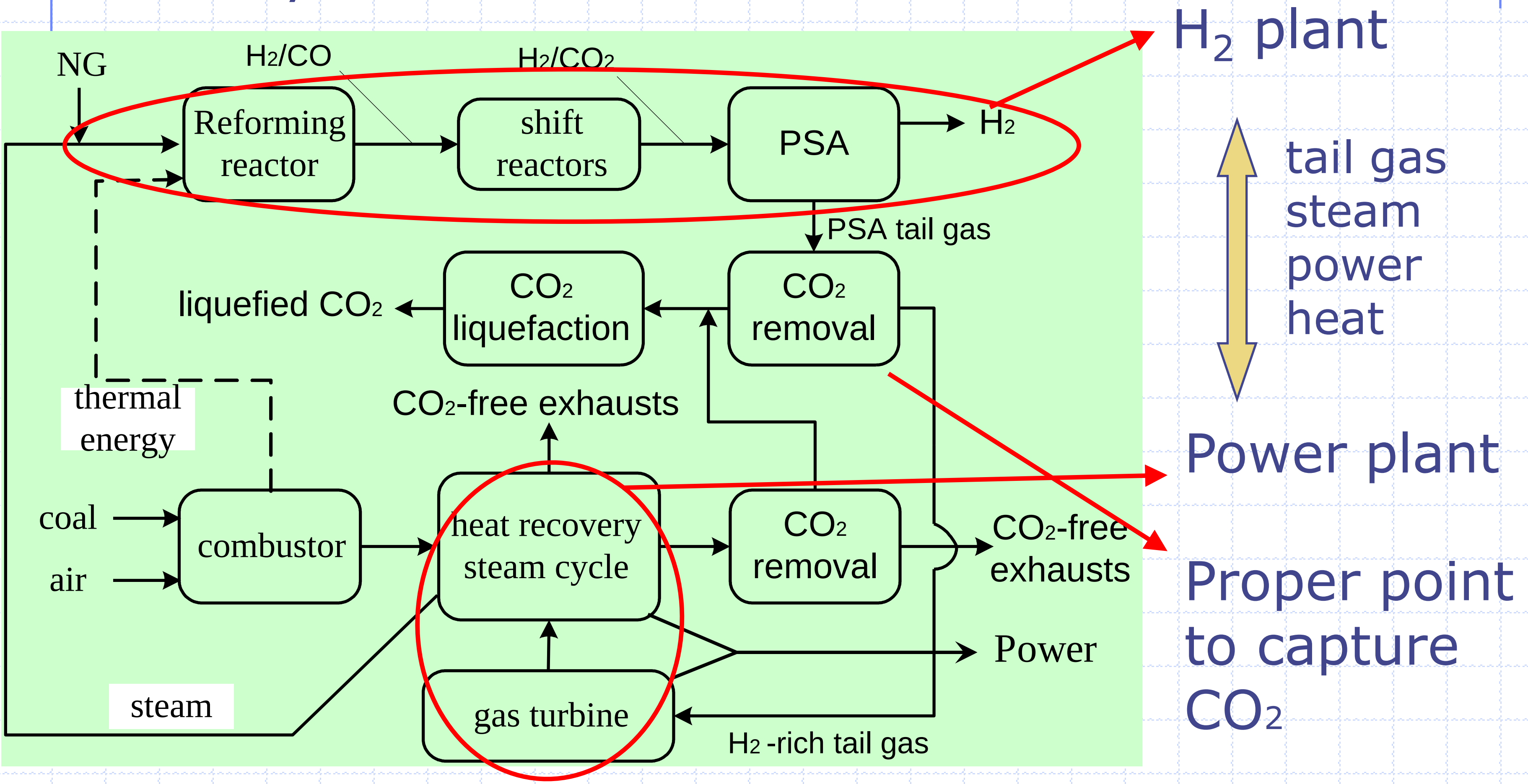


200MW electricity output and 0.4Mt methanol production per year

Conceptual design of the MES system

Two specific features of the MES system

- Integration of H_2 plant and power plant
- Synthetic use of NG and coal



Synthetic use of coal and NG

Reaction of methane/steam reforming

$$CH_4 + H_2O \rightarrow 3H_2 + CO$$

$$CO + H_2O \rightarrow CO_2 + H_2$$

Strong endothermic reaction

Reforming process in conventional H_2 plant

Steam generation in conventional power plant

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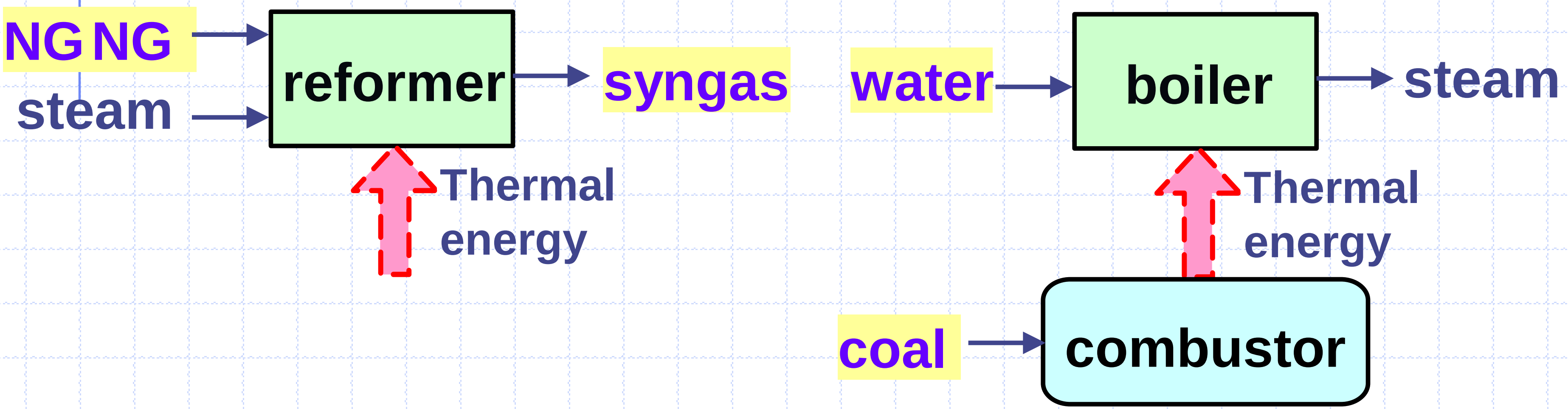

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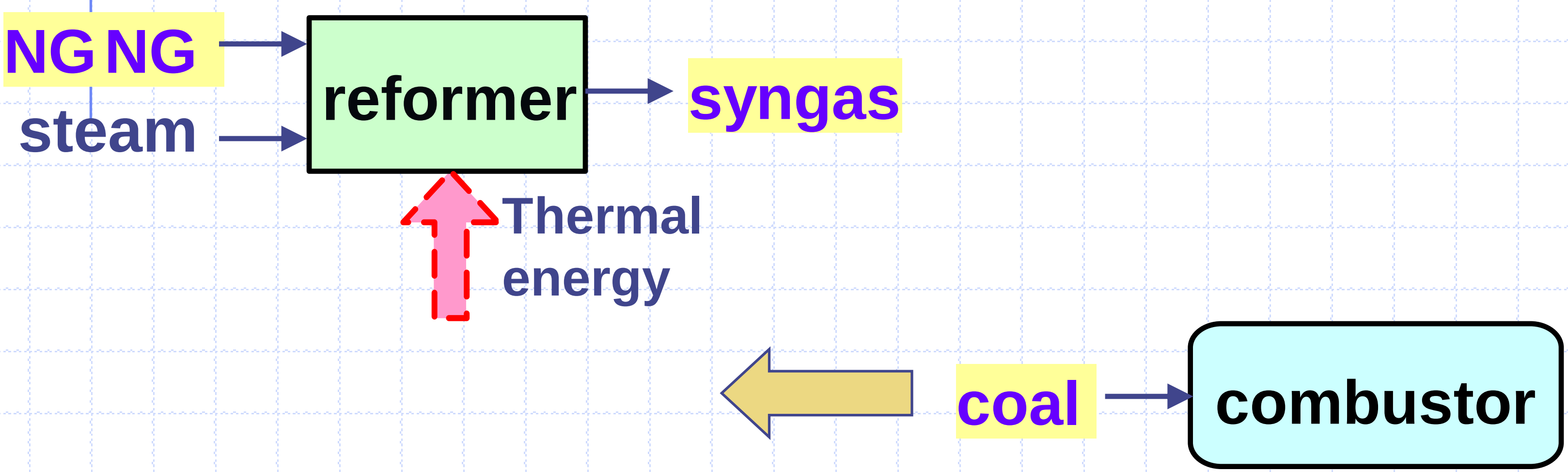

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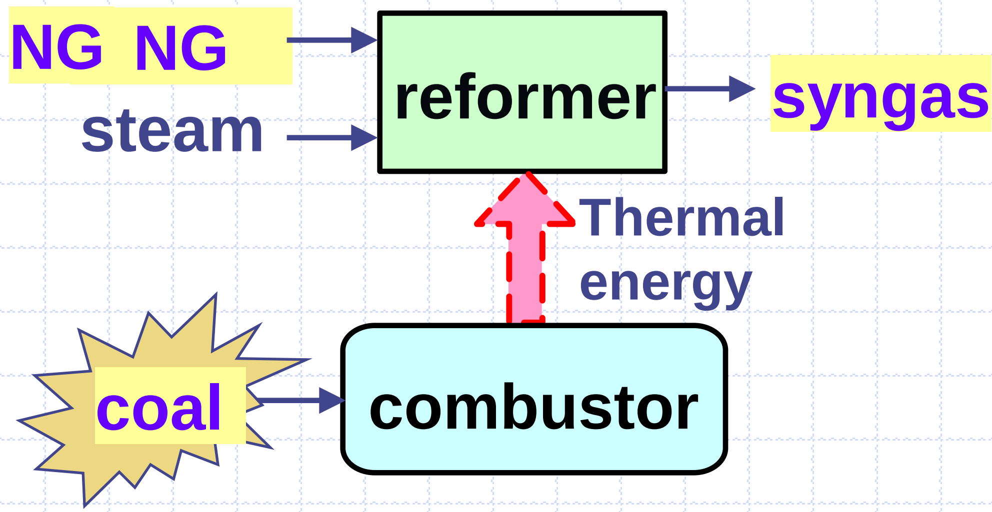


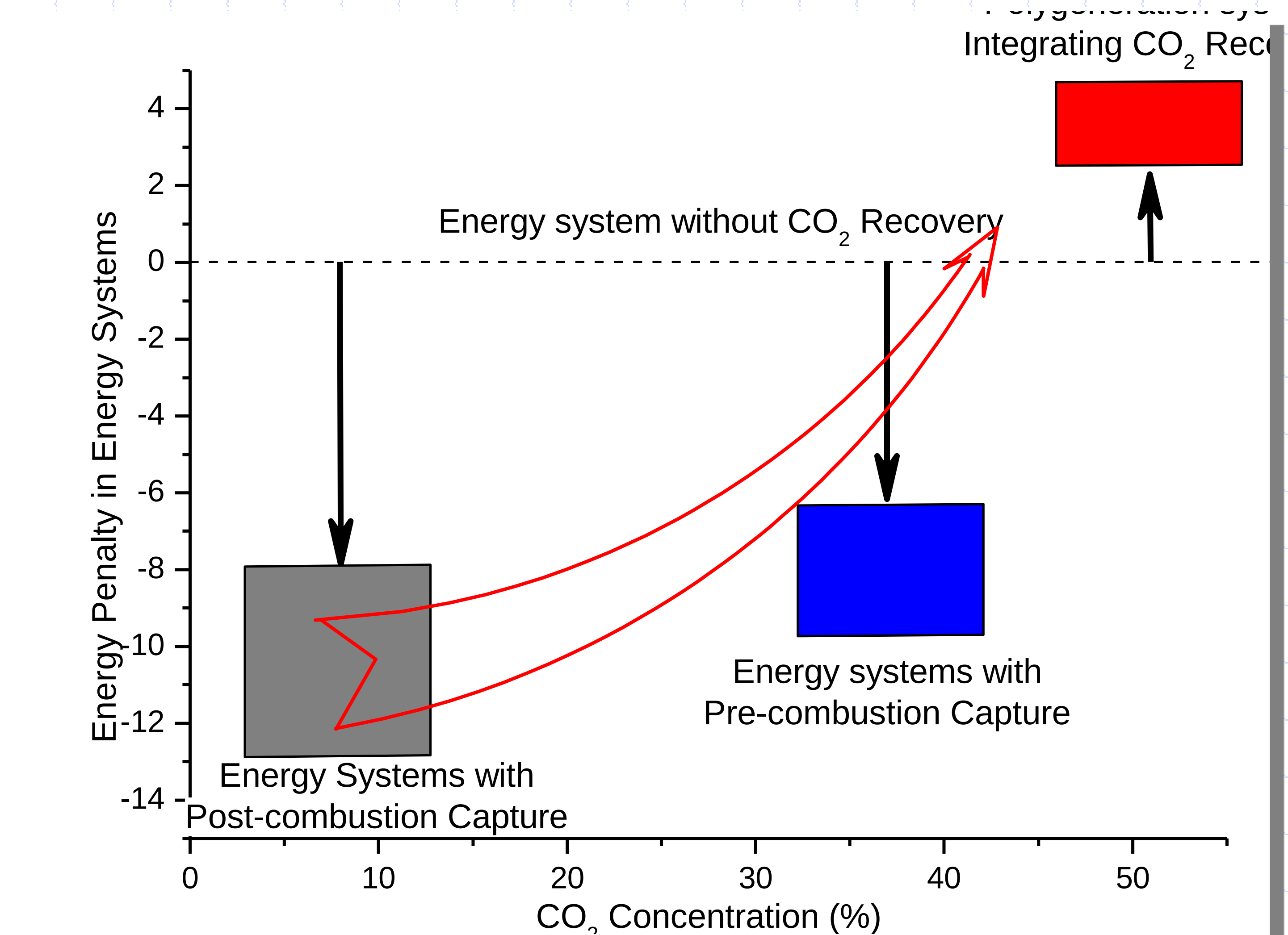
Dual fuel reforming process in MES system

Results and Discussion

System / Items	Ref. without CO_2 removal	MES system	Ref. with CO_2 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_2 liq.	**-**	**13.4**	**16.7**
CO_2 removal rate, %	**-**	**90.1**	**90.1**
Overall efficiency, %	**63.0**	**63.2**	**54.5**

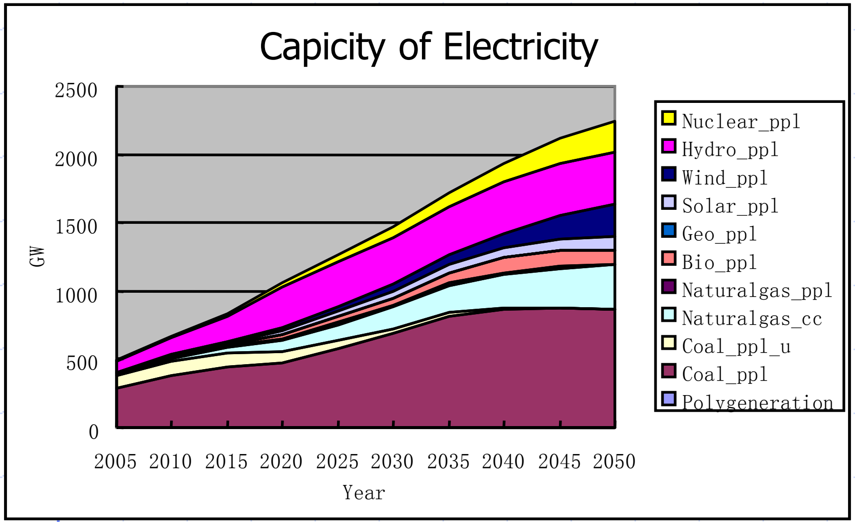
MES system has zero energy penalty for CO_2 removal!

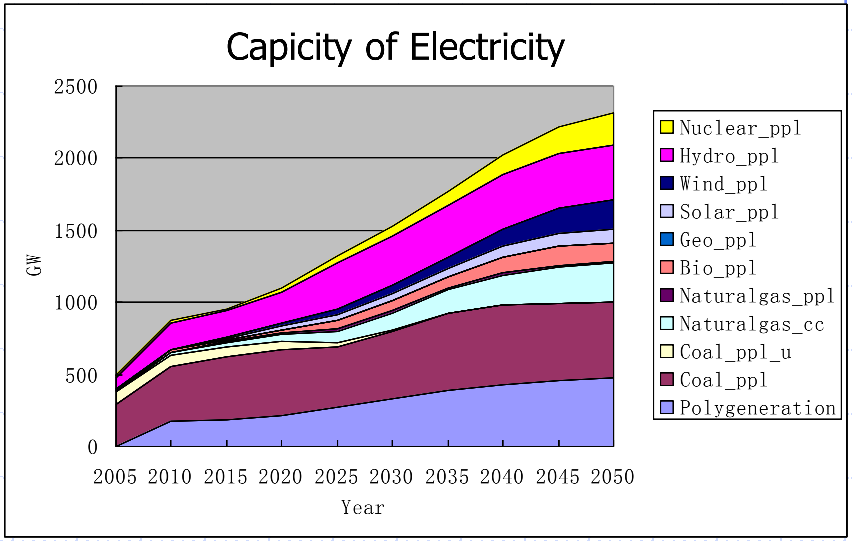
Breakthrough in CCS technology

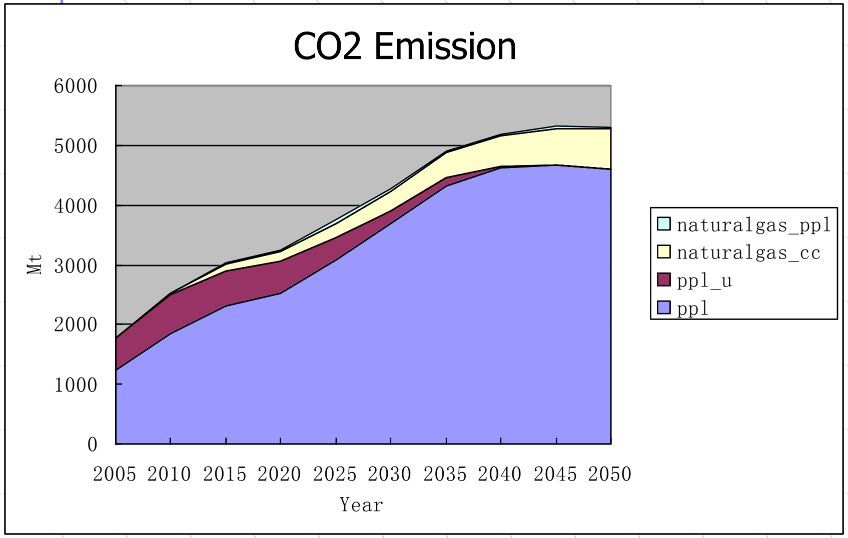


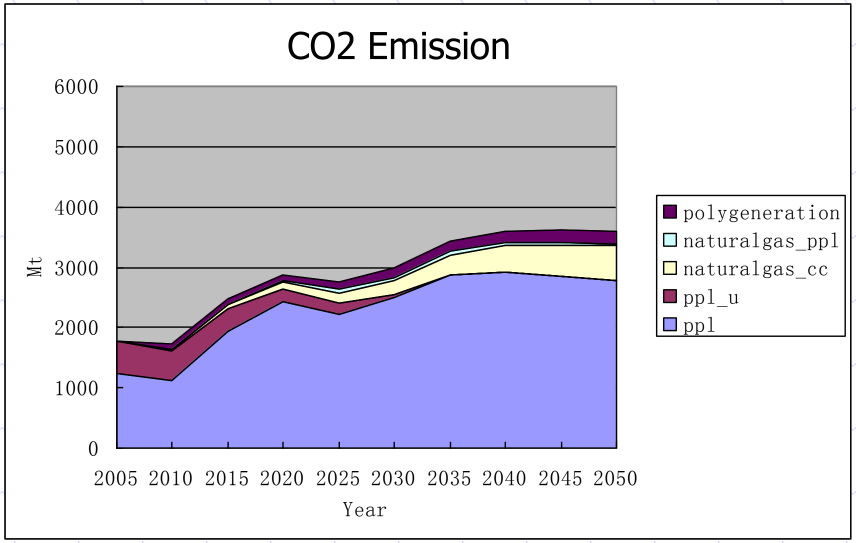
CO2 Concentration

Scenario for Different Technical Routes









Scenario with Traditional Technologies

Scenario with New Technologies

Innovative technology for CO_2 capture

- Integration of energy use and CO_2 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