Perspectives on reducing emissions in key industries: role of CCS

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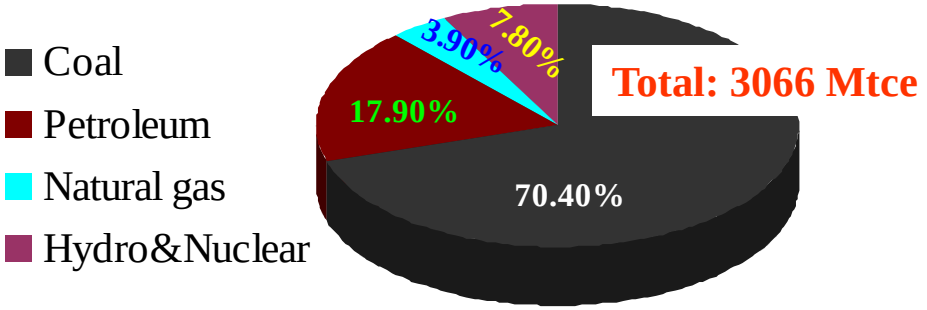
Outline

- Industry CO_2 emission in China
- Non-power industry CCS opportunities
  - Iron & steel industry
  - Coal chemical industry
  - Cement industry
- CAS carbon budget project
- Conclusion

Energy consumption & CO_2 emission in China

- **Coal provides the mainly power in China**

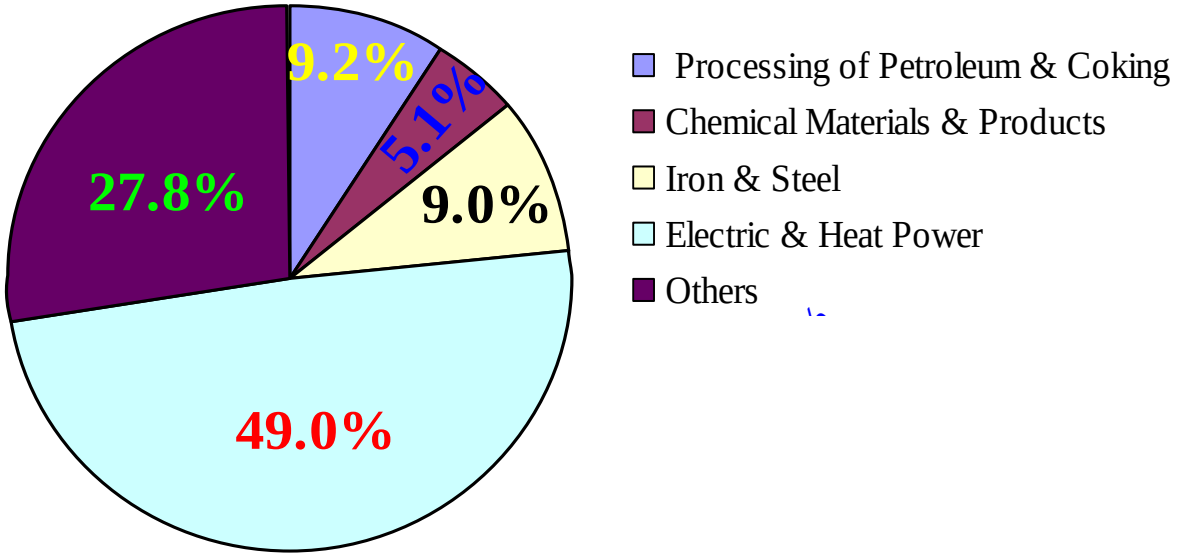
Coal makes up about 70% of China's total energy consumption, and CO_2 emission from industry accounts for a huge part.



Energy consumption (China,2009)

- **Fossil fuel consumption in China's main industries**

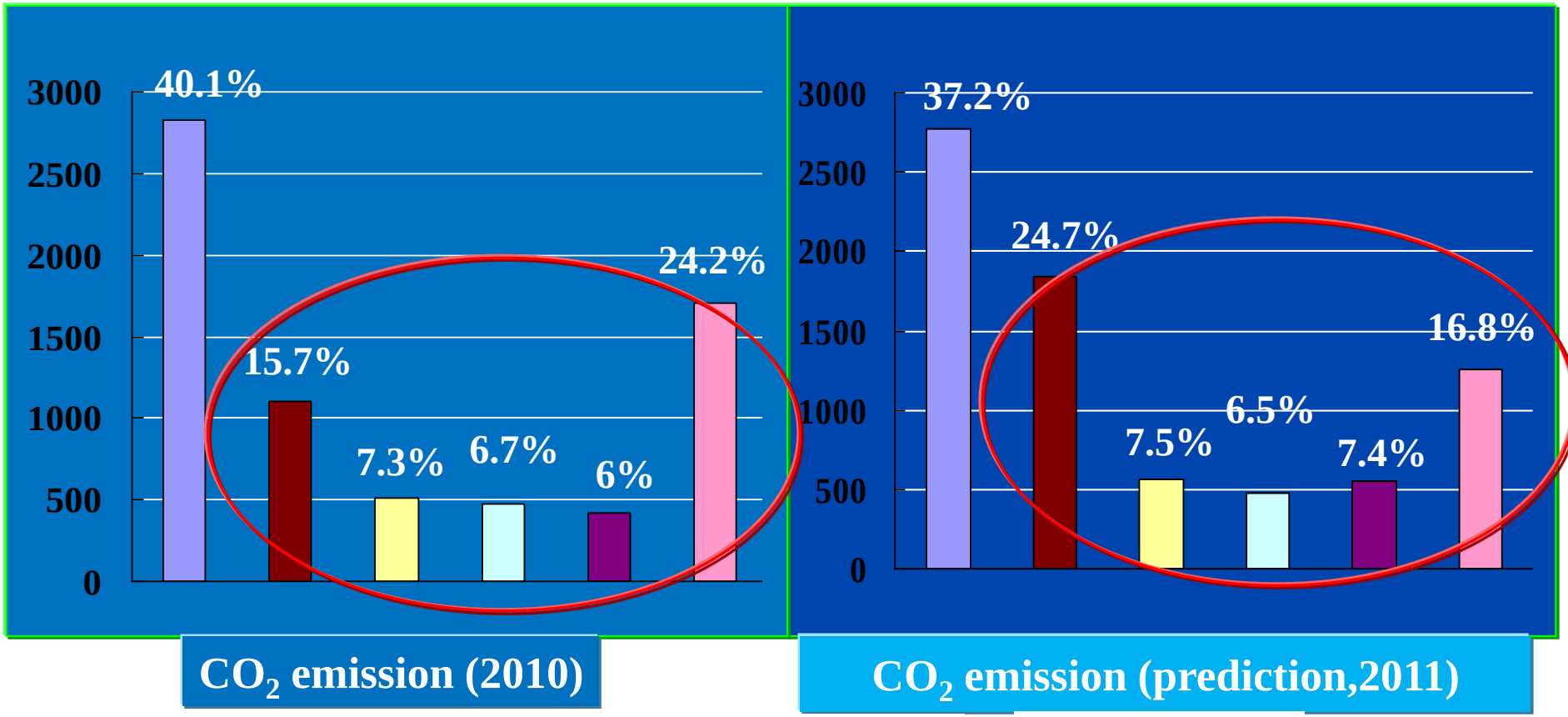
Petrochemical, cement and metallurgical industries consume over 40% of coal, which is one of the main sources of CO_2 emission.



Source: China energy statistical yearbook 2010

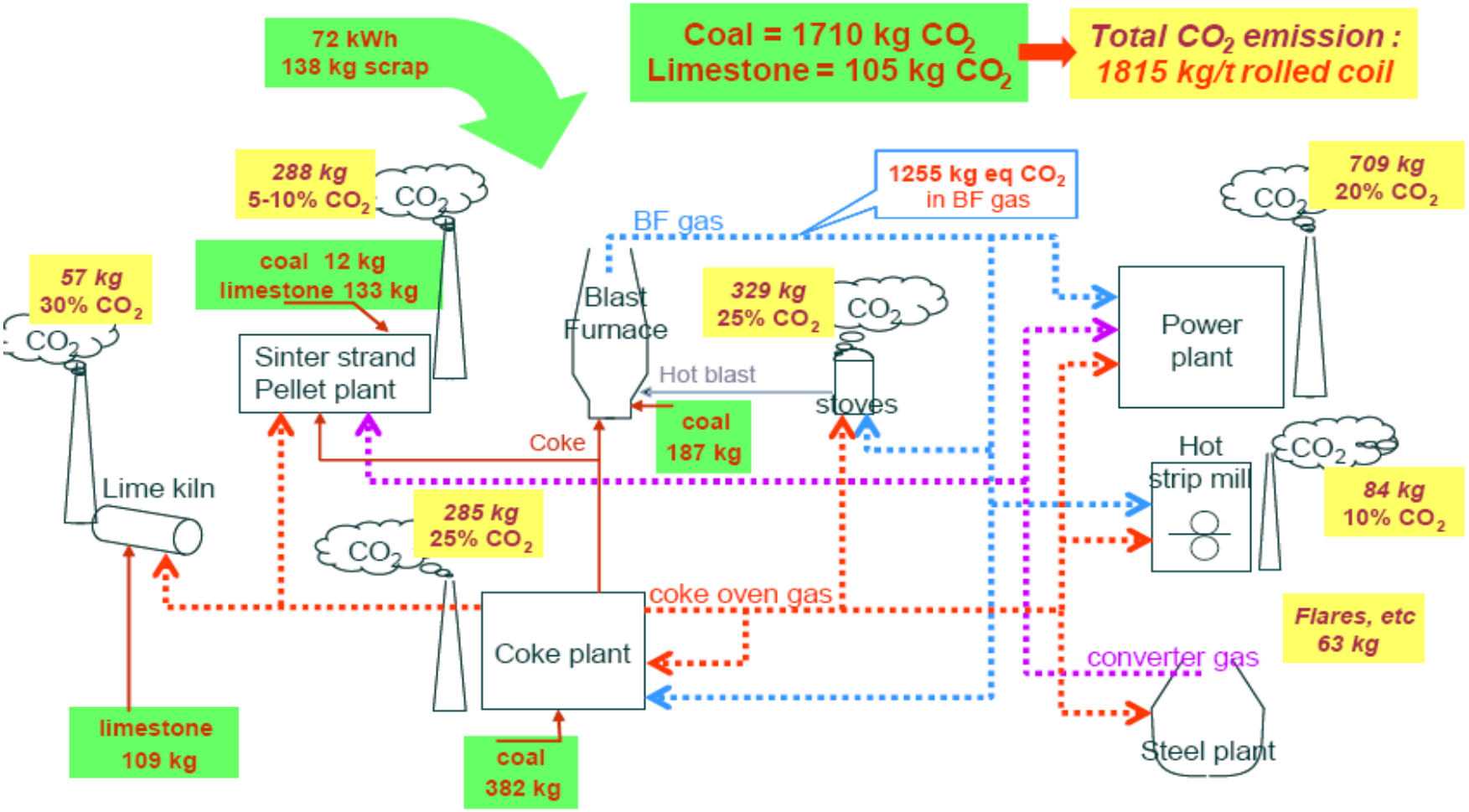
CO_2 emission in China's main industry

Non-power industries, e.g. petrochemical, cement and metallurgical industries, produce over 40% of CO_2 emission, and the figure is still growing.



CCS in Iron & steel industry

CO_2 emissions from a typical steel mill

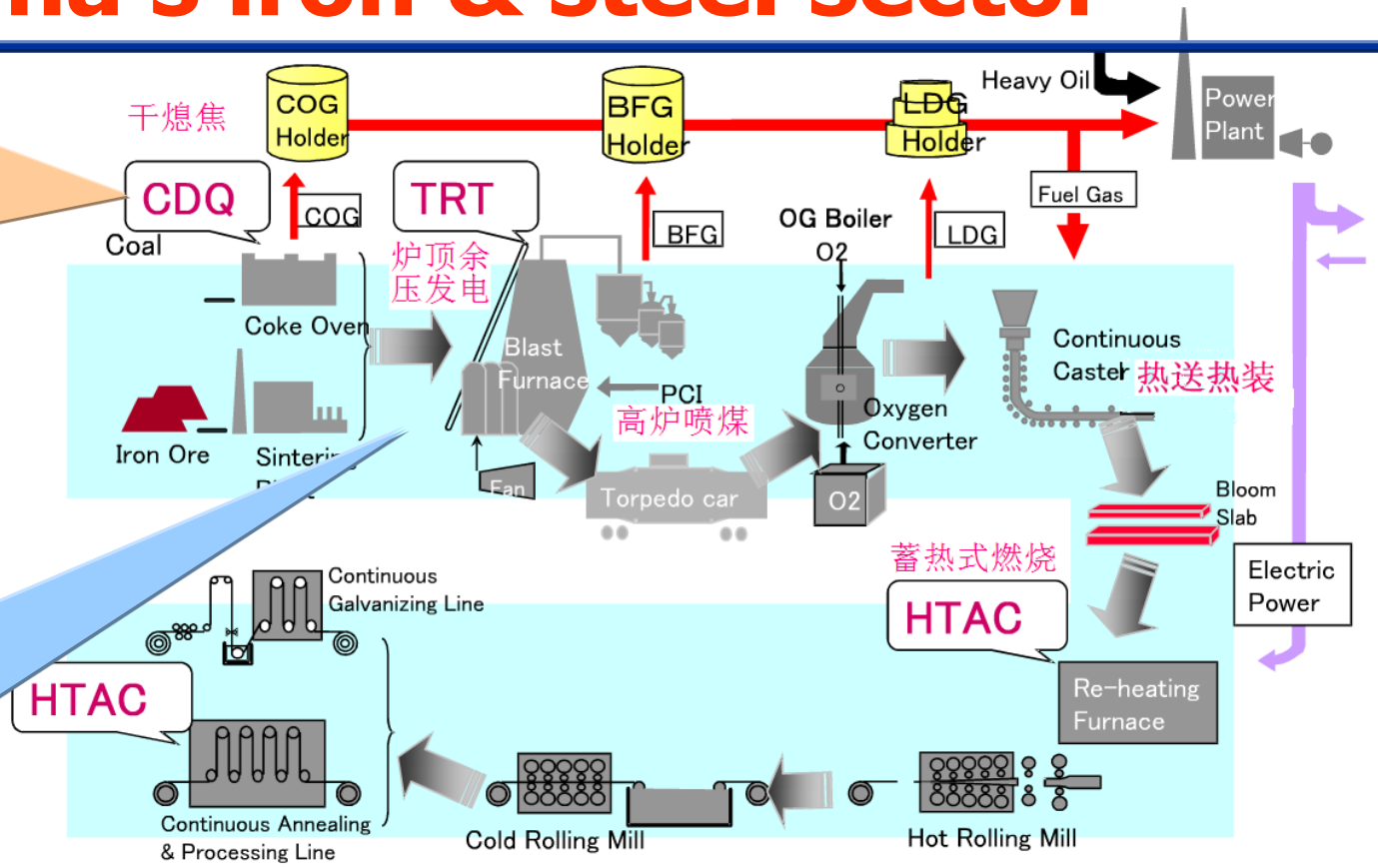


- CO_2 emission: 1800~2200kg/ t crude steel

Energy saving technologies in China's iron & steel sector

10~14kg Coal /t crude steel
30~40kg CO_2/t crude steel
CH_4 25.2%, H_2 57%, CO 6.5%, CO_2 2%, N_2 6.5%

40~60kWh /t crude steel
20~30kg CO_2/t crude steel
CH_4 0.3%, H_2 2%, CO 27%, CO_2 13%, N_2 58%

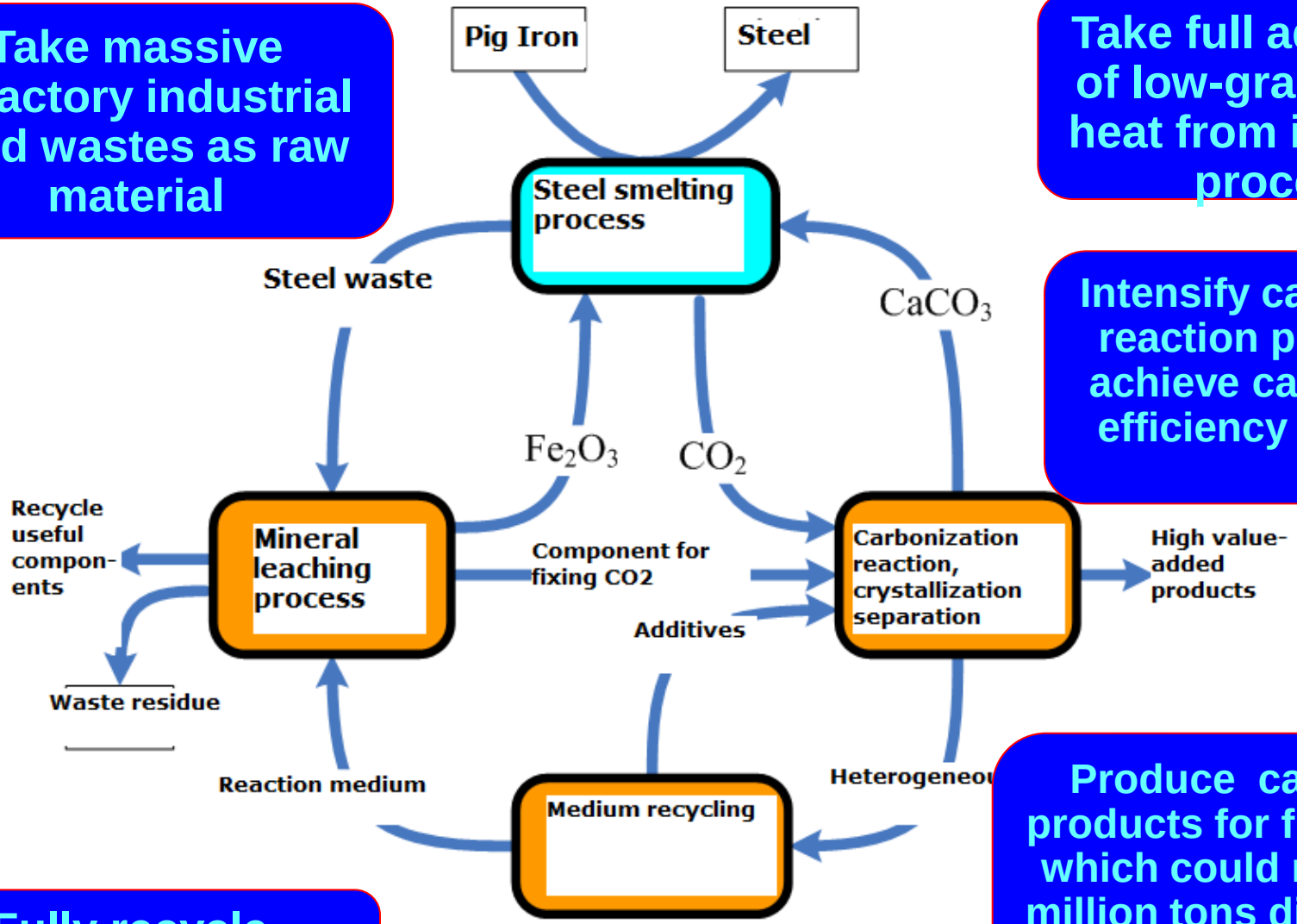


- **Energy saving technologies： the potential for minimizing CO_2 emission 20%~30%.**
- **End-of-pipe CCS on main emitter (BF) brings only 25 to 30% reduction in CO_2 emissions, at high abatement costs.**

IPE-Utilize iron & steel process wastes to fix captured CO_2

Take massive refractory industrial solid wastes as raw material

Take full advantage of low-grade waste heat from industrial process



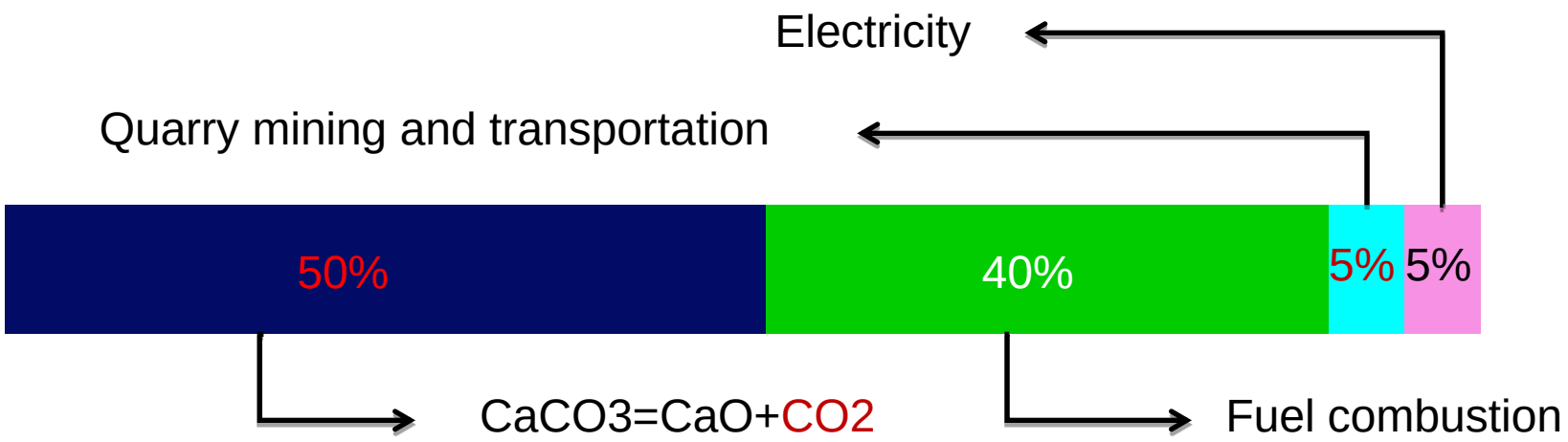
Intensify carbonation reaction process to achieve carbonation efficiency over 75%

Fully recycle reaction medium and utilize efficiently

Produce carbonate products for fixing CO2, which could reduce 10 million tons directly and 100 million indirectly of CO2 annually

CCS in Cement industry

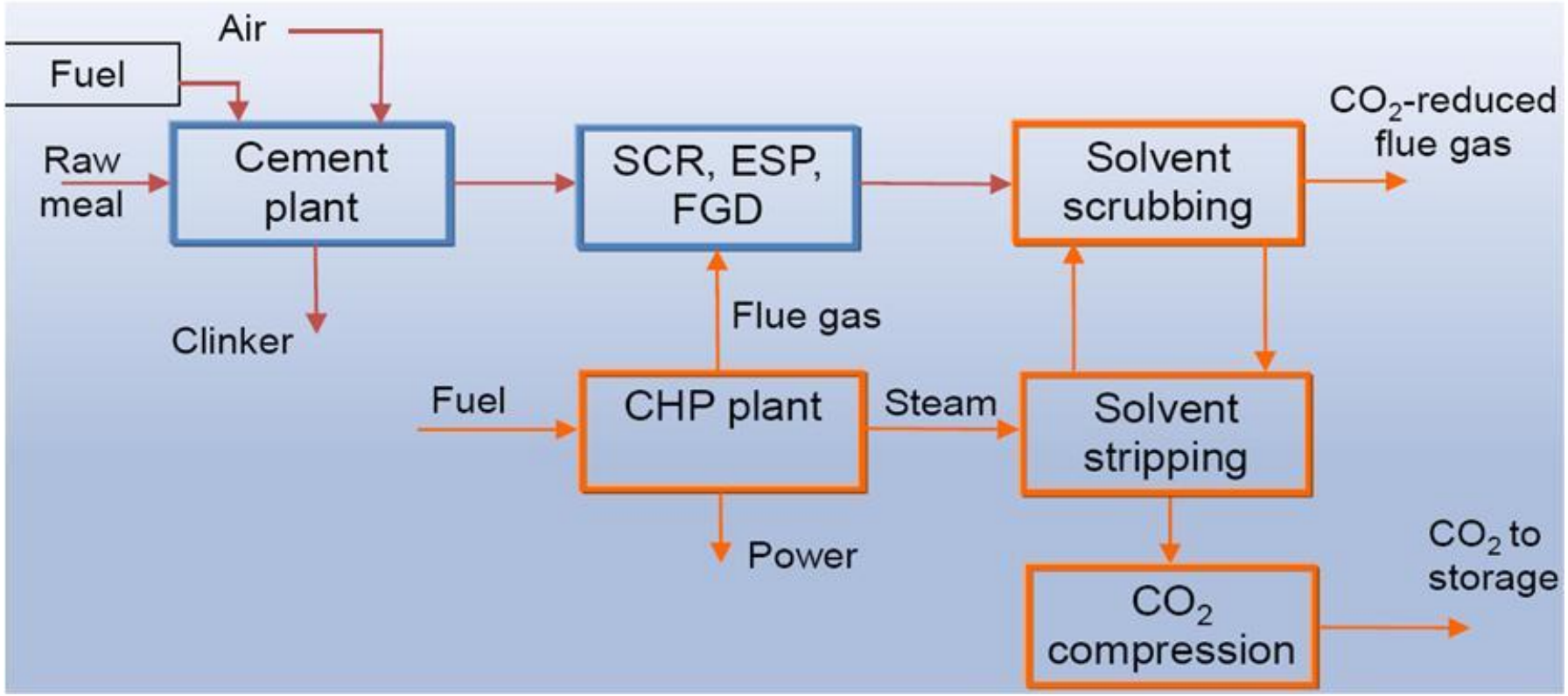
CO_2 emission in cement production process



China:0.89 t CO_2/t cement

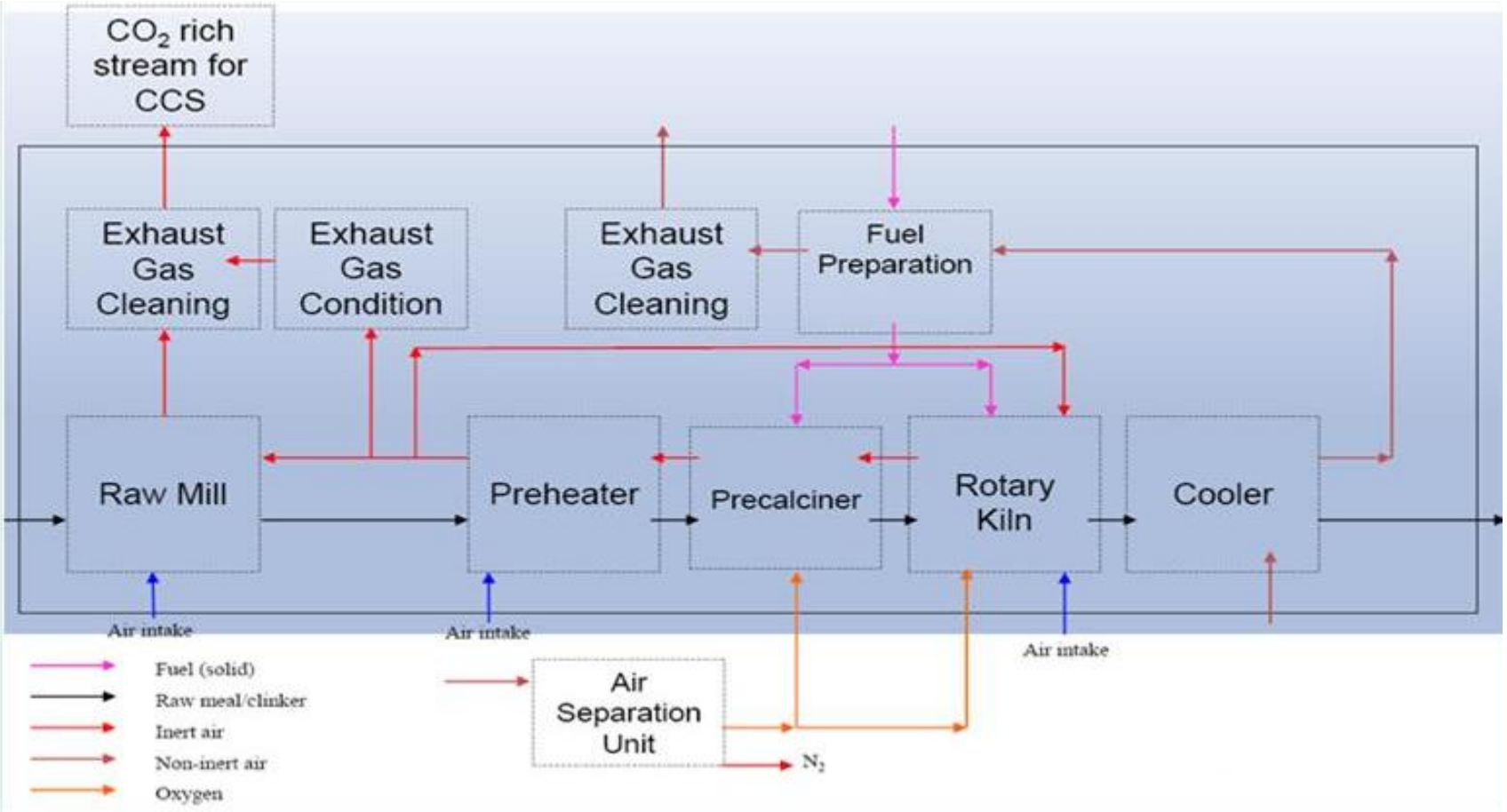
- **Half of CO_2 emission comes from $CaCO_3$ calcination, which can not be avoided.**
- **The potential for CO_2 reduction lies in fuel combustion processes, which has an upper limit to 40% as shown in the figure.**

Post-combustion cement plant



- **Cement exhausted gas CO_2 concentration: 14-33% (W/W)**

Oxyfuel cement plant (full capture)



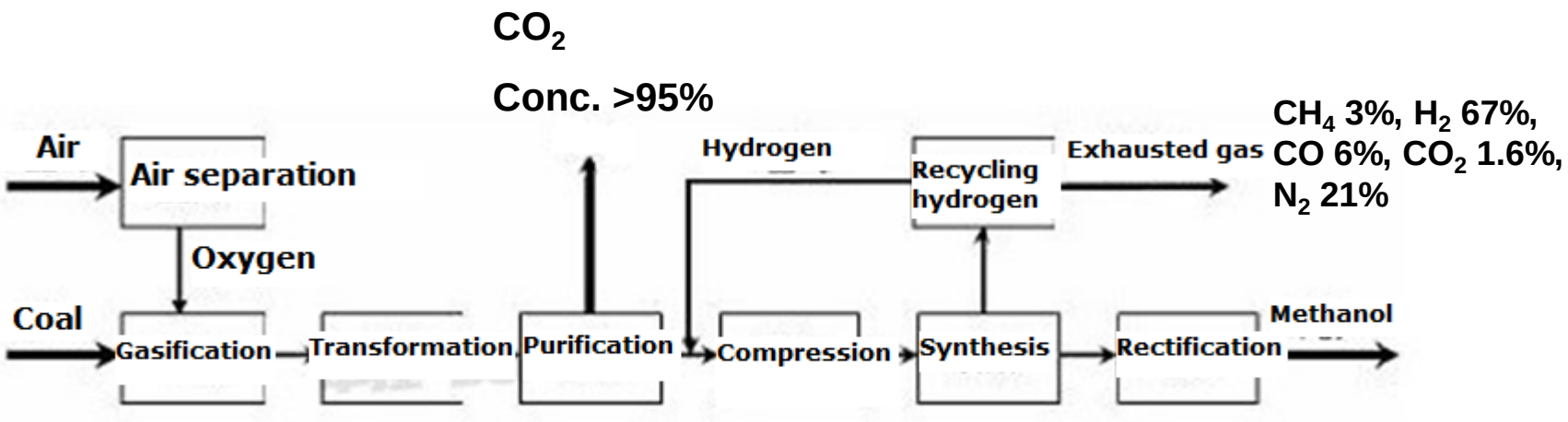
- **Oxy-fuel combustion technology is the most promising CCS enabling technology in cement industry**

CCS in coal chemical industry

Coal chemical industry in China

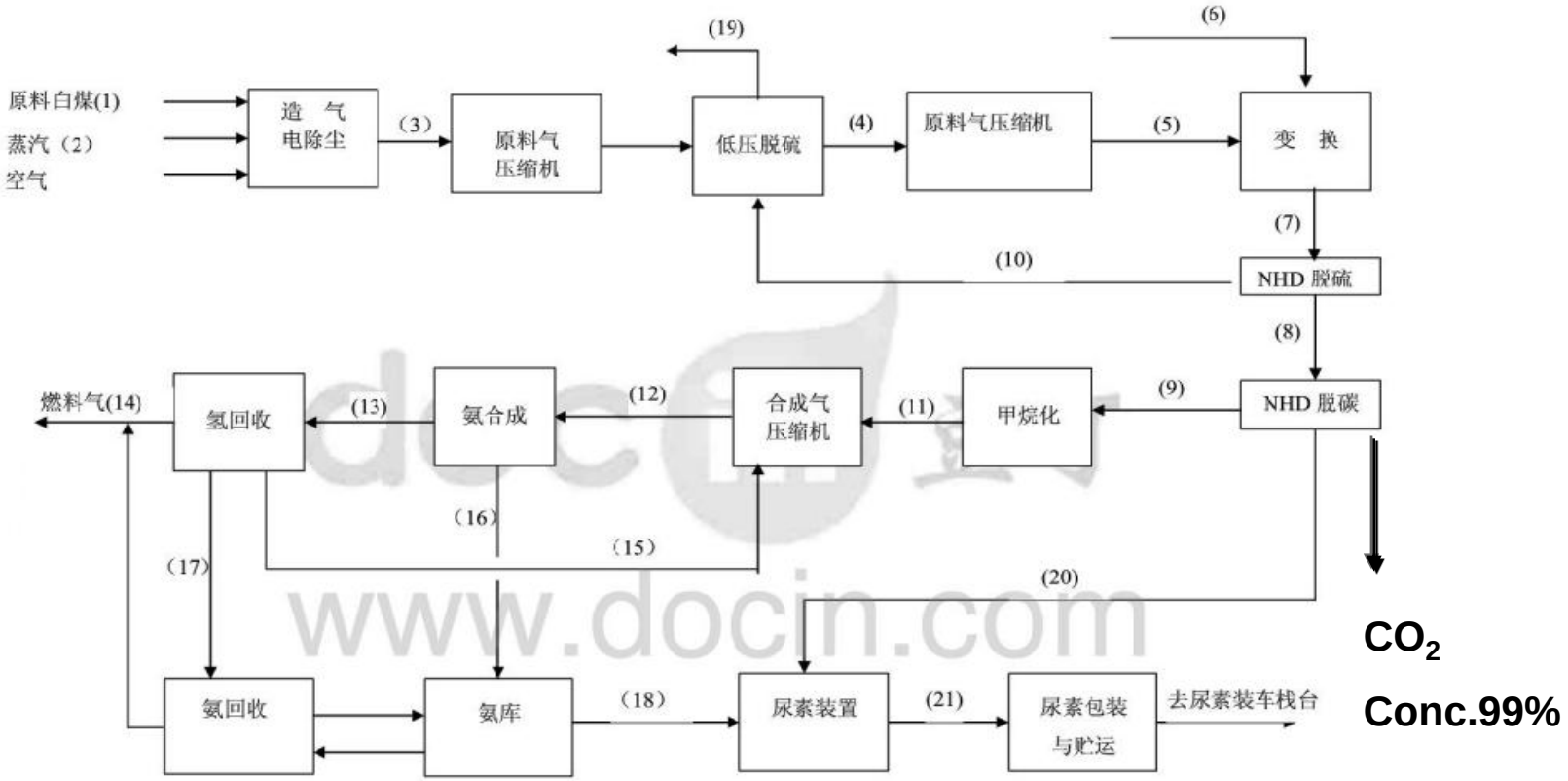
- **Coal to Methanol Process：＞ 40,000,000 ton/y**
- **Coal to Urea Process：＞ 50,000,000 ton/y**
- **Direct coal liquefaction (DCL) vs Indirect coal liquefaction (ICL)**
- **Coal to olefine**
- **Substitute natural gas (SNG)**

Coal to Methanol Process



- For purification process, higher CO_2 concentration(>95%) which is ready for storage can be obtained
- Lower CO_2 concentration and high flow rate for purge gas

Coal to Urea Process



- For decarbonation process, higher CO_2 concentration(>99%) can be obtained(0.4 t CO_2/t urea)

China needs new coal chemical industry

Direct liquefaction:

Indirect liquefaction::

Coal to olefin 2020:8Mt/a

Olefins

11 projects in the construction & plan

MeOH/ DME

Coal to MeOH/DME

2020:60Mt/a

CTL

2020:30Mt/a

Scale:16~40×10^{12} m^3

MeOH

Coke

Coal chemical

Amonia

Carbide

New coal chemical

(ethylene) glycol

NG/ SNG

6 projects in the construction & plan

2020: Huge emission of CO_2(>2Gt)

Large CO_2 emission of coal chemical industry

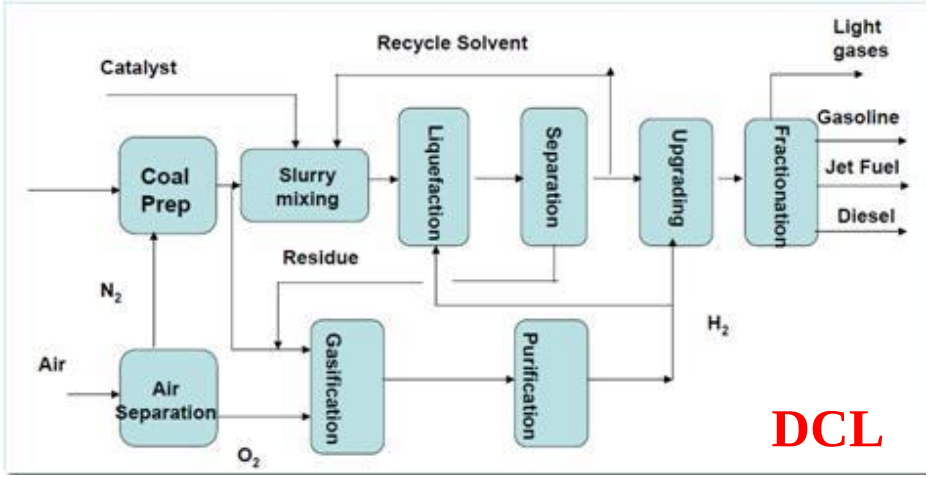
- **New coal chemical industry**

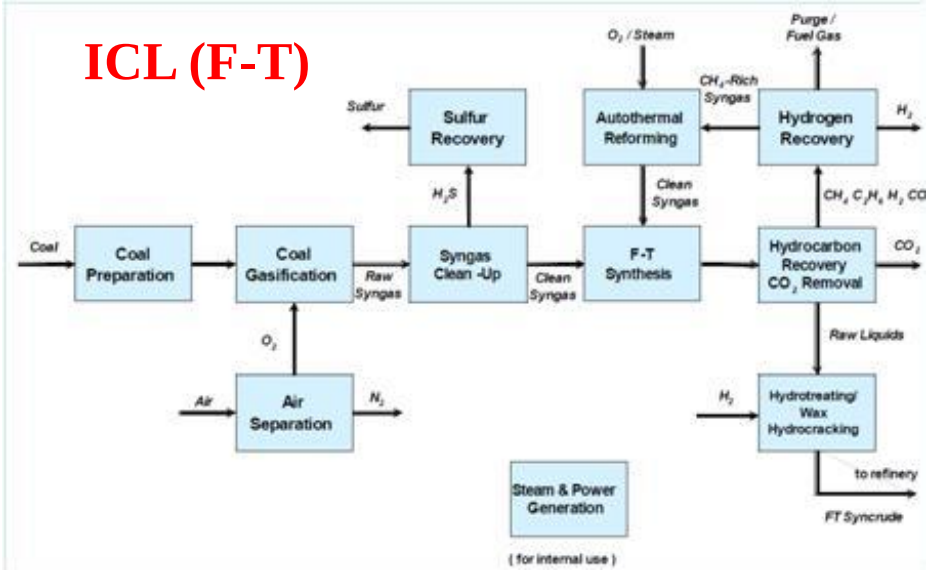
✓ **A direct coal liquefaction project of 1 million tons/y will only emit about 10 million tons of CO_2**

✓ **A polyolefin project of 60 million tons/y will only emit over 360 tons of CO_2**

✓ **A coal to natural gas project of 2 billion tons/y will only emit nearly 6 million tons of CO_2**

Direct coal liquefaction (DCL) vs Indirect coal liquefaction (ICL)



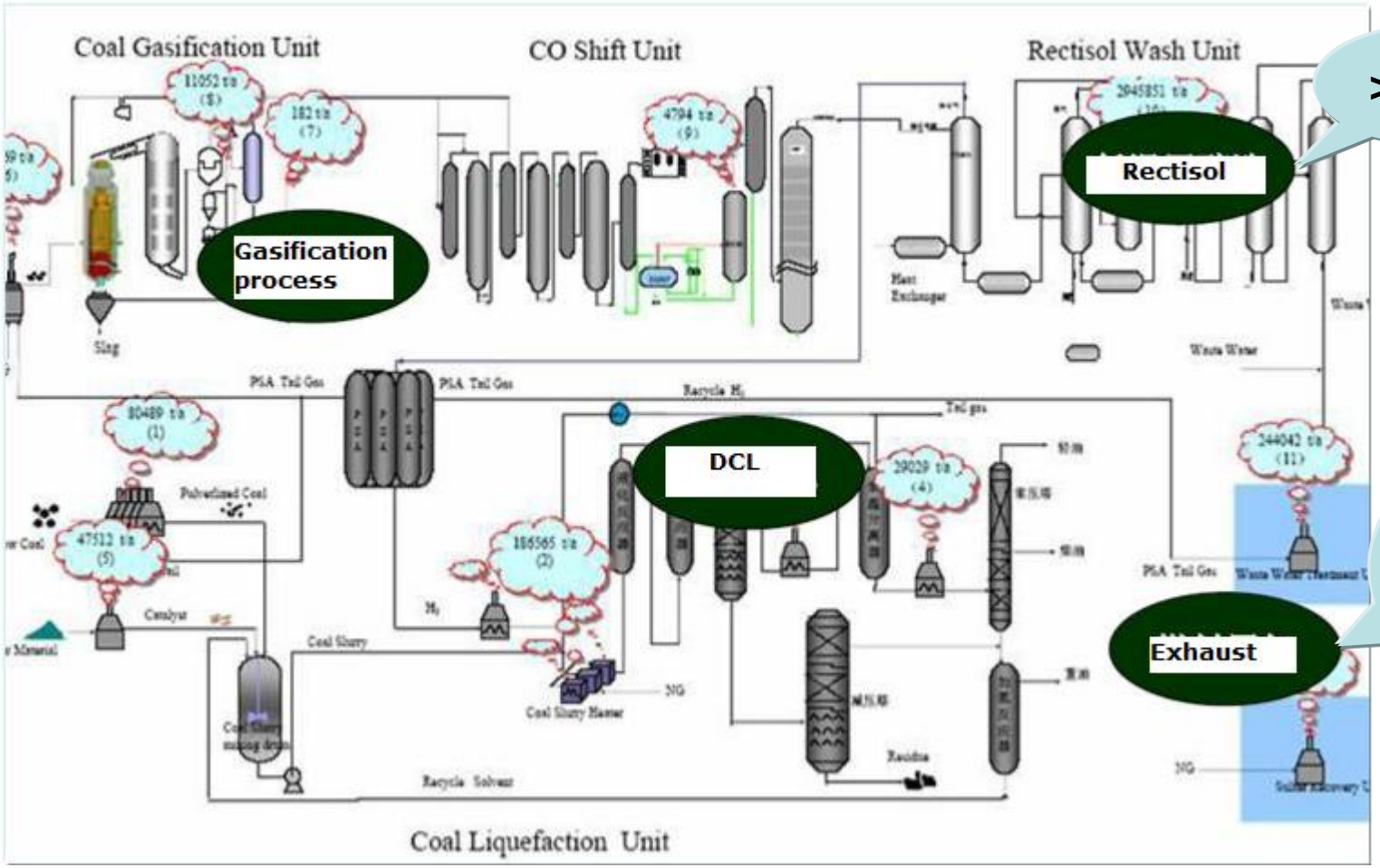


Comparison of various CTL configurations

	DCL	ICL Recycle	ICL Once Through	Hybrid DCL/ICL
Coal consumption (tonnes per day, dry basis)	23,027	29,307	34,450	23,146
Product Mix				
Diesel (bpd)	45,812	47,687	47,687	46,750
Naphtha (bpd)	18,863	22,313	22,313	20,591
LPG (bpd)	5,325	0	0	2,660
Total (bpd)	70,000	70,000	70,000	70,000
Net Export Power (MW)	0	399	1139	45
Thermal efficiency (%)	60.1	48.4	47.4	58.7
Product yield (bbl/t dry coal)	3.04	2.39	2.03	3.02
Plant CO_2 generation (kg CO_2 /bbl product)*	434	706	894	458

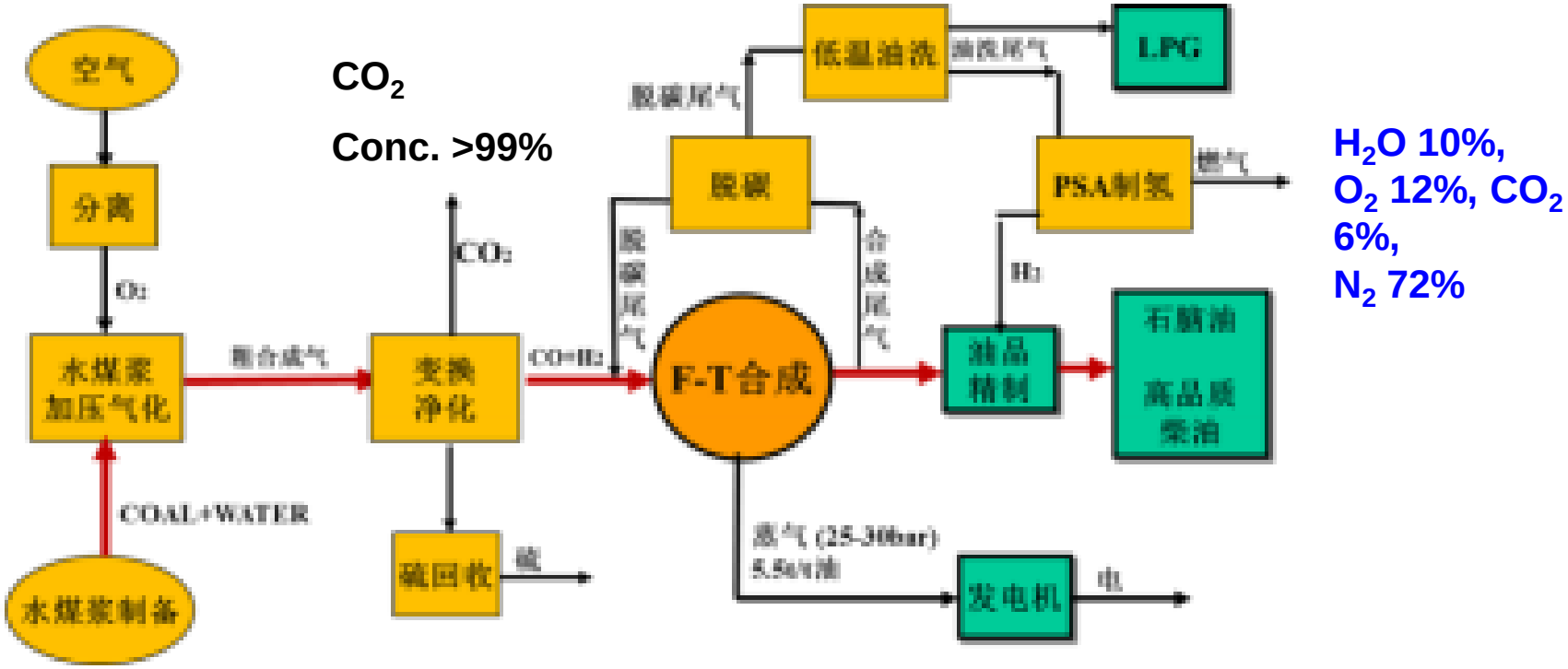
- **CO_2 emission from DCL is 50% less than ICL**
- **Over 80% of this CO_2 is in concentrated form ready for sequestration**

CO_2 Emission sketch map of DCL demonstration plant in Ordos



- Direct liquefaction process produces little CO_2
- CO_2 comes from: hydrogen production (2.9 t/t), fuel combustion (0.7t/t) ,total 3.6t/t

CO_2 Emission sketch map of ICL demonstration plant in Yitai



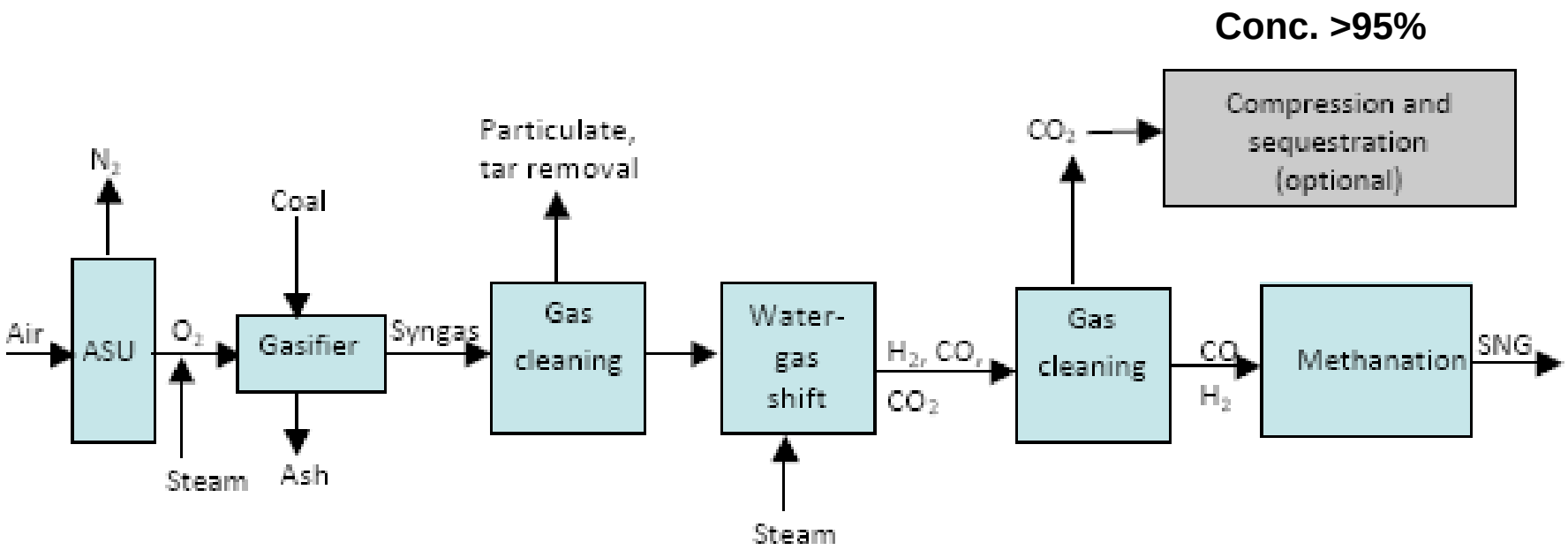
CO_2

Conc. >99%

H_2O 10%, O_2 12%, CO_2 6%, N_2 72%

- CO_2 derived from: hydrogen production (7.8 t/t), fuel combustion (2.0t/t) ,total 9.8t/t

CO_2 Emission sketch map of SNG Process

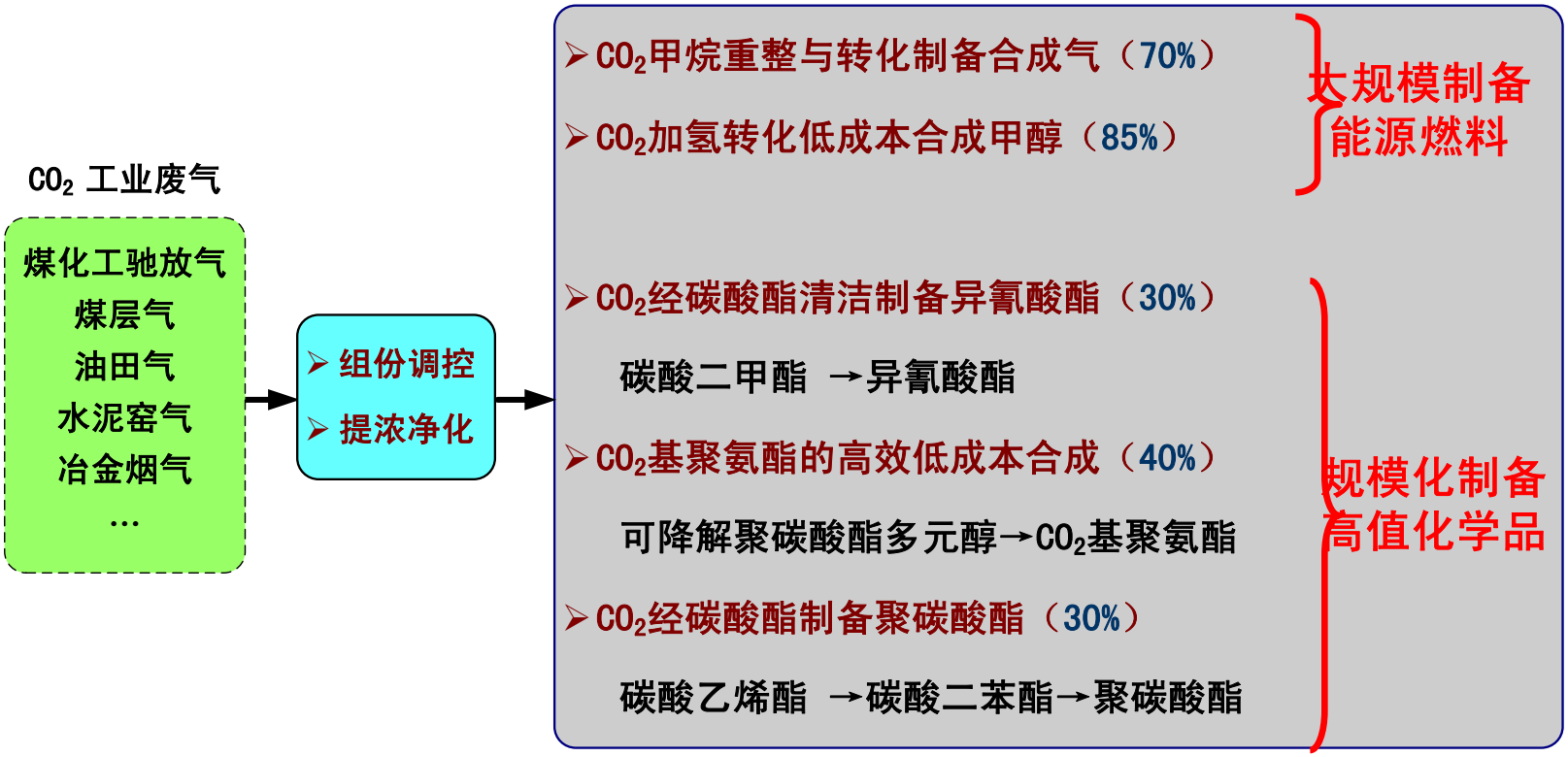


- CO_2 emission: 5.89 t/k m^3 SNG

Characteristics of CO_2 emission in non-power key industry

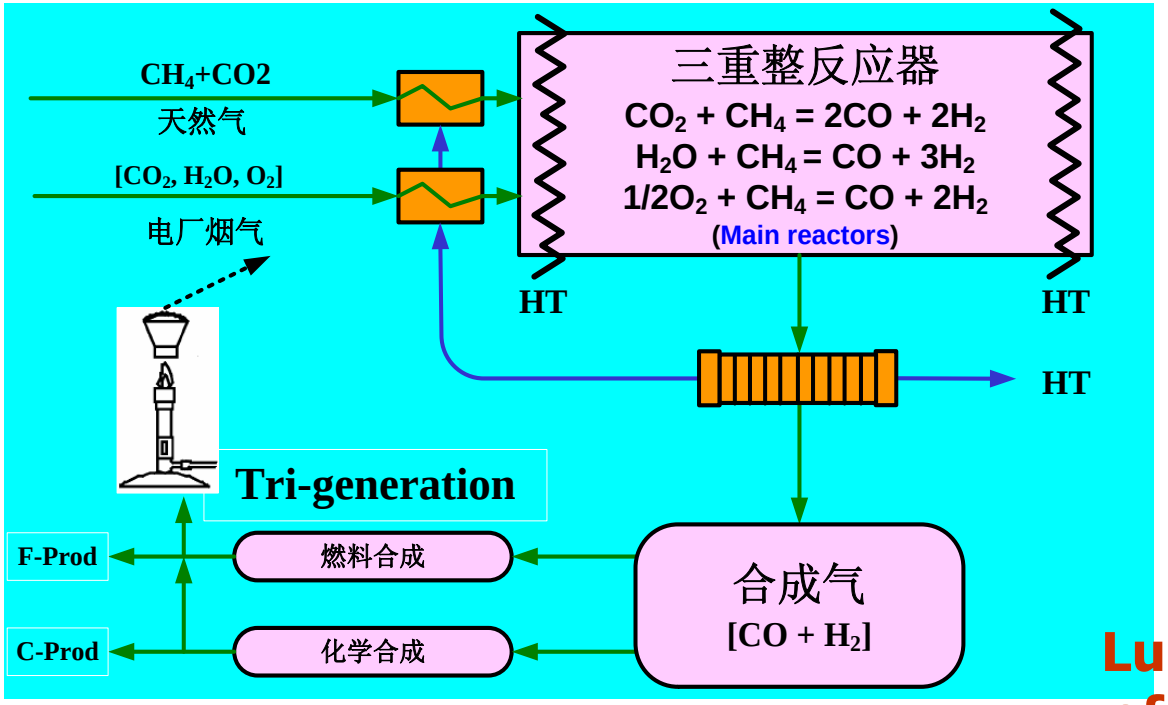
- Mainly refers to Iron & steel, petroleum & chemical, cement.
- The amount of CO_2 emission accounts for about 40% of the total China's CO_2 emission, which nearly to that of from power industry.
- Discharged gases from non-power industry usually have higher CO_2 concentration (20~100%), and more complicated compositions.
- CO_2 production does not restrict to fuel combustion like in power generation, the conversion of C to CO_2 are flexible , such as gasification, reduction reaction.
- Lower energy penalty and cost can be achieved in some processes with higher CO_2 concentration, which regarded as early opportunity for CCS.

CO_2 Chemical utilization



- **CTP is an important technological direction of CO2 emission reduction in coal chemical process**
- **Coal chemical process has high CO2 concentration, and current separation and purification technologies are efficient**
- **It is predicted that the volume of CO2 chemical utilization can achieve 100 million tons annually**

CO2 reforming to syngas



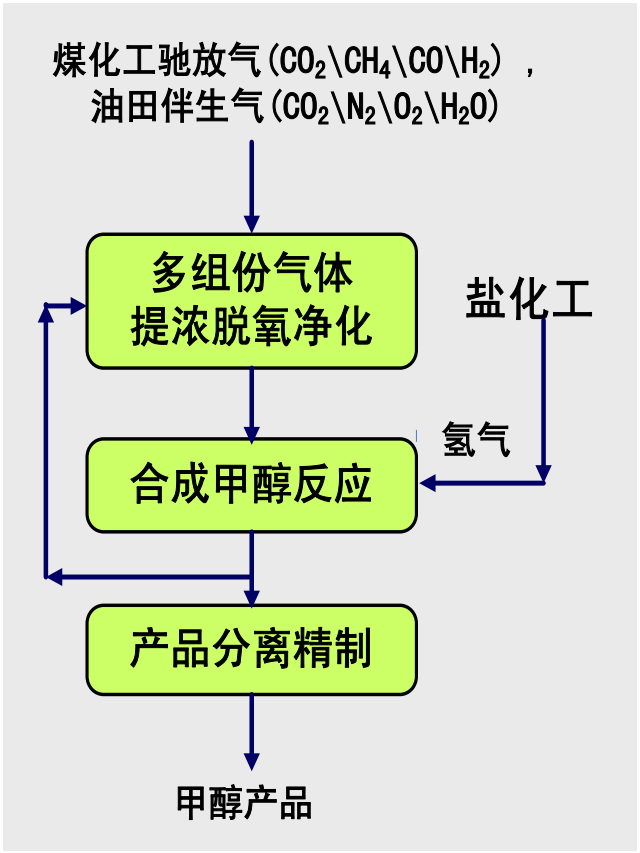
Lu'an's demonstration plant of CO2 reforming to syngas under construction

- Tri-reforming of CO2 and methane can produce syngas with high concentration of CO2 from coal chemical process and coalbed methane, which can achieve large-scale capture and utilization of CO2

CO2 hydrogenation to methanol to syngas

$$2CH_3OH + 3O_2 \longrightarrow 2CO_2 + 4H_2O$$

$$CO_2 + 3H_2 \longrightarrow CH_3OH + H_2O$$



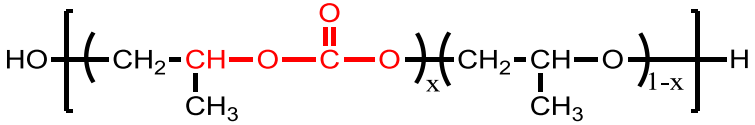
Multi-component composite catalyst

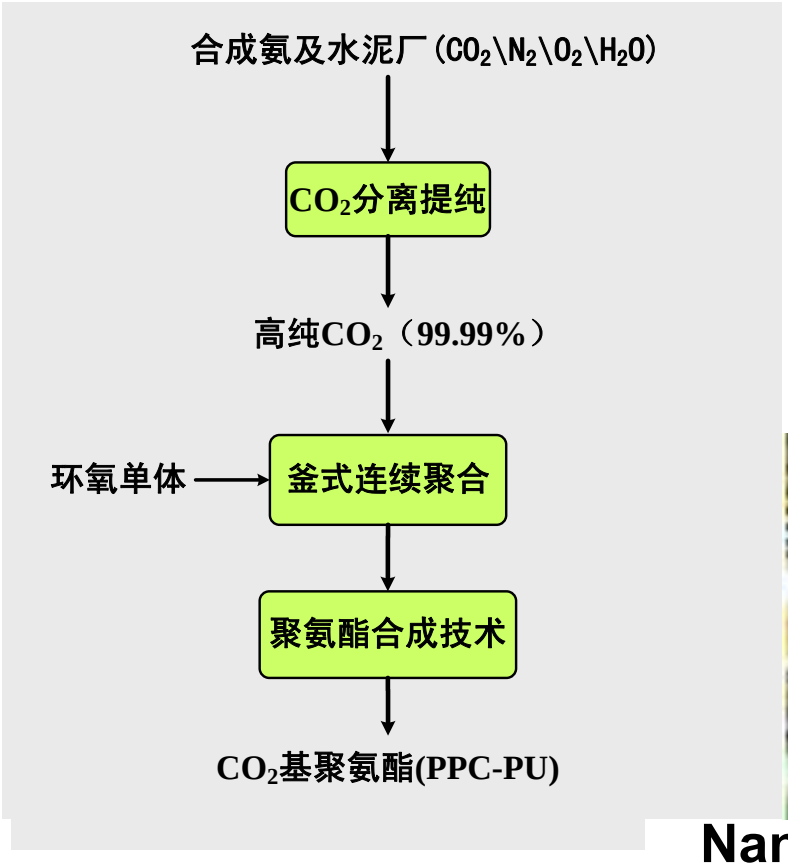
Single-tube test platform

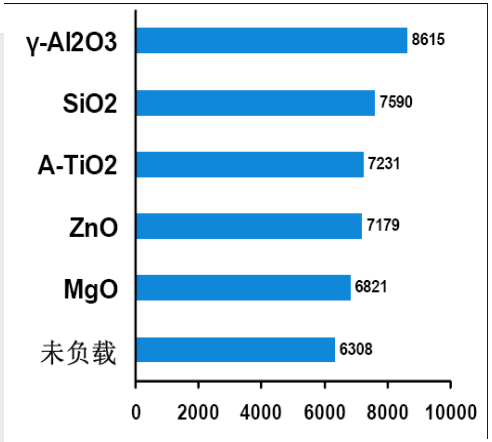
React. T °C	H_2/CO_2 Molar	P MPa	GHSV h^{-1}	CO_2 conV. %	MeOH Yield g/ml.h	Selectivity, %	
						CHx	MeOH
230	3:1	5.0	3732	16.51	0.44	0	100
250		5.0	4191	21.31	0.59	0	100
270		5.0	4327	26.21	0.46	0.86	99.14
290		5.0	4160	35.80	0.30	8.66	91.34

The 3,000 hours operating data of catalyst

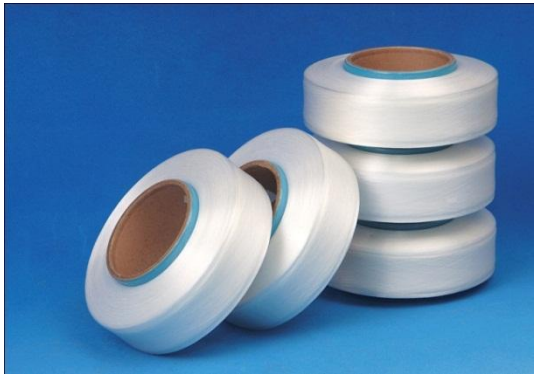
CO_2 → poly(propylene carbonate)polyols → CO2-based polyurethane







New high active supported catalyst



Nantong Huasheng's test production line and product of polyurethane

CAS carbon budget project (2011~2015)

CAS Strategic Priority Research Program

Climate Change: Carbon Budget and Relevant Issues）

The total budget：800million RMB

The emission of energy consumption and cement production

（1）The different energy consumption amount；
（2）Carbon content of the different fuel；
（3）Carbon oxidized fraction of the main industry for energy utilization；
（4）The dynamic database of China carbon emission and forecast model

Power	Petroleum refining	Natural gas
Iron&steel	Oil terminal using	Coal seam gas
Non-Ferrous Metal industry	Bulk chemicals	Coke oven gas
Building material	Fine chemicals	LNG
Traditionlal coal chemical industry	Cement	
New coal chemical industry		
Civil coal		

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