Polygeneration and CO_2 Capture

Li Zheng, Ni Weidou

Tsinghua BP Clean Energy Research & Education Center

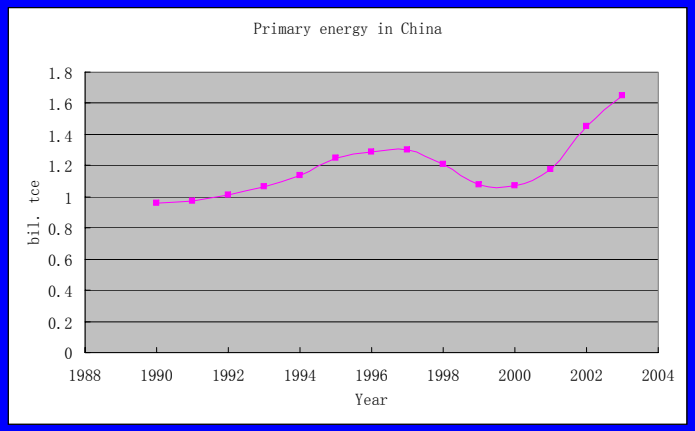
August 23rd, Beijing

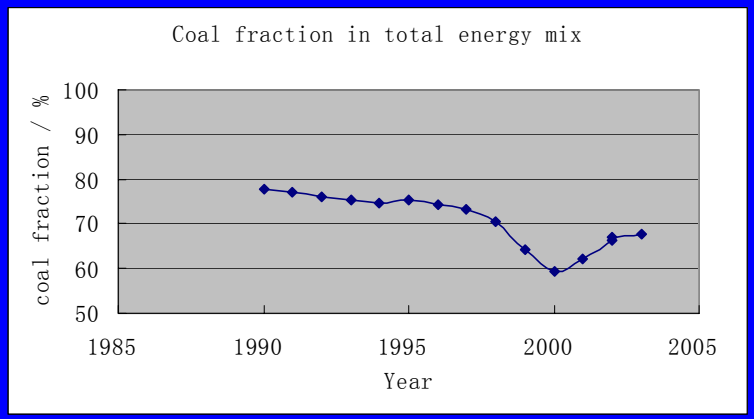
清華大學

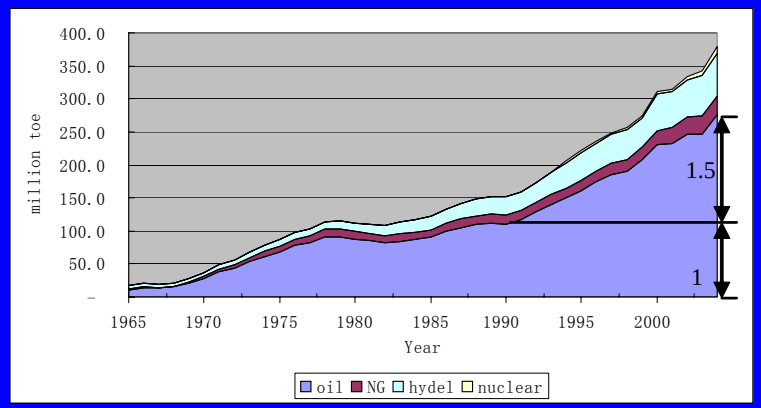
Outline

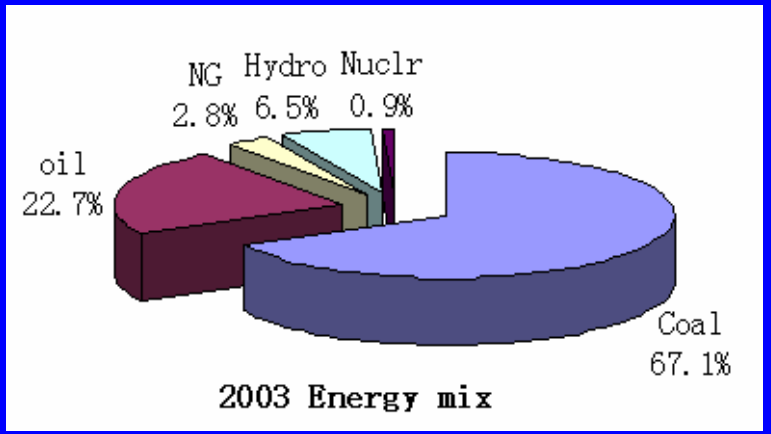
- **Energy challenges China is facing: strongly related with coal**
- **Polygeneration could be a comprehensive way to solve China's energy problem**
- **Polygeneration and CO_2 capture**
- **Conclusions**

Statistics of China Energy

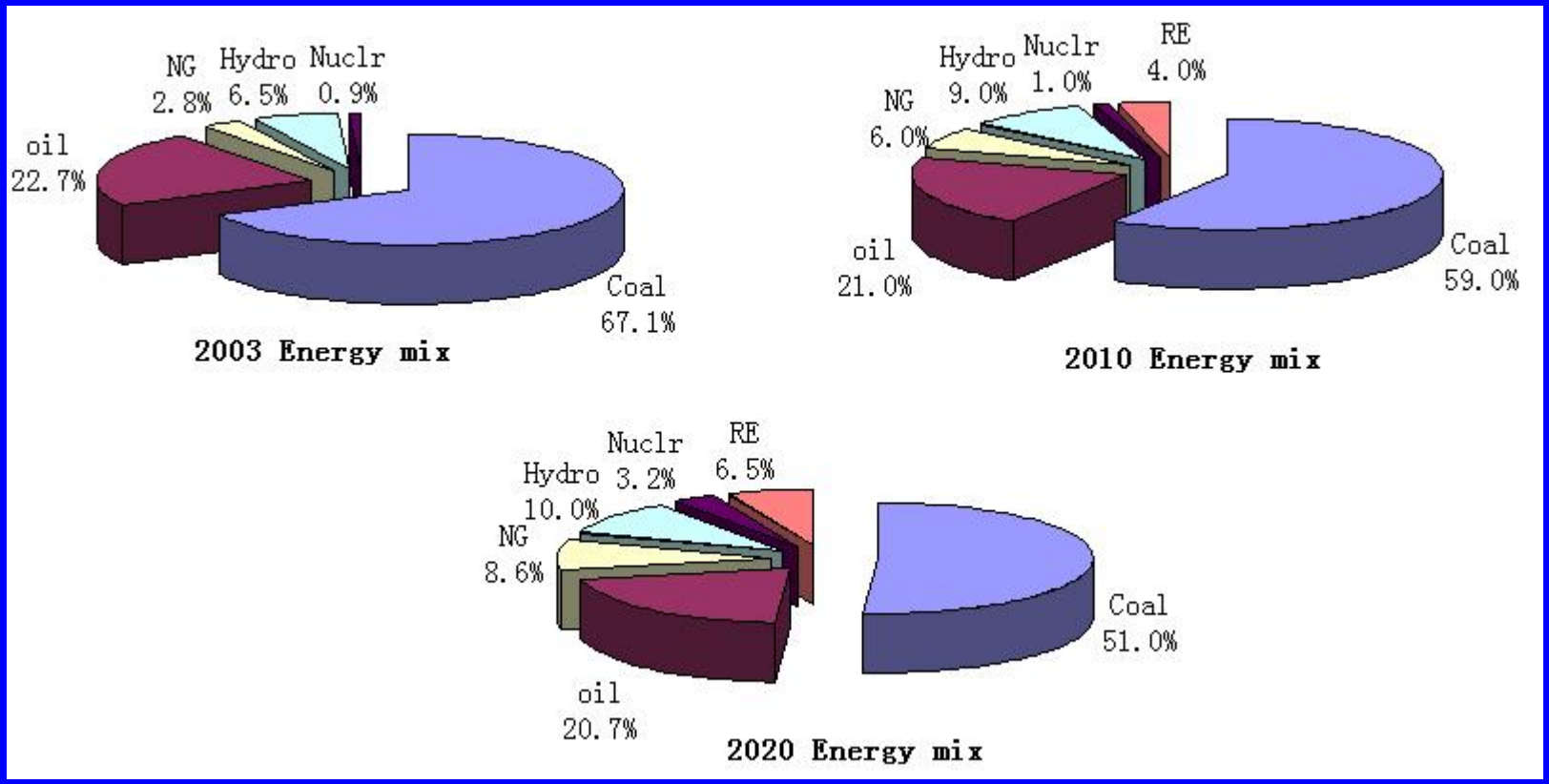






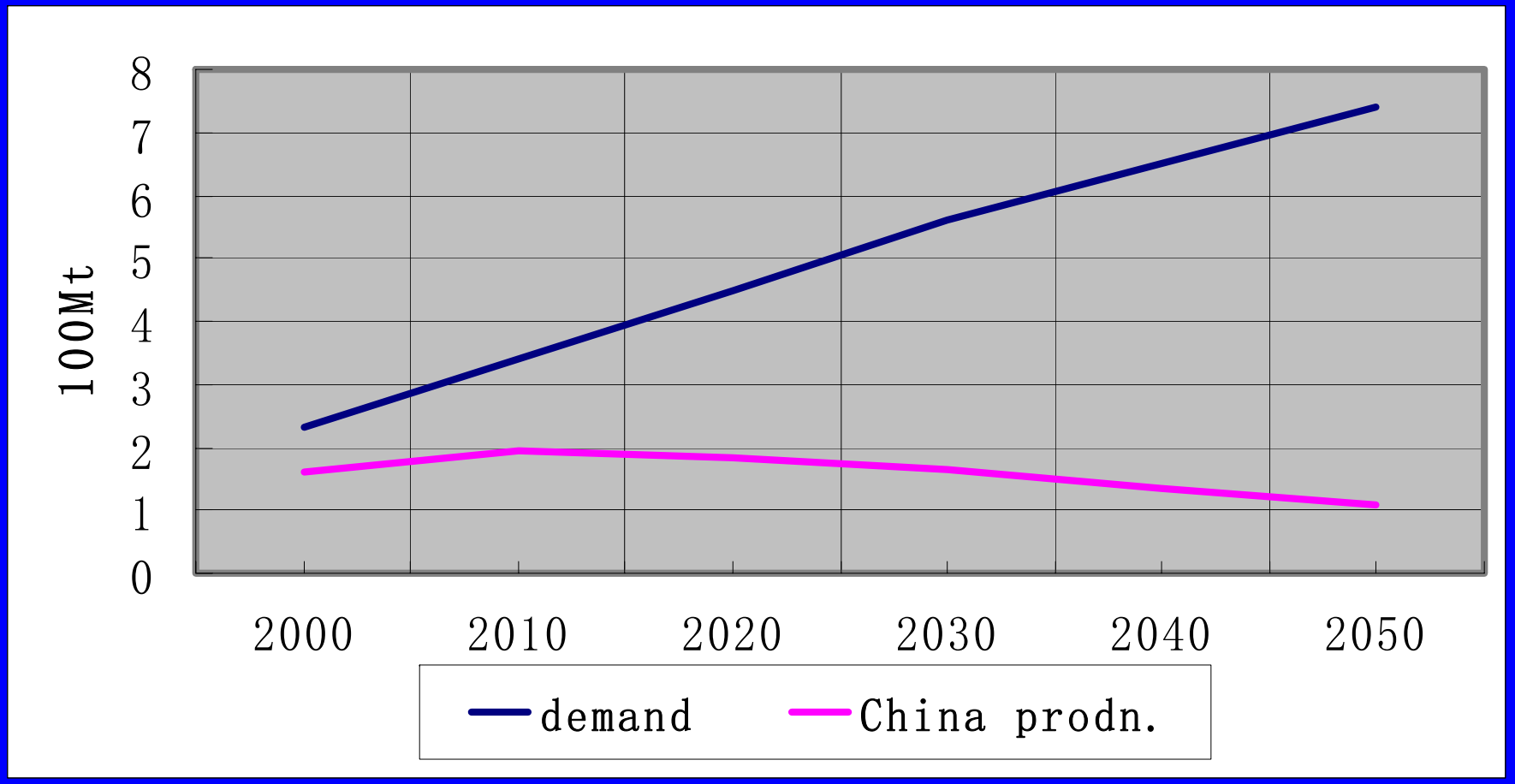


Current and future energy mix of China



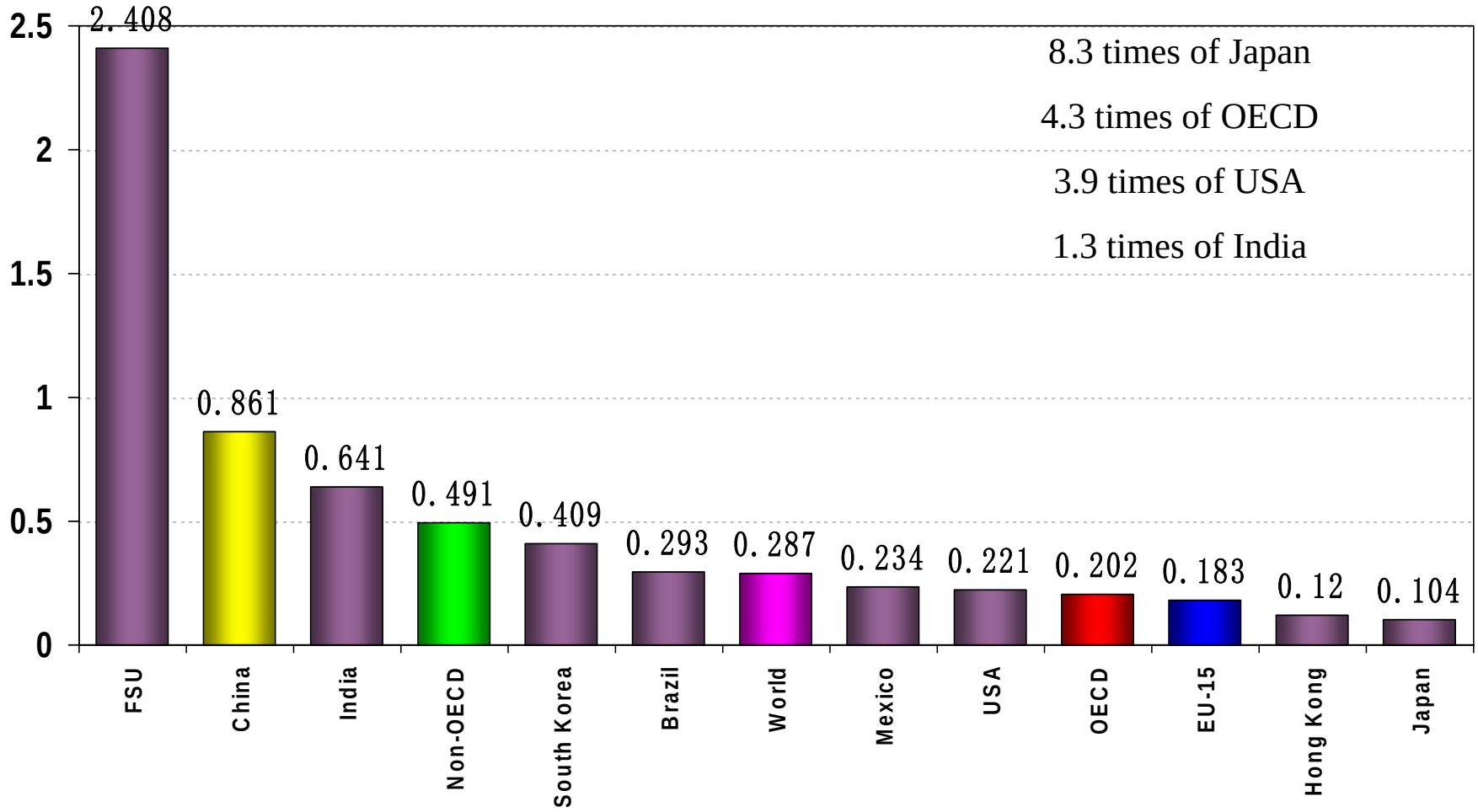
清華大學

Increasing Dependence on Oil Import

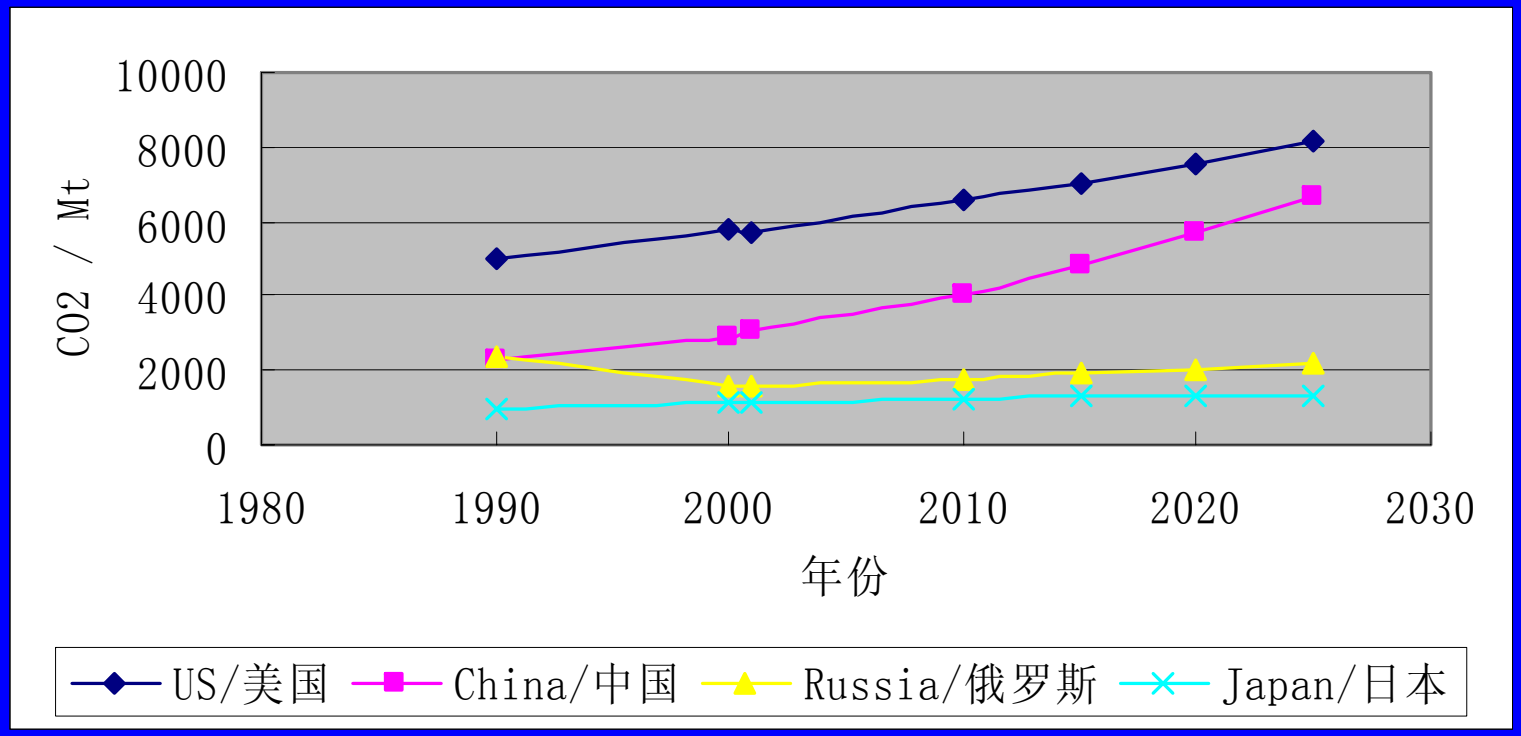


Energy intensities (GDP @ market exchange rates)

toe per $1000 GDP (2000$ mkt fx)



China's CO_2 emission: 2nd place and increase fast



Source: IEO2004, EIA/DOE

清華大學

CO_2 emission from power and transportation @2001

- **total CO_2 emission: 3050 Mt**
  - **coal: 2340 Mt, 76.8%**
  - **oil: 640 Mt tons, 21.1%**
- **coal power:**
  - **50.9% of total coal consumption, CO_2=1190 Mt**
- **transportation: total=148 Mt**
  - **gasoline: 14.2Mt, CO_2=52 Mt**
  - **diesel: 26.7Mt, CO_2=97Mt**
- **CO2 emission: Power : transportation=8:1**

Sources: IEO2004, EIA/DOE，中国能源统计年鉴2004

清華大學

Coal vs Energy challenges China is facing

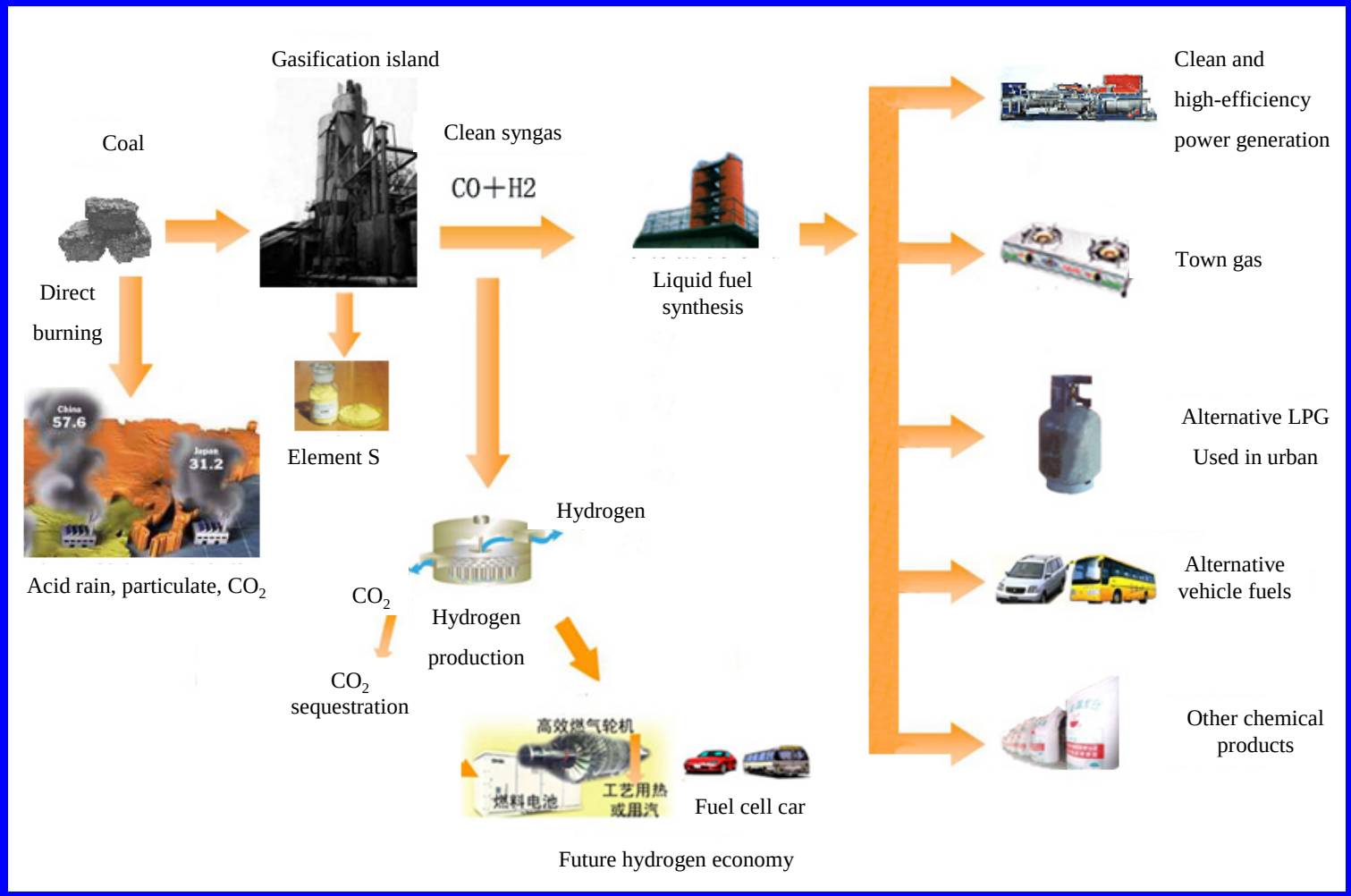
- **Energy security**
  - **especially import oil dependency**

} coal expected to help

- **Energy efficiency improvement**
- **Environment pollution**
  - **SOx，NOx，dust**
  - **mercury, inspirable particulates**
- **GHG emission**

} coal dominant

Polygeneration: a promising comprehensive solution



清華大學

Polygeneration: a comprehensive solution

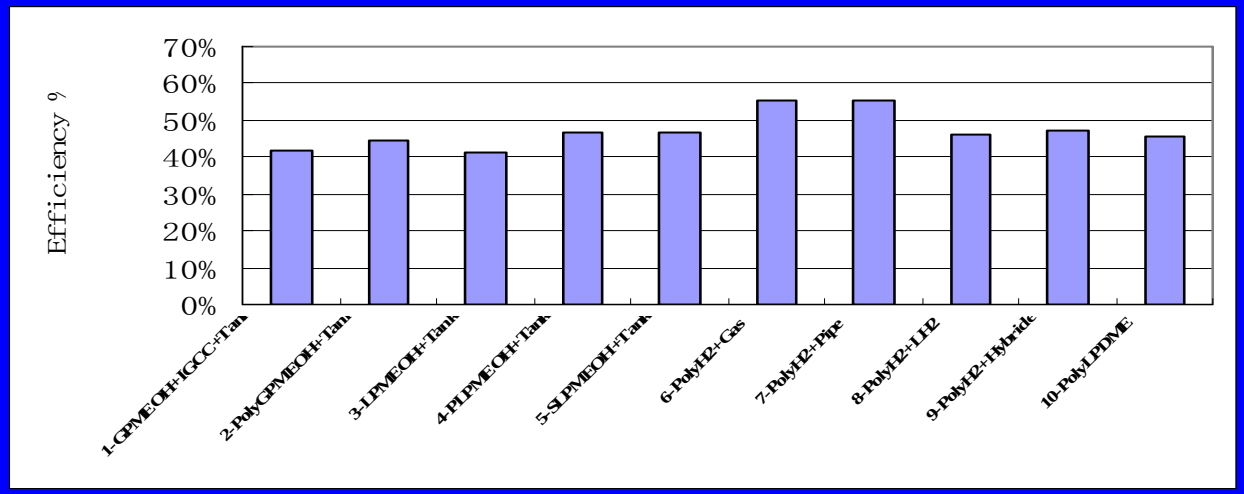
- Ease the pressure for energy resource: due to higher efficiency to co-produce multi-products; use high sulfur coal
- Ease and buffer shortage of liquid fuel: large scale production of alternative fuels as methanol, DME, F-T liquid and hydrogen
- Superior environmental behavior: eliminating conventional pollutants completely, less incremental cost for heavy metals and inspirable dust
- Ultimate clean energy solution for small town and rural area:
  - To provide clean town gas for urban areas with no NG supply
  - To provide DME as an alternative to and using the infrastructure of LPG for distributed small towns and rural areas
- Meet future CO_2 reduction requirement:
  - the coal gasification based systems can be easily shifted to CO2 capture with less incremental cost
  - It is also easier and cheaper to change into H2 production

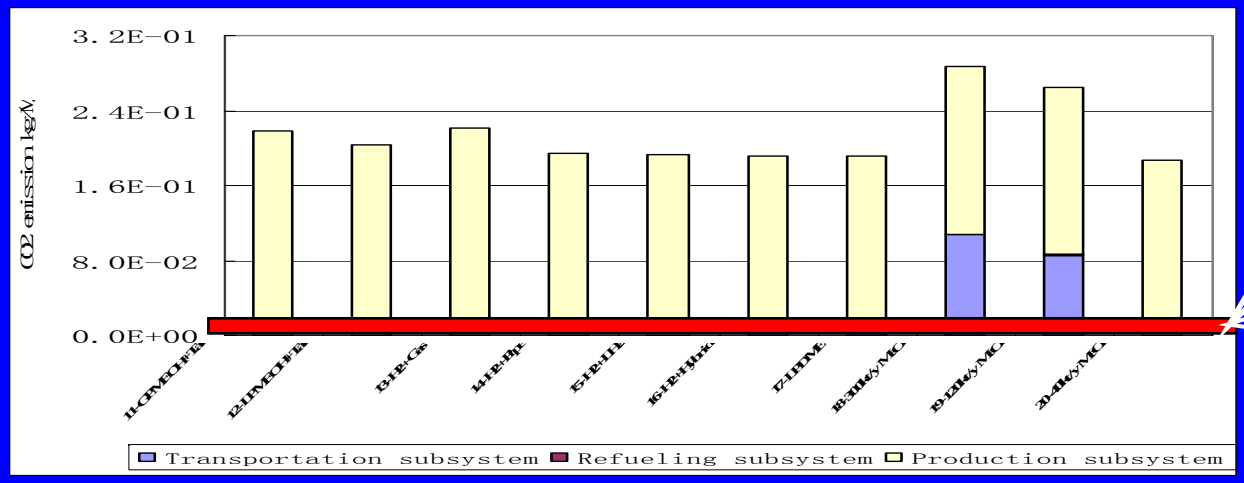
清華大學

Polygeneration and CO_2 reduction

- **Polygeneration by its nature can make the CO_2 capture easy**
- **Different polygeneration configurations could meet time progressive CO_2 reduction needs**
- **Polygeneration can reduce CO_2 with less efficiency penalty and less incremental capital cost**

WTT CO_2 emission of different coal-derived fuels



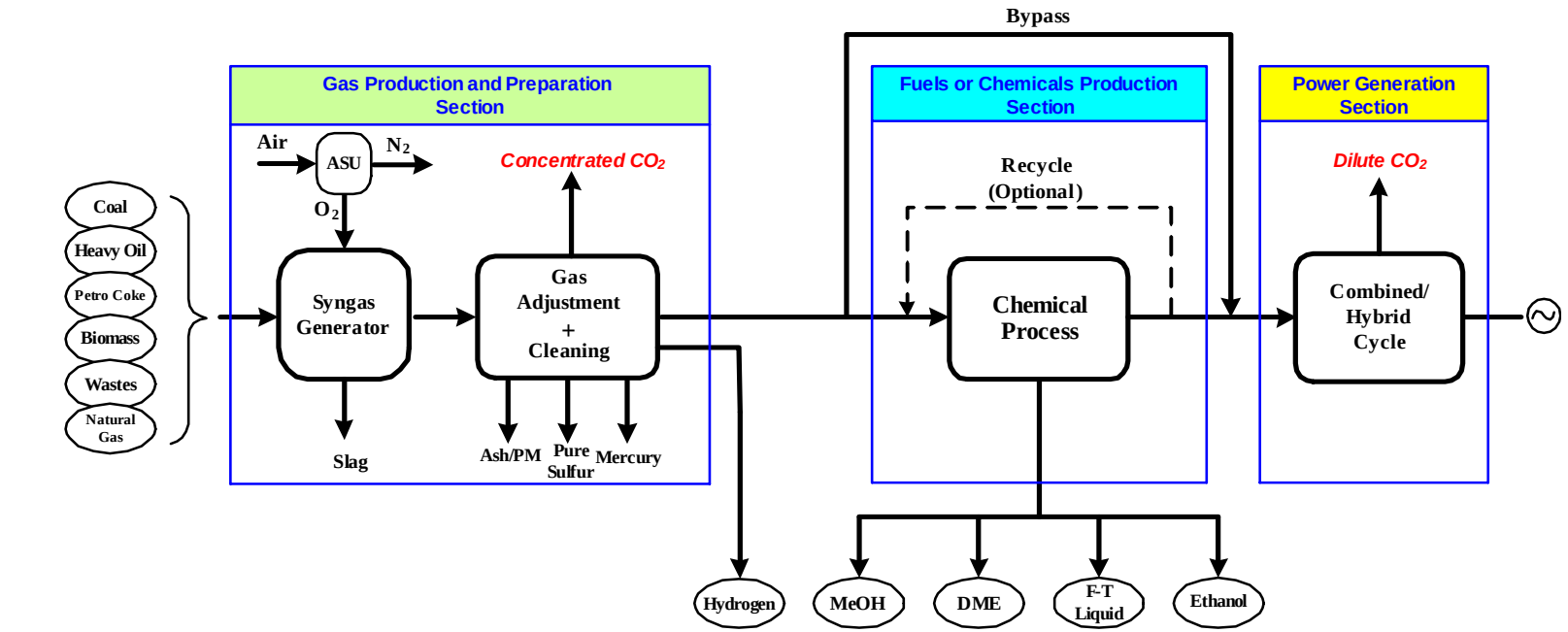


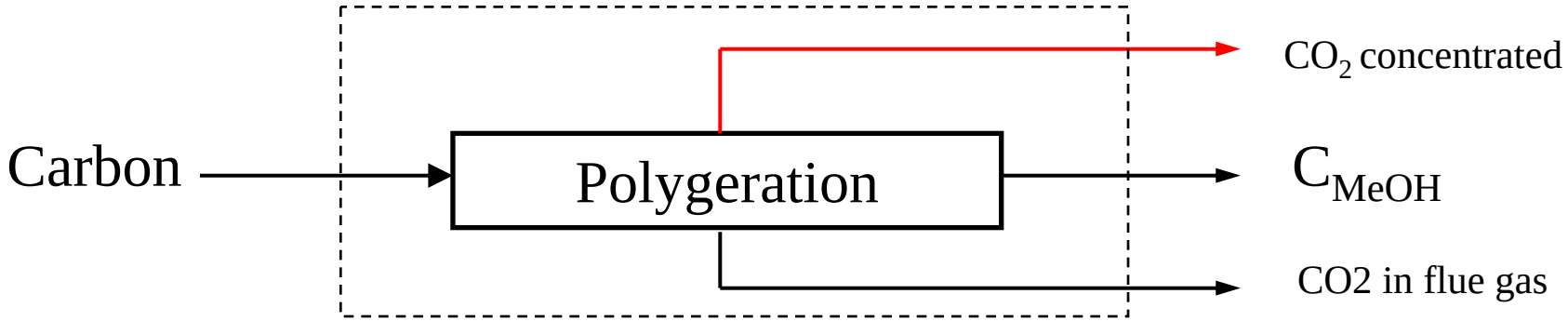
1-GPMeOH+IGCC
2-Parallel polygeneration, recycle
3-LPMeOH+IGCC
4-Parallel polygeneration, once-through
5-Series polygeneration, once-through

CO_2 emission of oil (~10-13g/MJ)

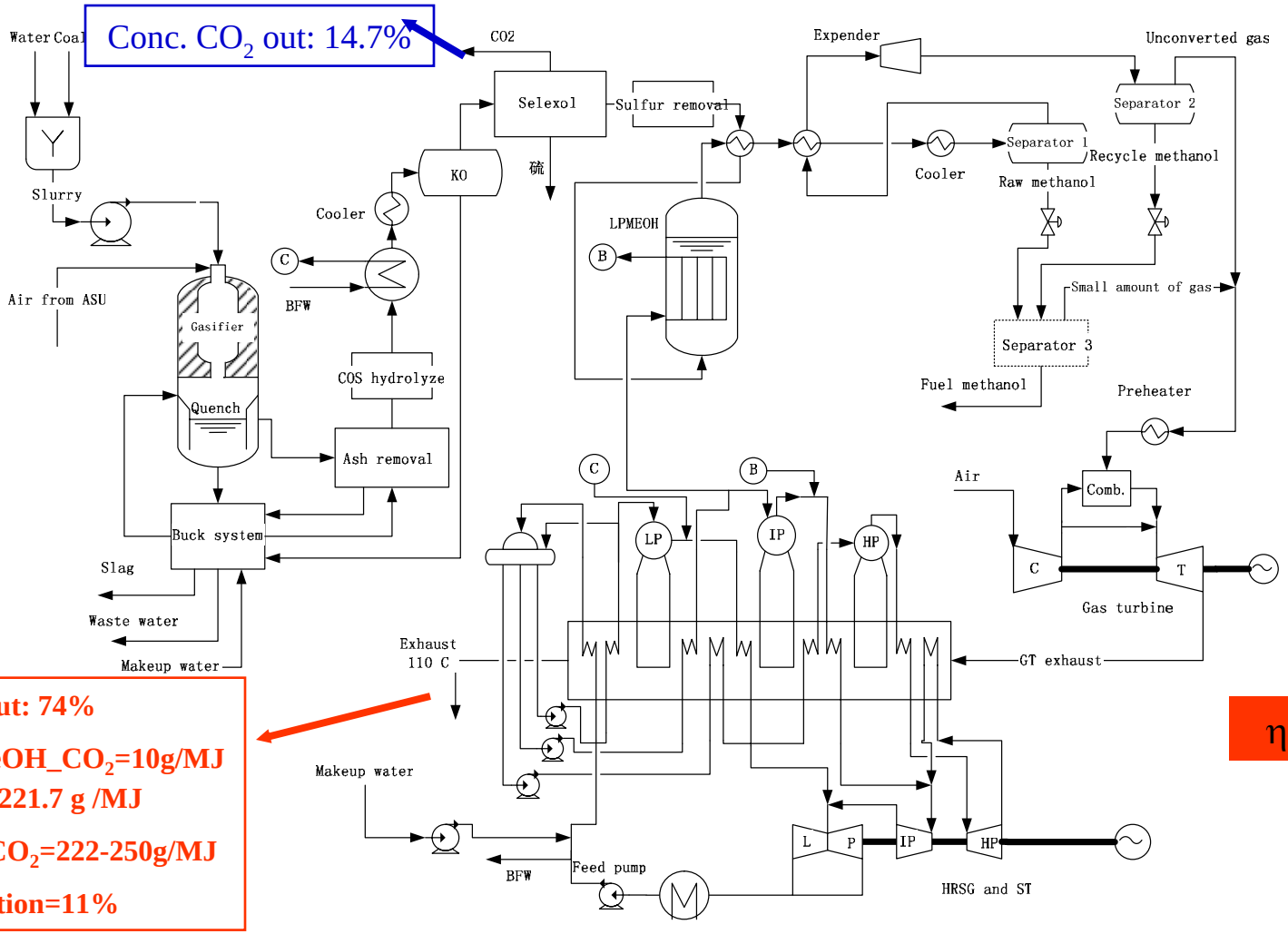
How can coal based system be competitive with oil in CO_2?

Polygeneration by its nature can make the CO_2 capture easy

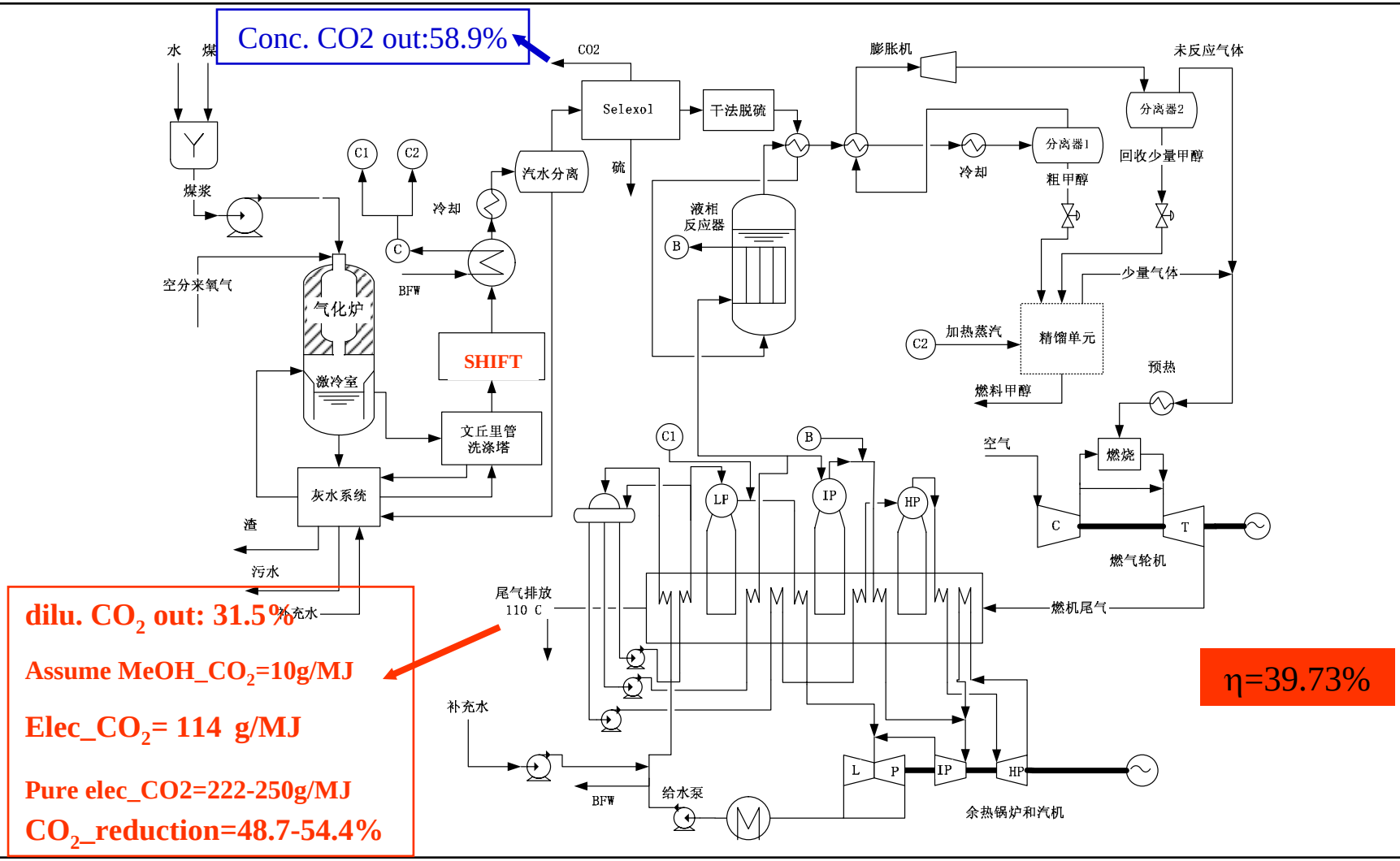




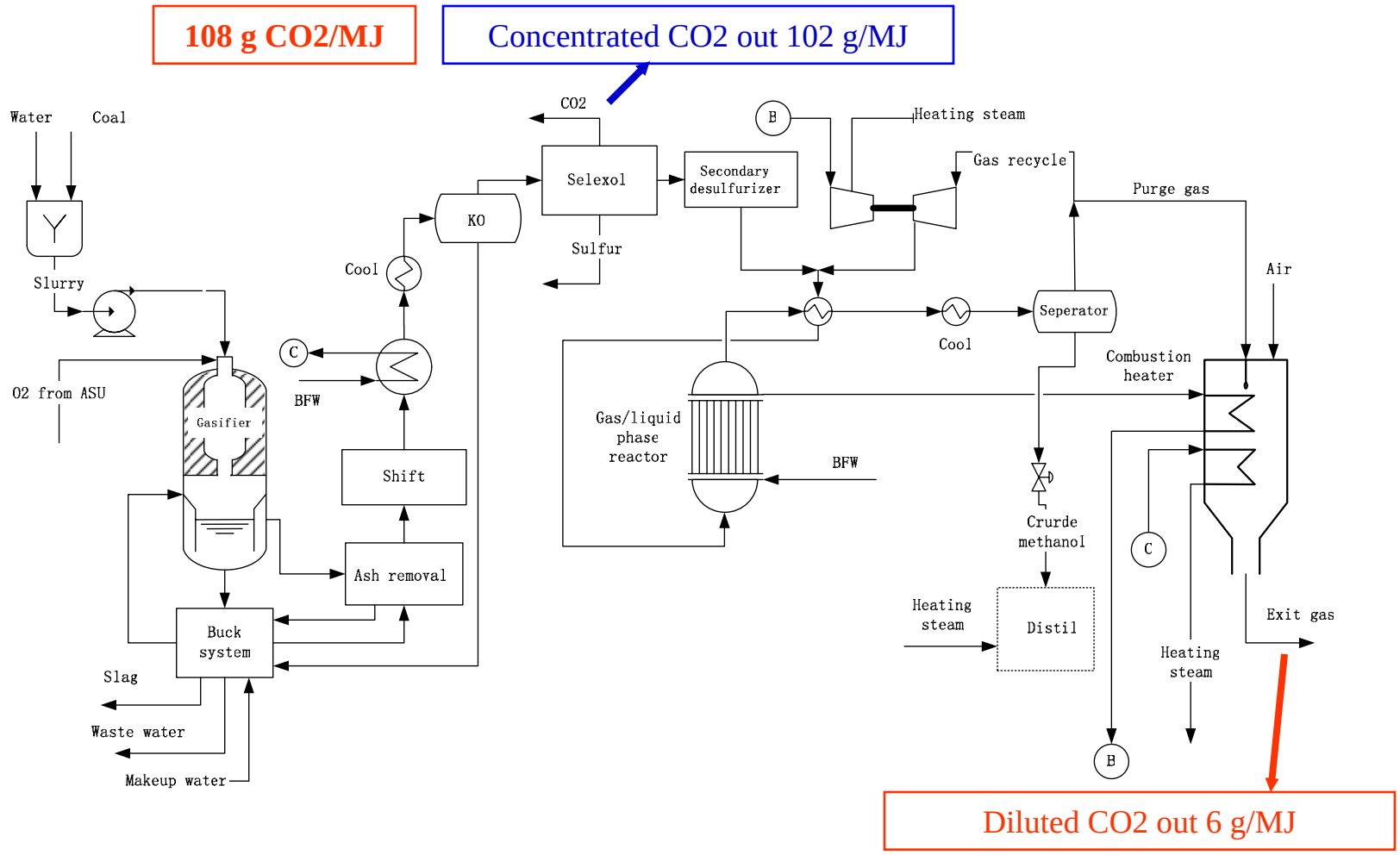
Power-MeOH Polygeneration with CO-rich gas and in once-through mode (no shift)



Power-MeOH Polygeneration with H_2-rich gas and in once-through mode (w. shift)



Coal to MeOH with shift and recycle

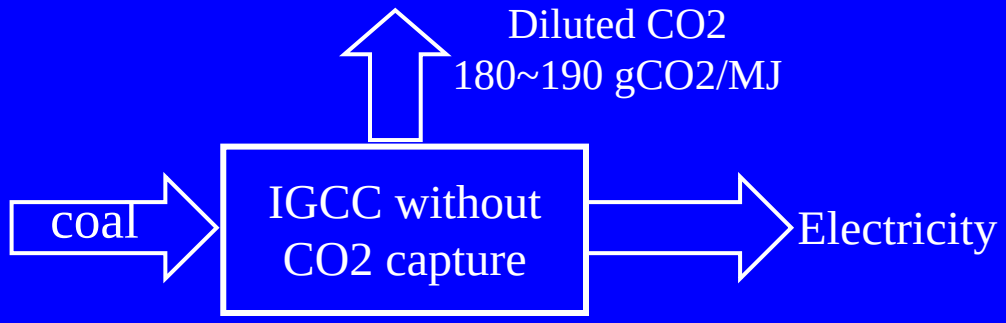


清華大學

Four steps for polygeneration development --meeting time progressive CO_2 reduction needs by different configurations

1. **By increasing IGCC efficiency**
2. **Co-production of power and high value added chemicals or fuels**
   - **e.g. Power + Methanol**
3. **CO_2 recovery from power and/or hydrogen production**
   - **CO_2 capture in H2 production from coal gasification**
   - **CO_2 capture from IGCC plant**
   - **CO_2 capture from IGCC+H2 production**
4. **Hybrid cycle with SOFC to increase efficiency further**

To Increase IGCC efficiency



CO_2 reduced by 15-25% than supercritical PC plant

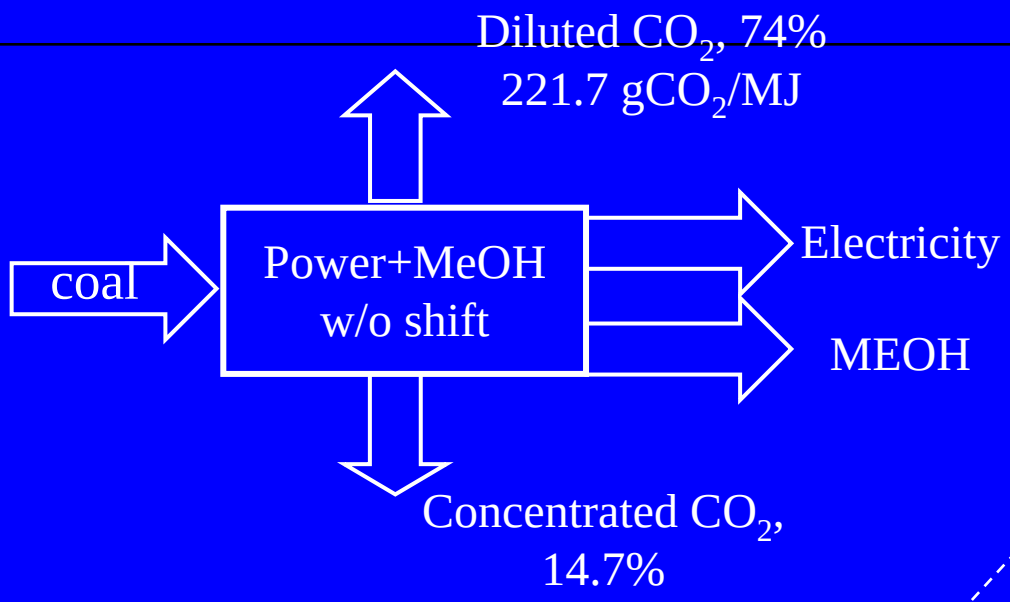
η=52.49%

by using

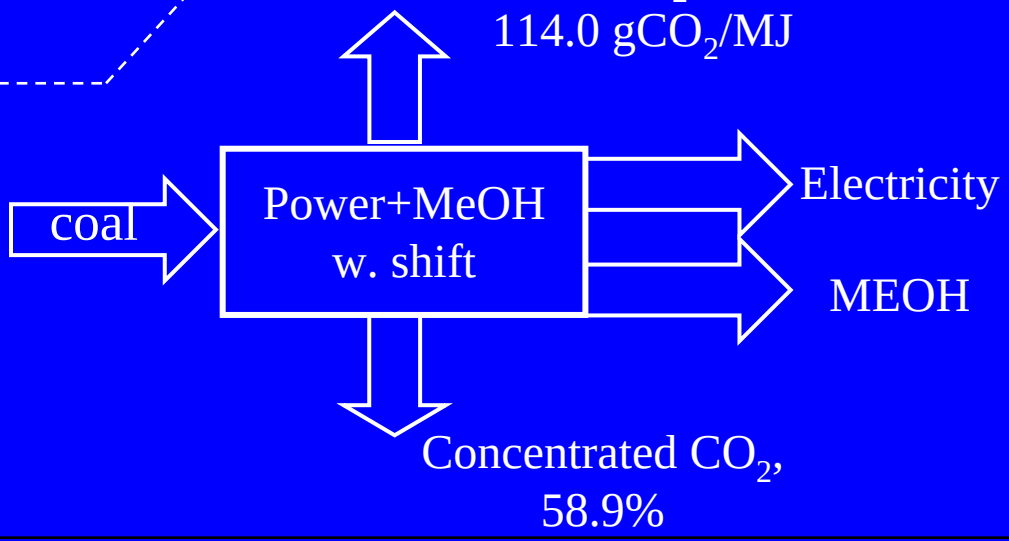
- 9H gas turbine
- dry powder coal gasification
- high temperature dry cleaning

清華大學

Co-production of power and methanol

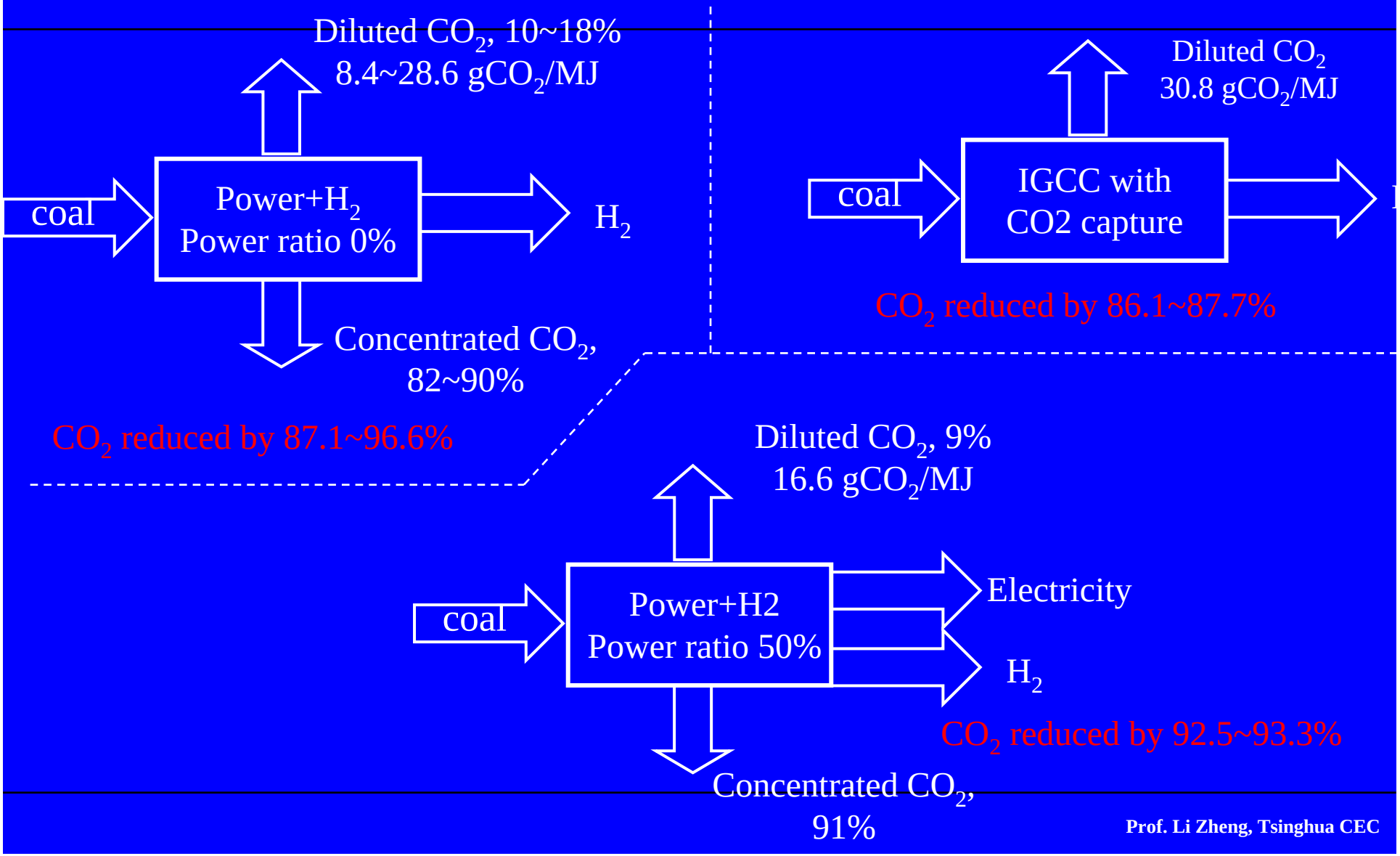


η=46.8% (LHV)
CO_2 reduced by 11% than supercritical PC plant



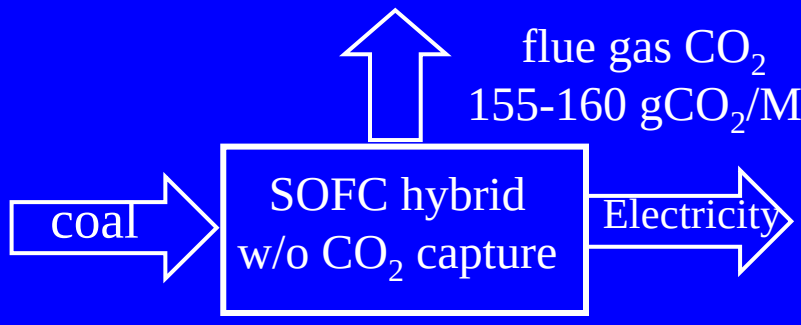
η=39.7% (LHV)
CO_2 reduced by 49-54% than supercritical PC plant

CO_2 recovery from power and/or hydrogen production

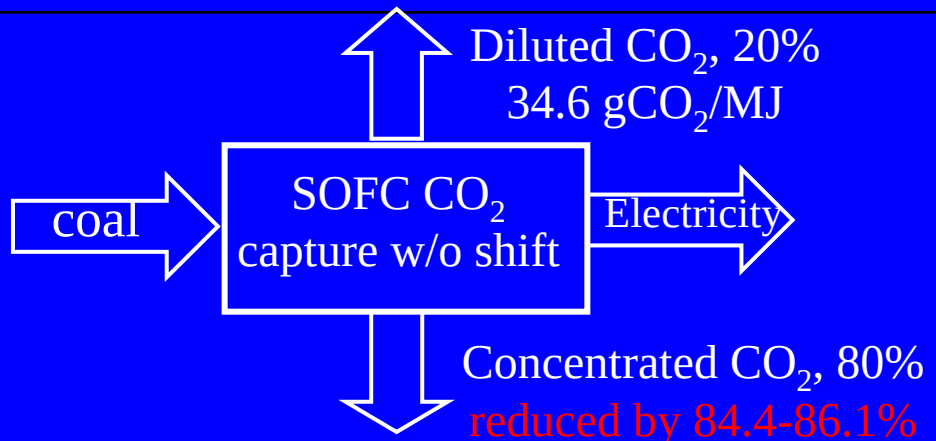


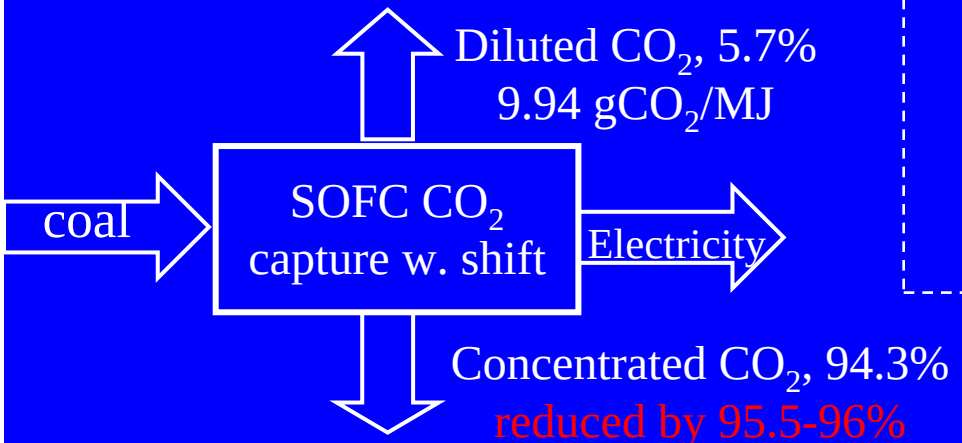
清華大學

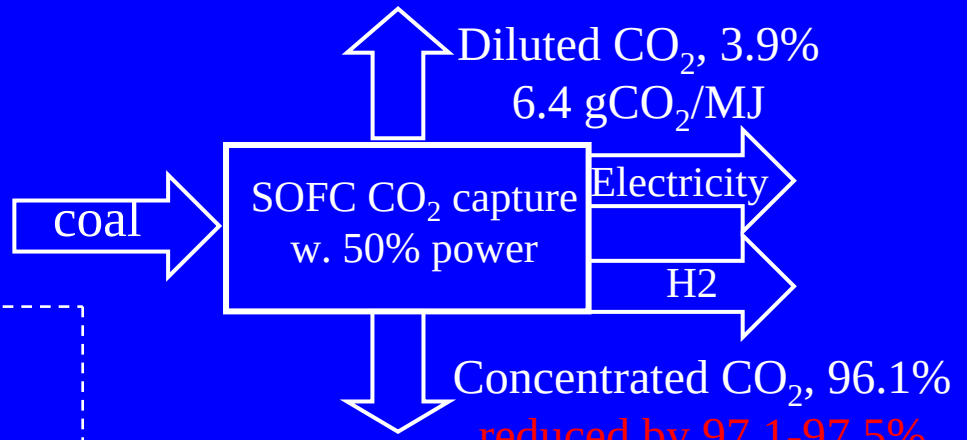
Hybrid cycle with SOFC to increase efficiency further



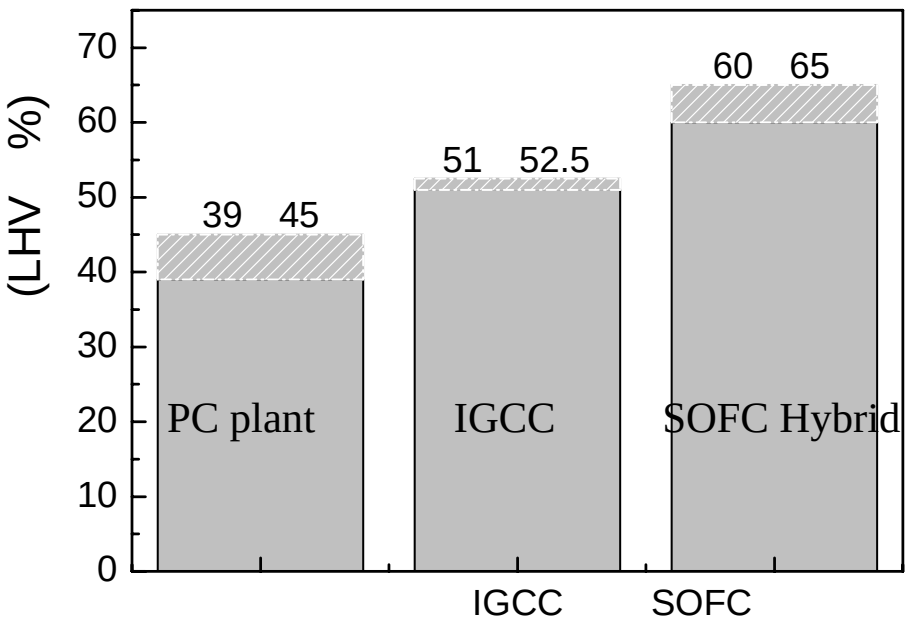
CO_2 reduced by 28-38%

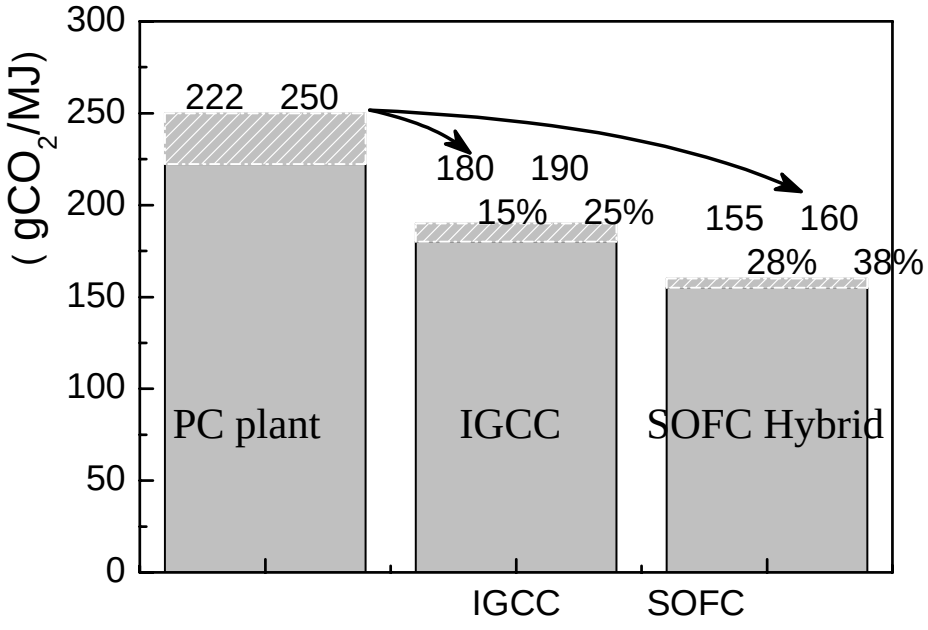




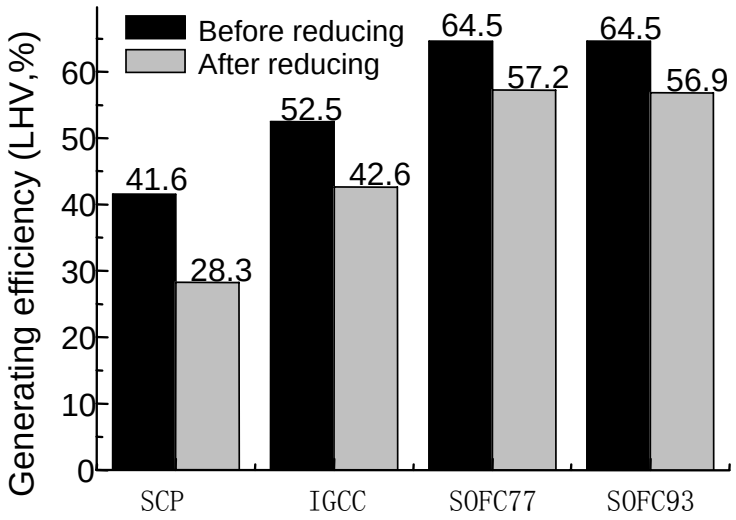


CO_2 reduction by increasing energy efficiency of power generation

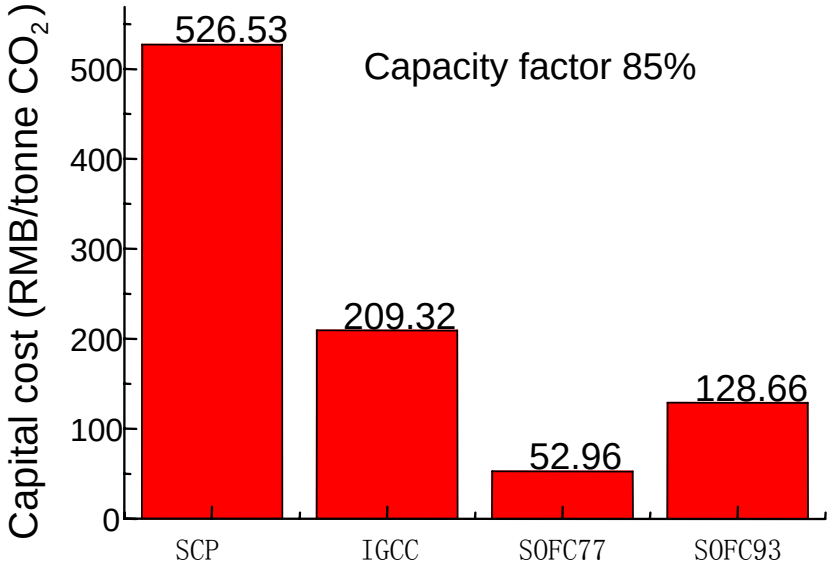




Efficiency penalty and incremental capital cost for CO_2 reduction



	SCP	IGCC	SOFC77	SOFC93
$\Delta\eta$	**13.3**	**9.9**	**7.3**	**7.6**



清華大學

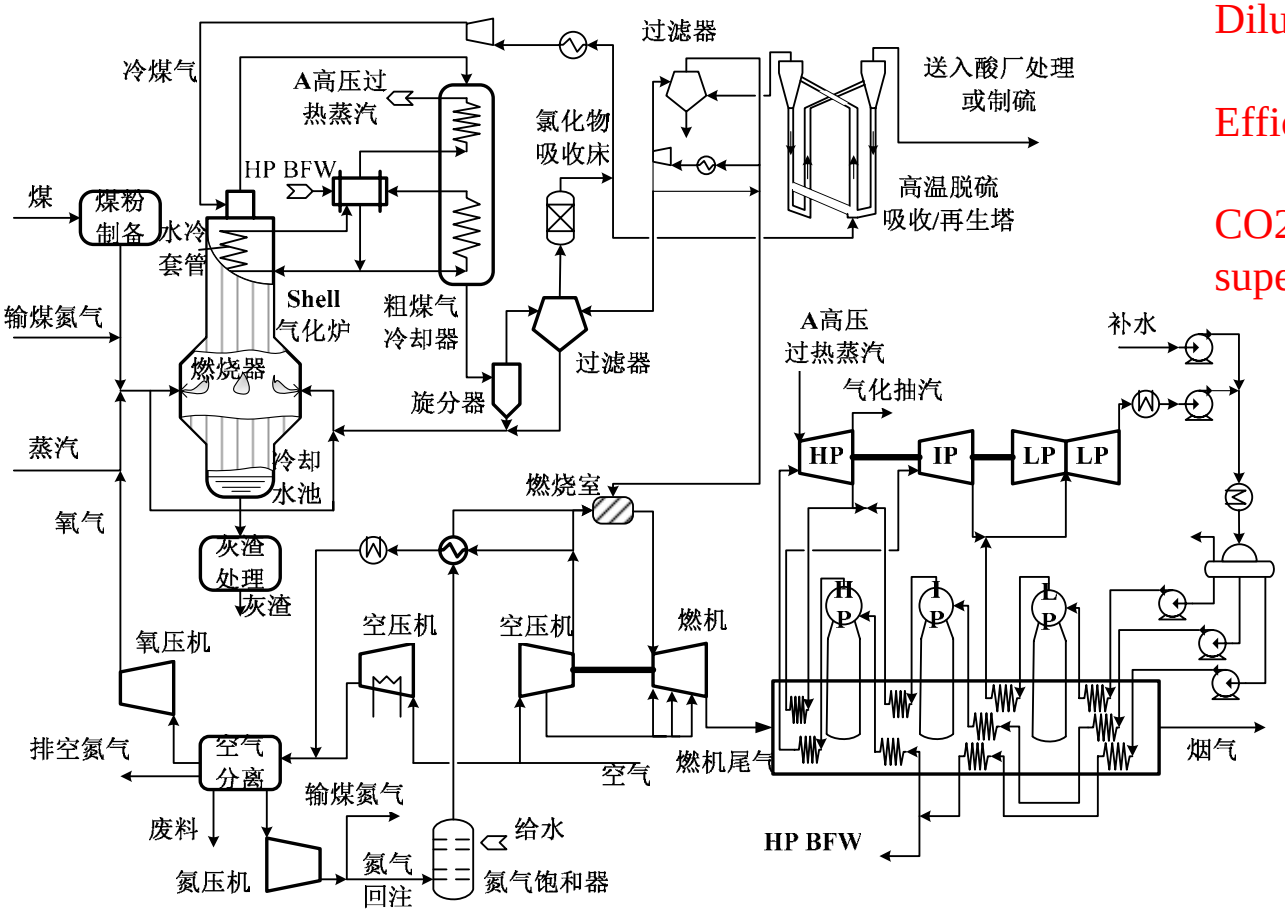
Conclusions

- **Polygeneration is a promising comprehensive solution for energy challenges China is facing**
- **CO2 emission from coal power is 8 times higer than that of transportation and has characters of large scale and central emission. Therefore, CO_2 reduction from coal power should be the major start point.**
- **Polygeneration by its nature can make the CO_2 capture easy**
- **Different polygeneration configurations could meet time progressive CO_2 reduction needs**
- **Polygeneration can reduce CO_2 with less efficiency penalty and less incremental capital cost**

清華大學

- backup slides

Example 2: 600 MW IGCC plant with HT dry cleaning, w/o CO2 capture

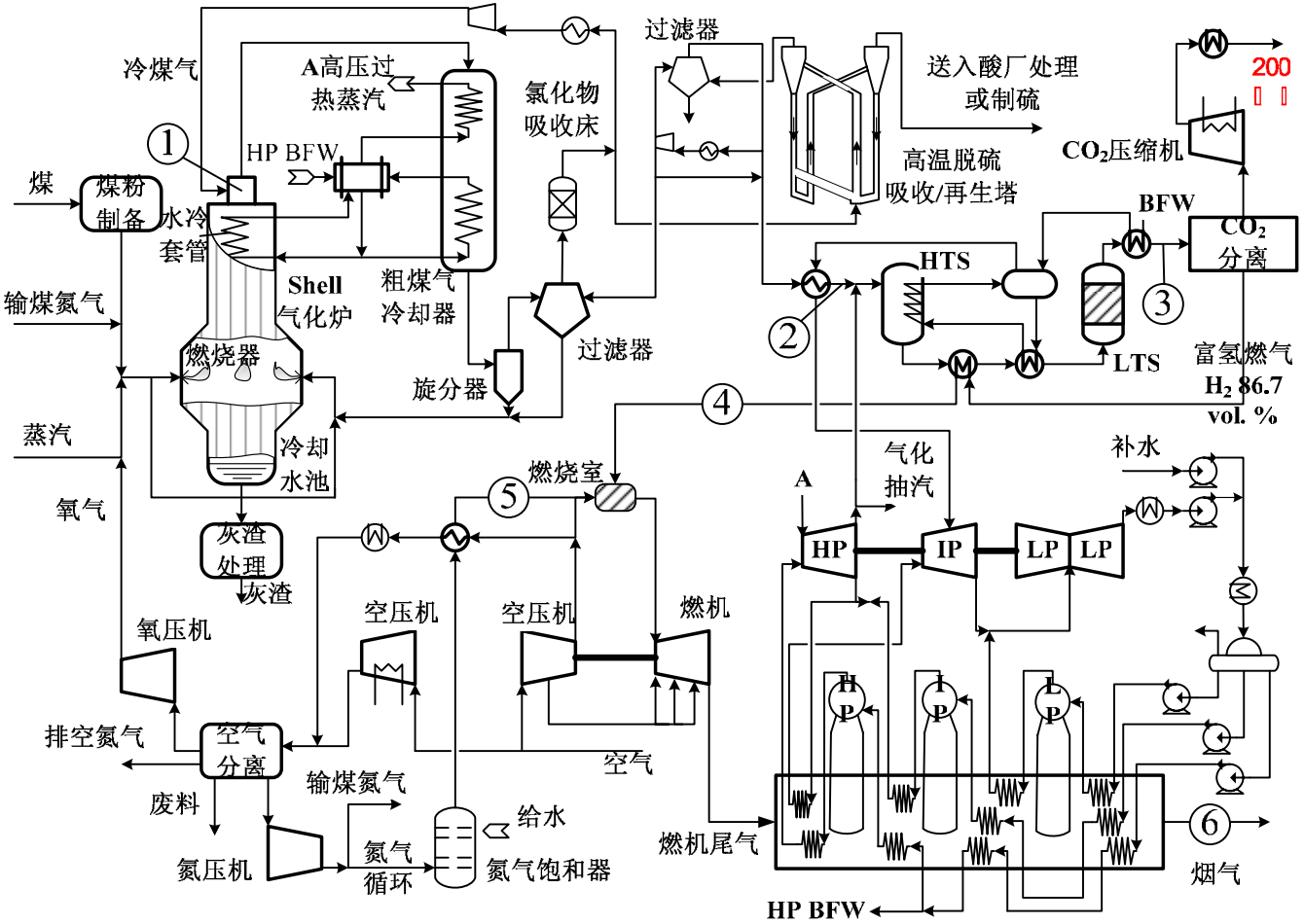


Diluted CO2 180~190 gCO2/MJ

Efficiency 52.5% (LHV)

CO2 emission less than supercritical plant 15~25%

600 MW IGCC plant with HT dry cleaning, w. CO2 capture

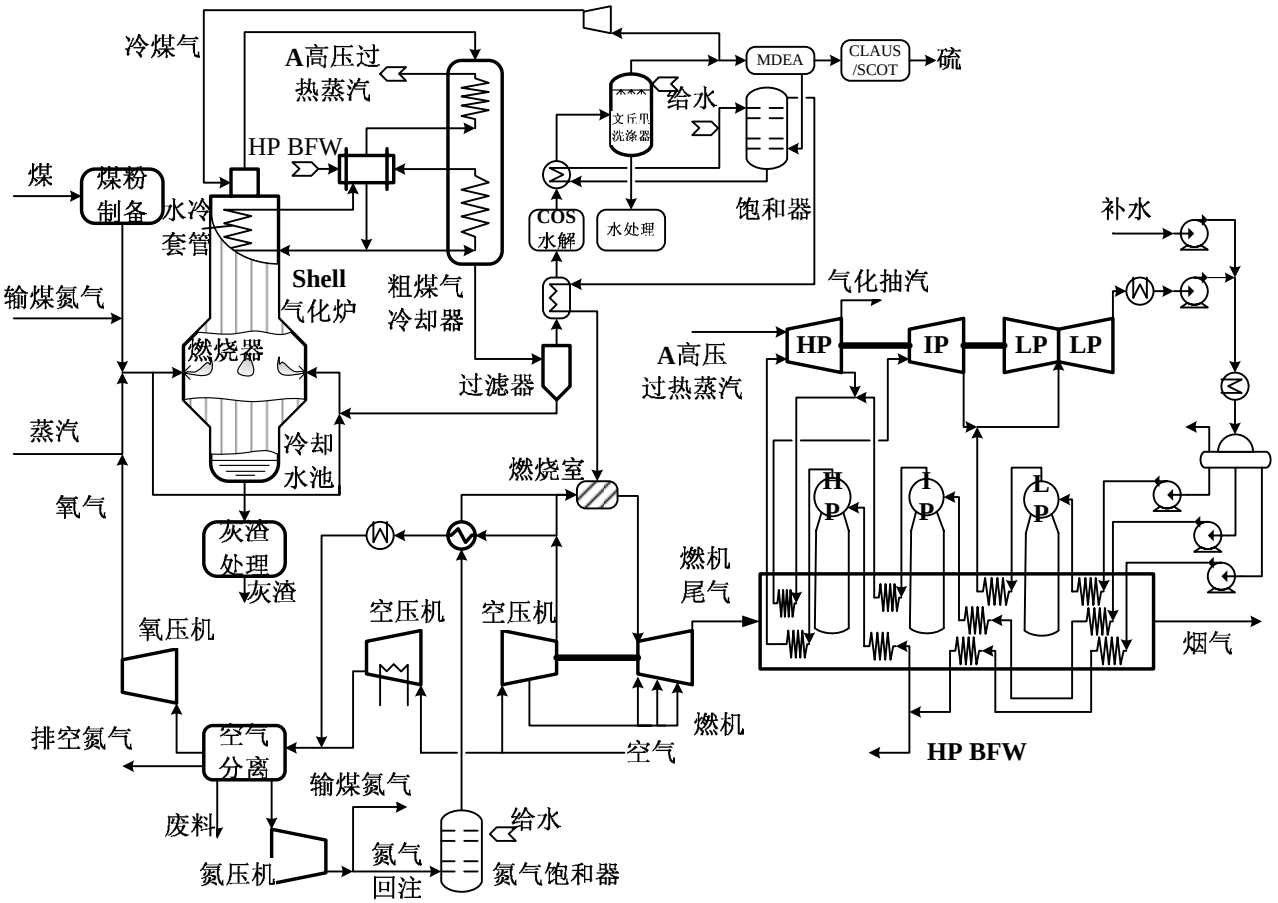


Diluted CO2 ： 180~190 gCO2/MJ

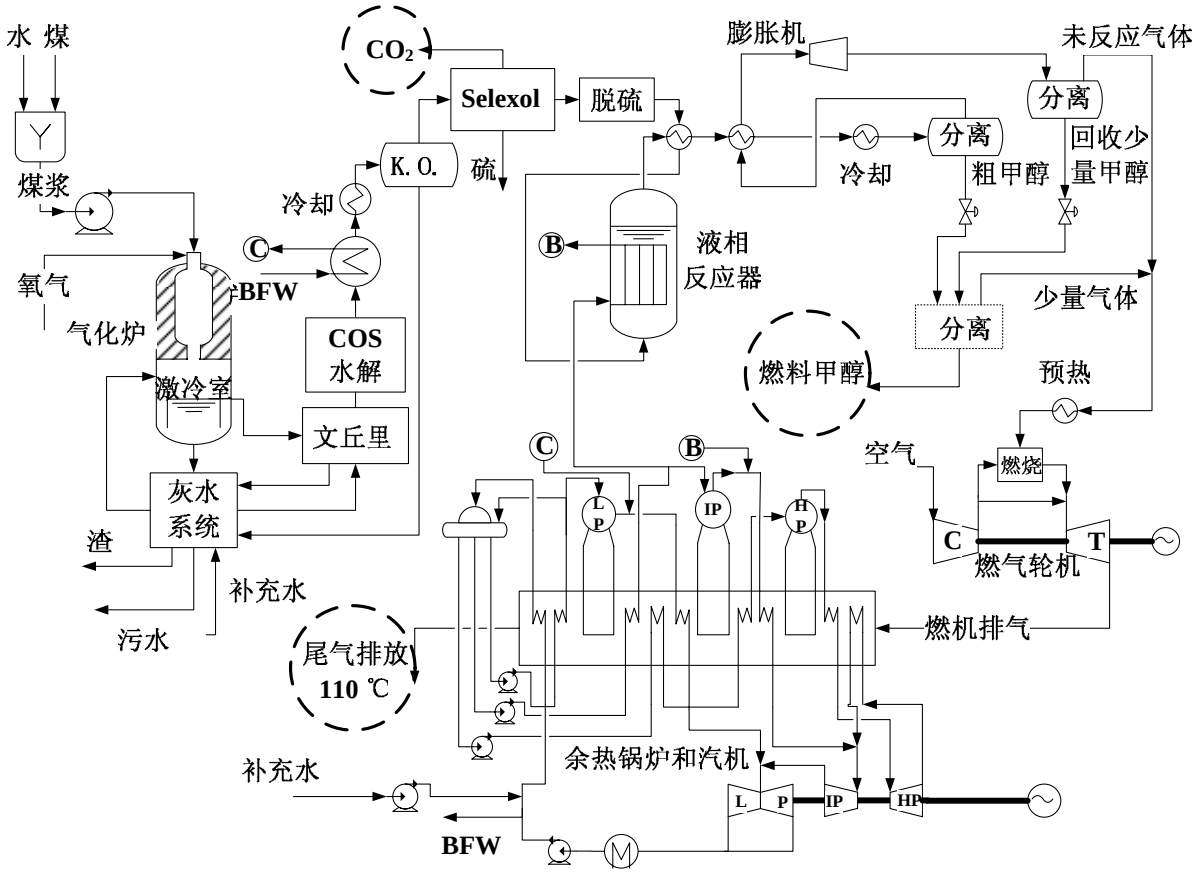
Efficiency：52.5% (LHV)

CO2 emission less than supercritical plant 15~25%

600 MW IGCC plant with ambient temp. cleaning, w/o CO2 capture



Power+MeOH production witn CO-rich syngas once through

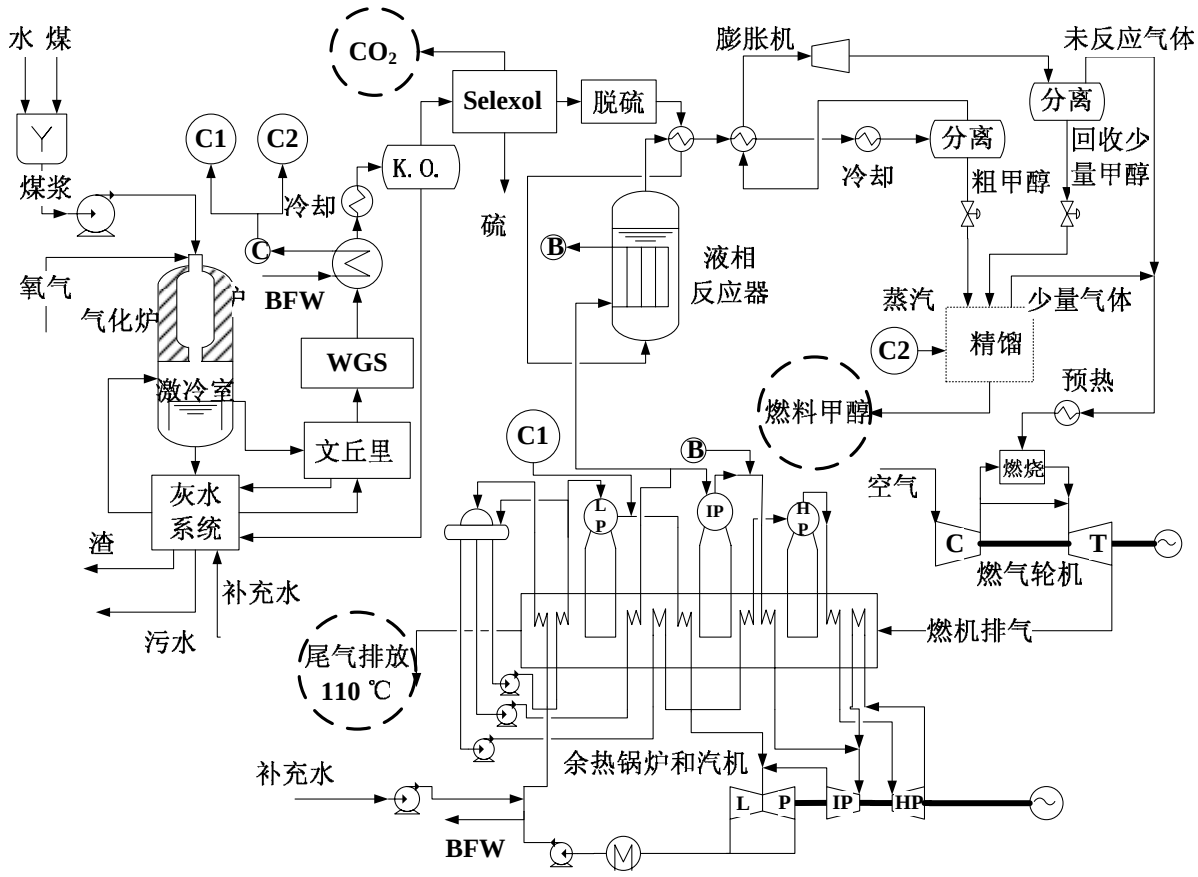


Diluted CO2：74%，221.7 gCO2/MJ

Efficiency 46.8% (LHV)

CO2 emission less than supercritical plant 11%

Power+MeOH production with shift reactor

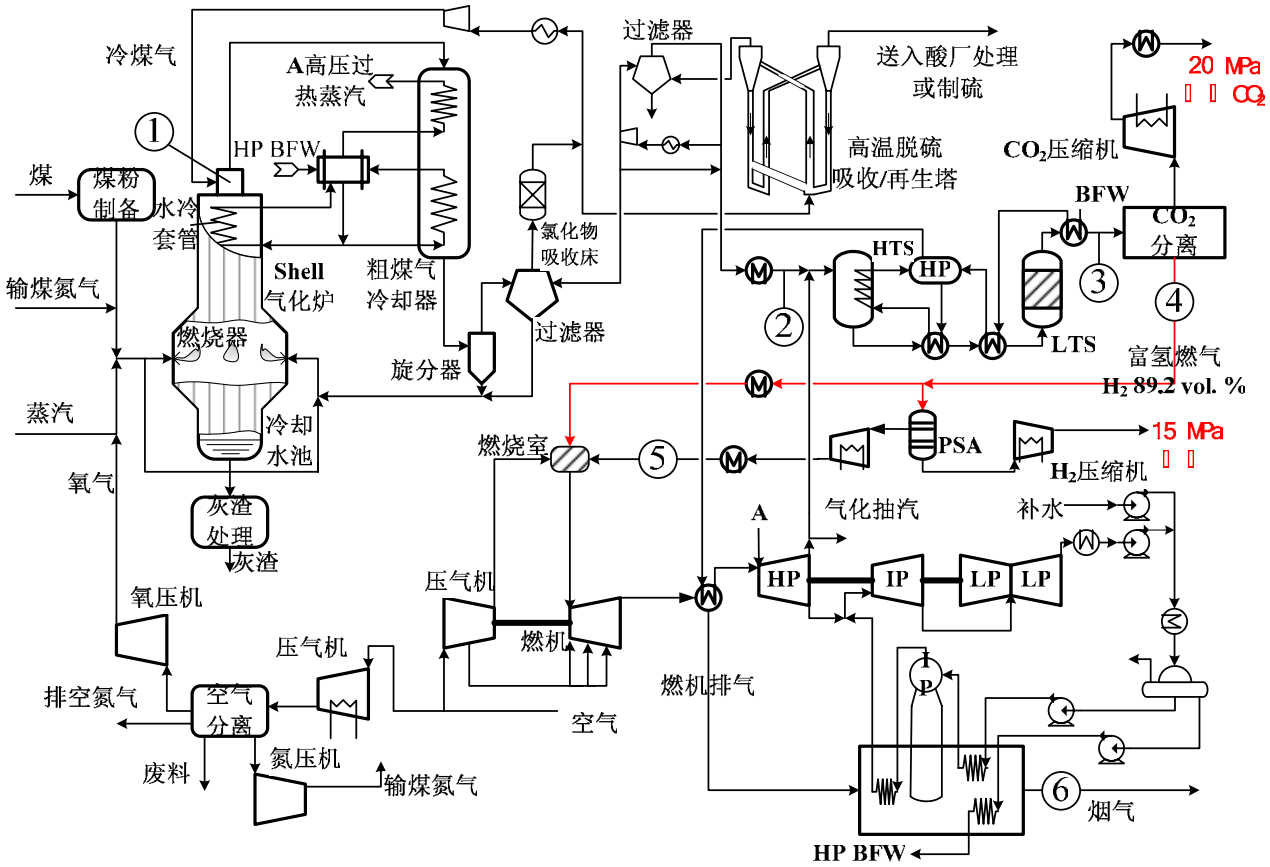


Diluted CO2：31.5%，114 gCO2/MJ

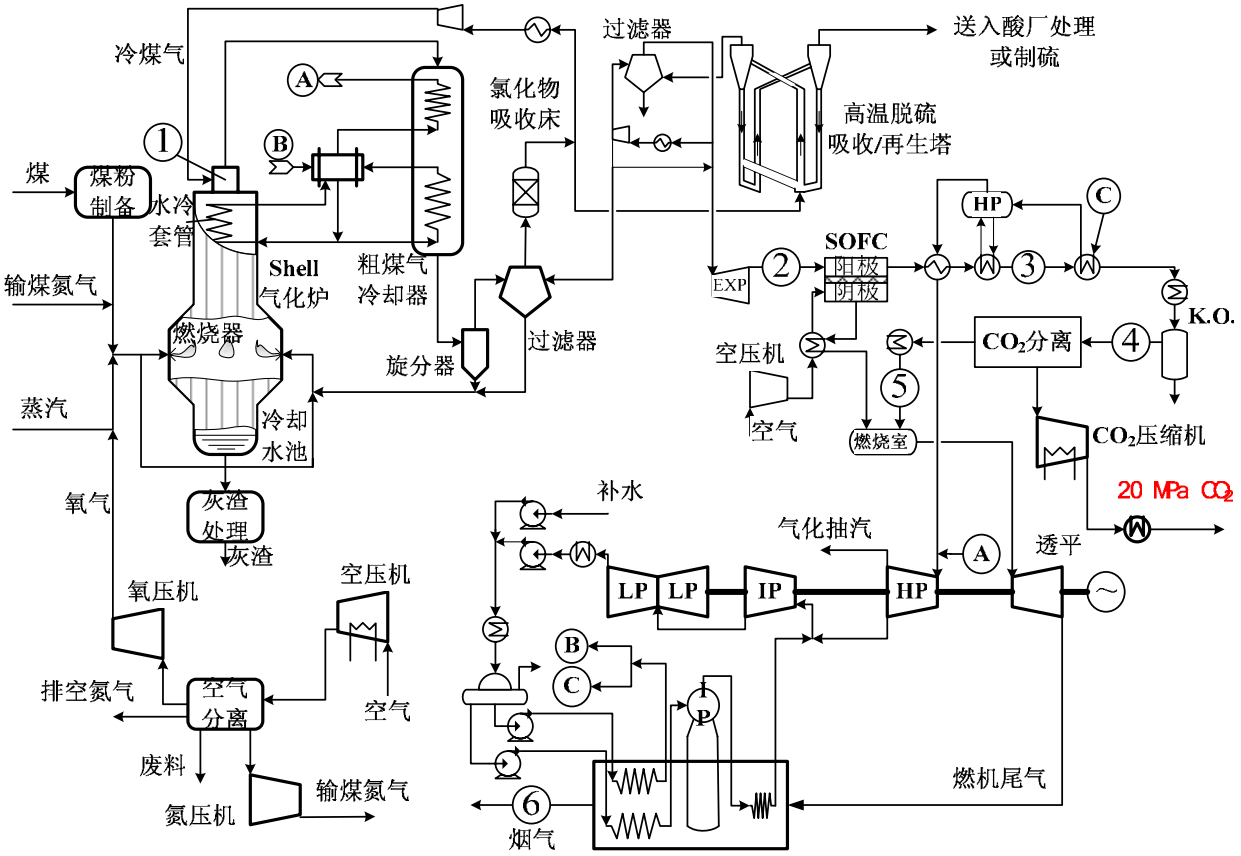
Efficiency 46.8% (LHV)

CO2 emission less than supercritical plant 11%

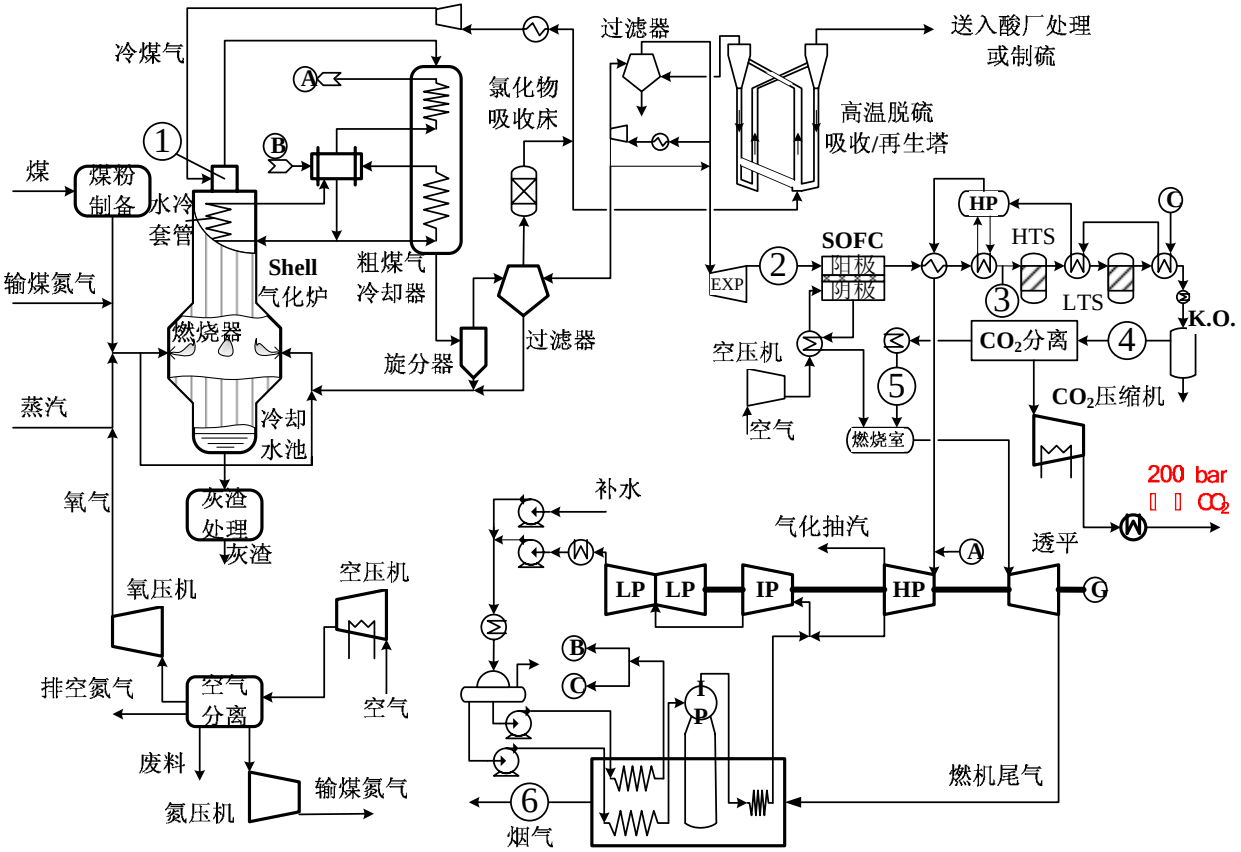
IGCC+H2 production with different power fraction



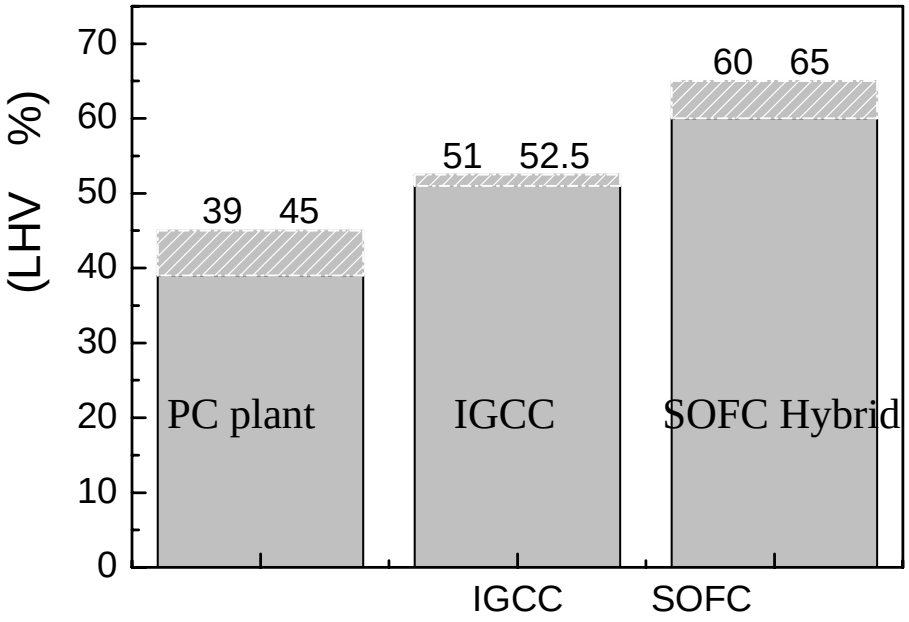
减排CO2的煤气化SOFC混合循环

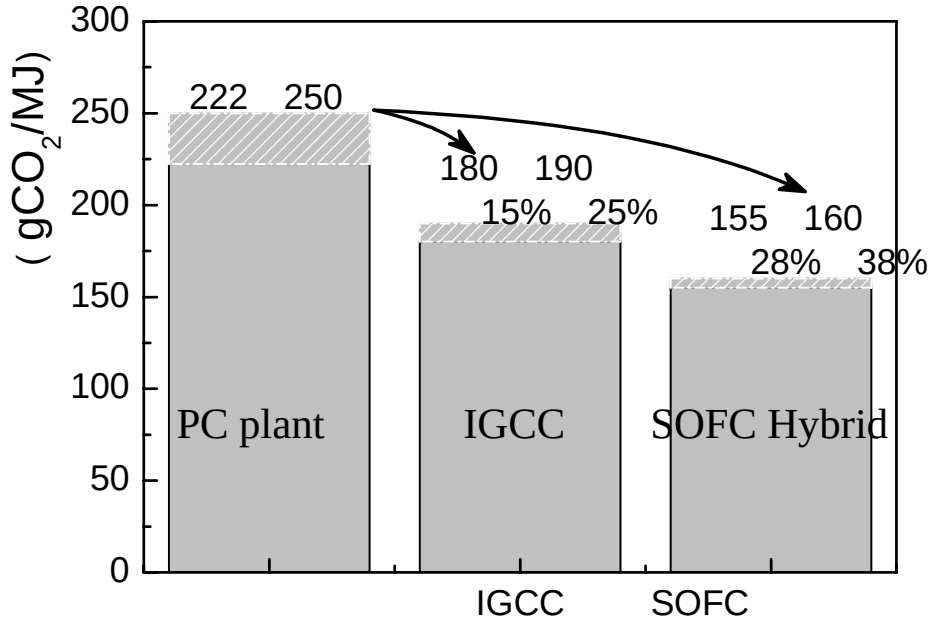


减排CO2的煤气化SOFC混合循环（带水煤气变换）

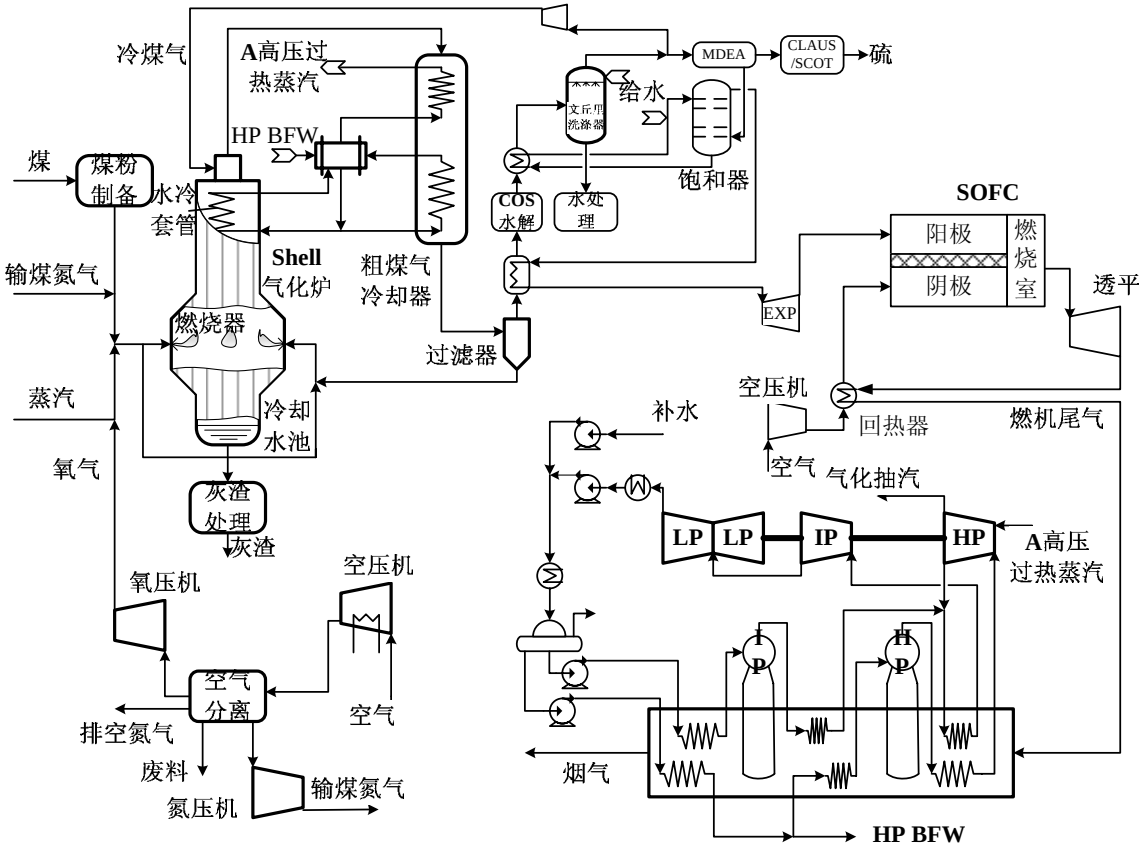


能量效率和二氧化碳排放对比总结



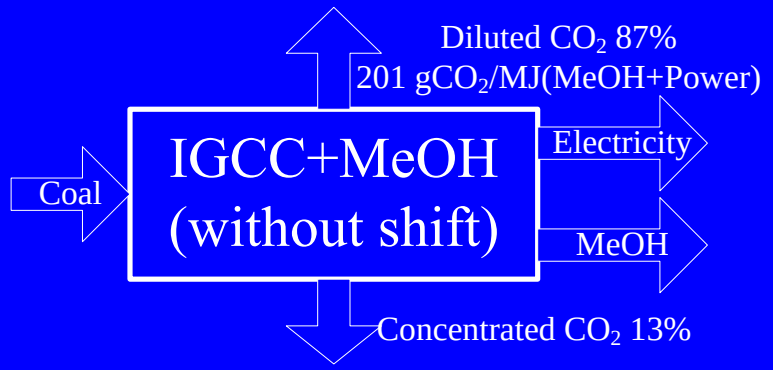


采用常温净化系统的煤气化SOFC混合循环电厂（无补燃，单压SOFC结构）

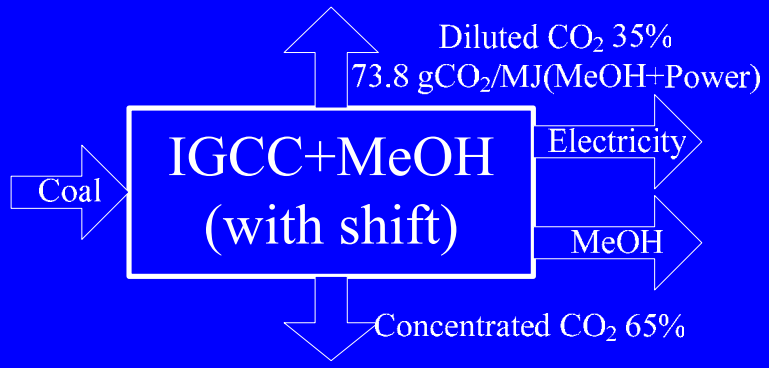


CO_2 reduction rates of different configurations

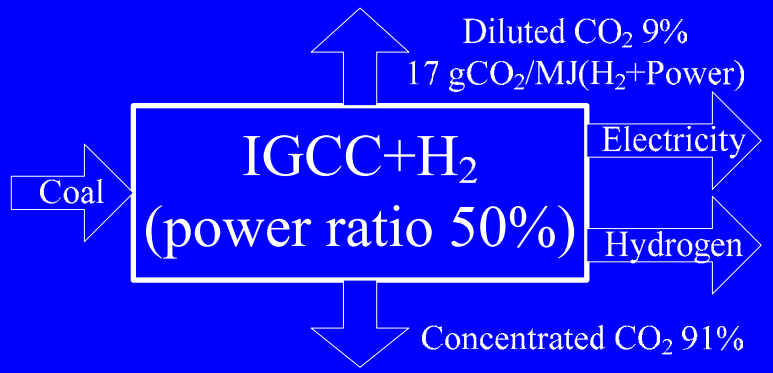
In comparison with SuperCritical power plant
210 gCO_2/MJ, *less CO_2 9.5%~14.3%*



Electricity from 40% coal power plant 235 gCO_2/MJ
CO_2 reduction for electricity about 15%



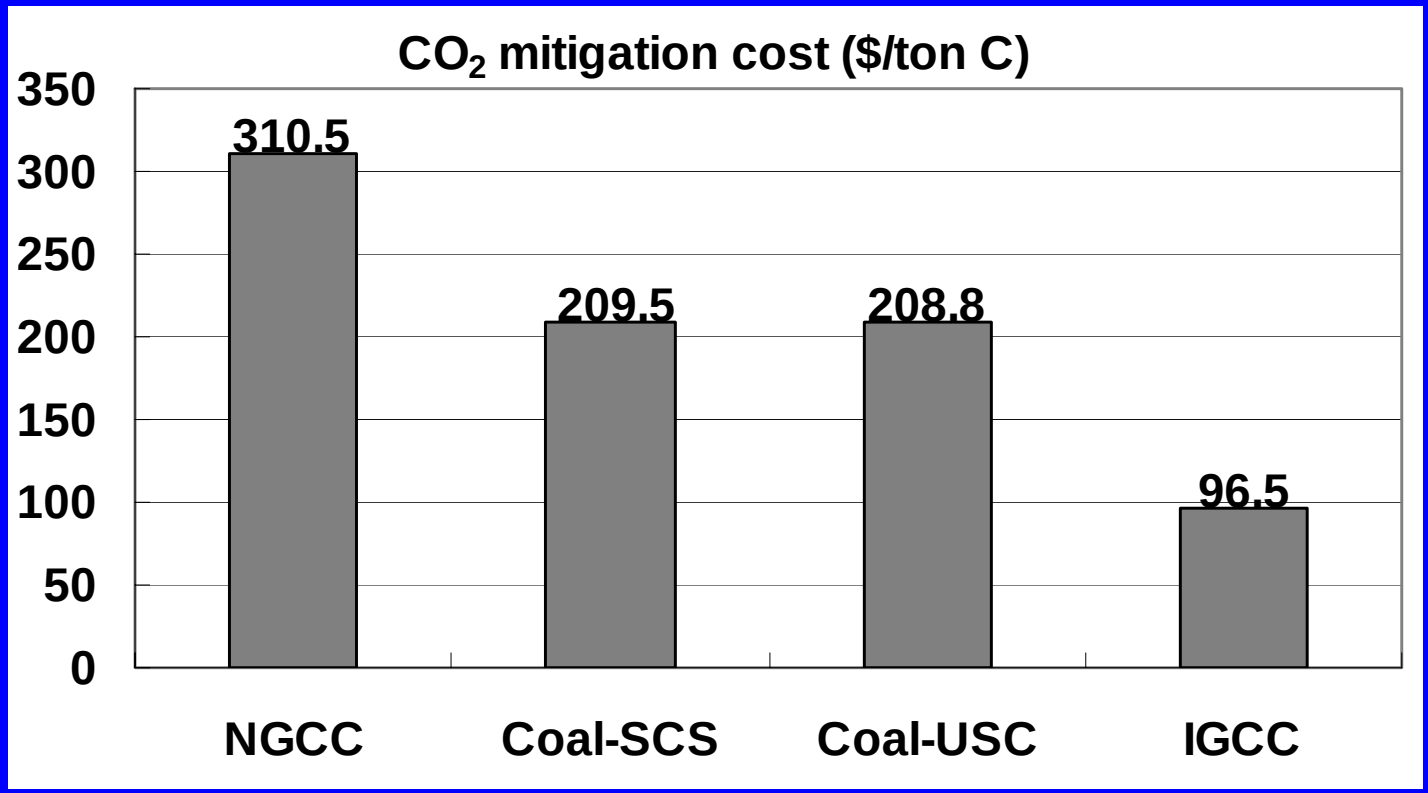
Electricity from 40% coal power plant 235 gCO_2/MJ
CO_2 reduction for electricity about 68.7%



Electricity from 40% coal power plant 235 gCO_2/MJ
CO_2 reduction for electricity about 93%

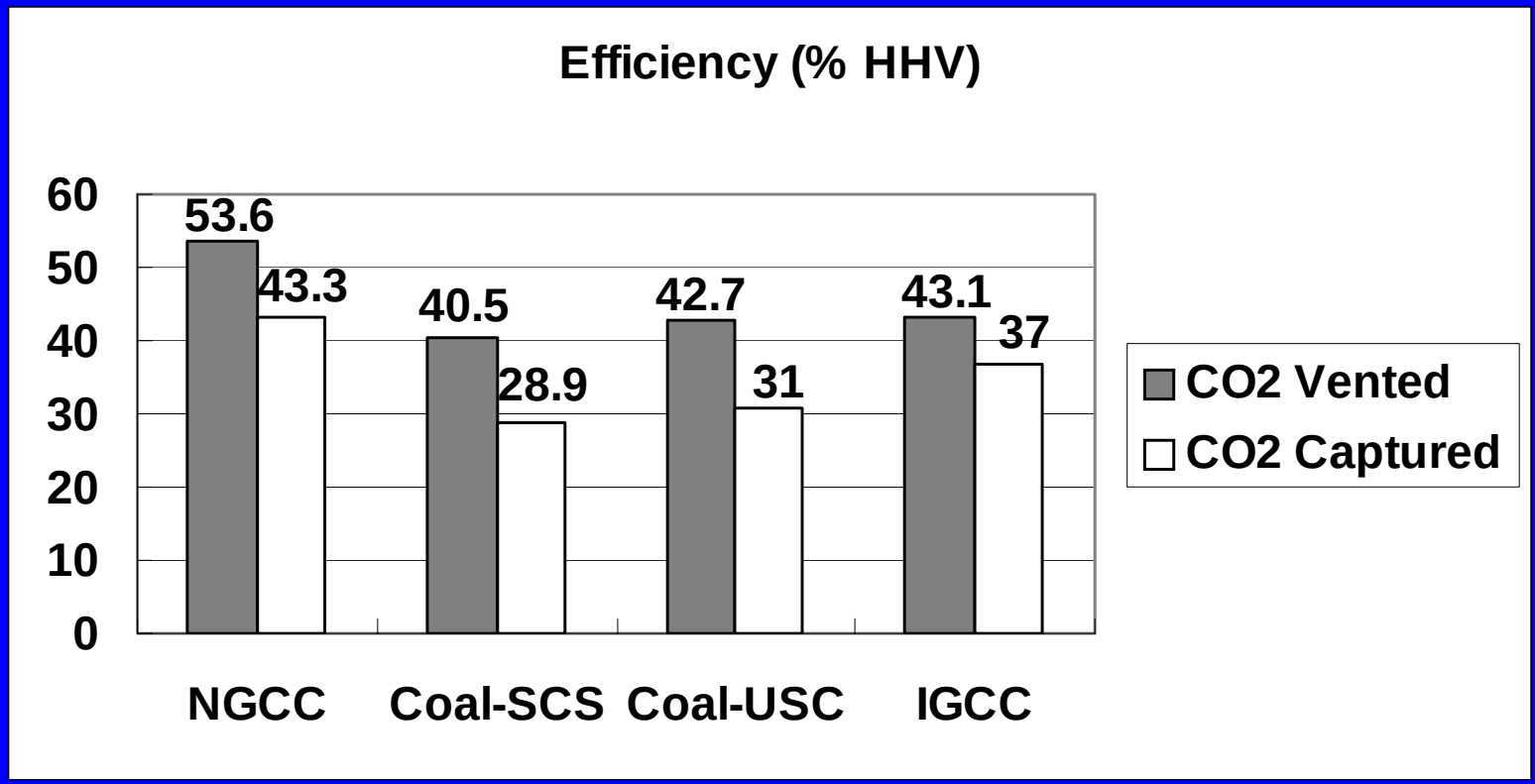
清華大學

Analysis of power plants with CO_2 mitigation (contd.)



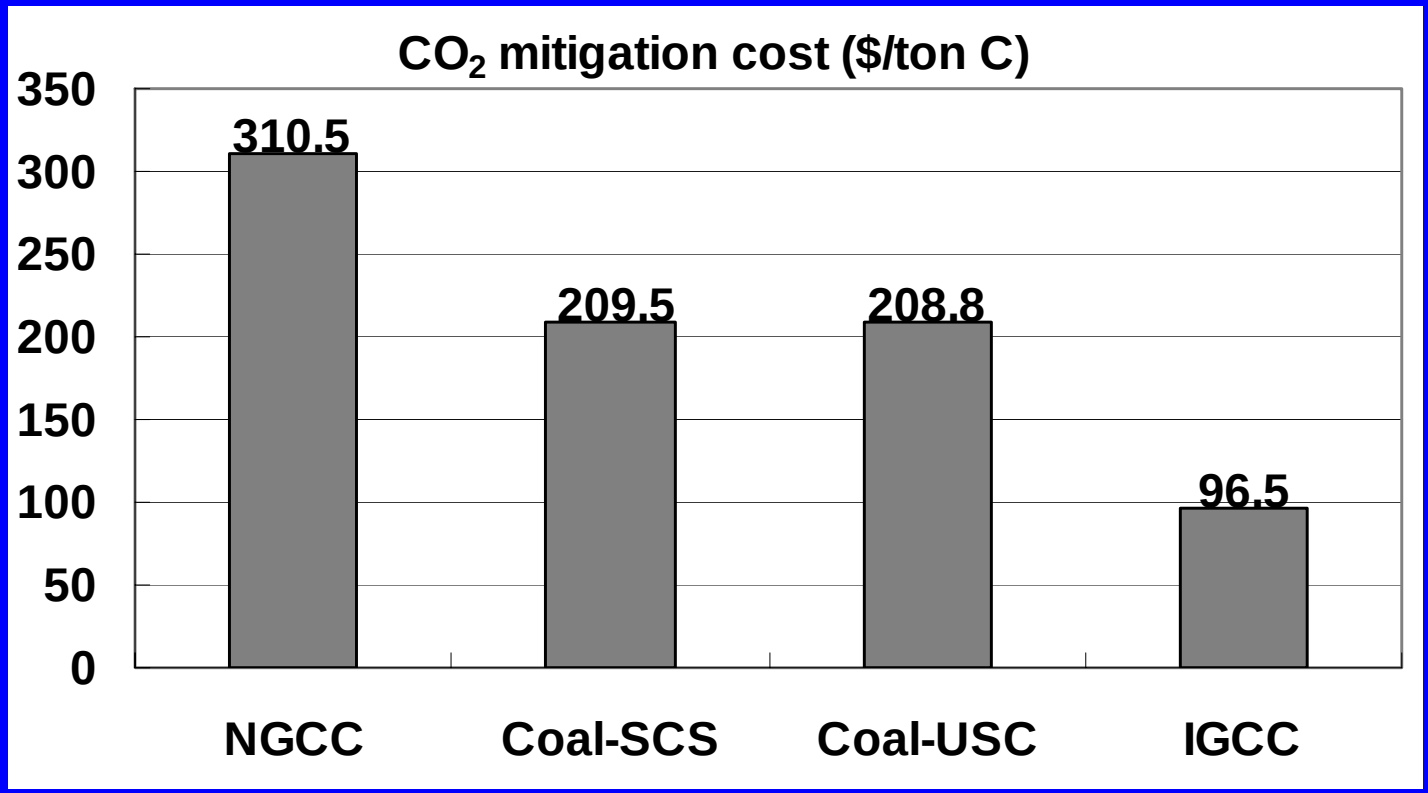
清華大學

Analysis of power plants with CO_2 mitigation (contd.)

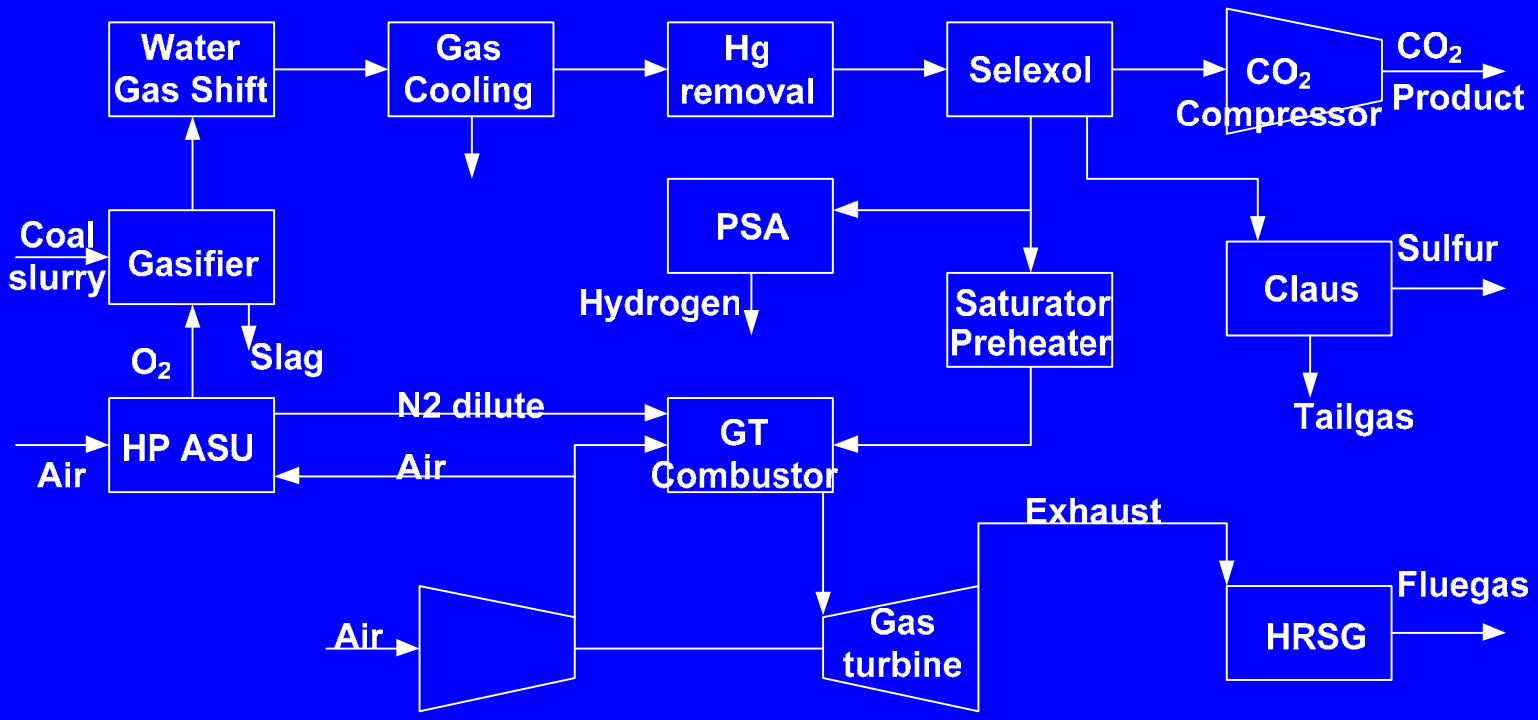


清華大學

Analysis of power plants with CO_2 mitigation (contd.)

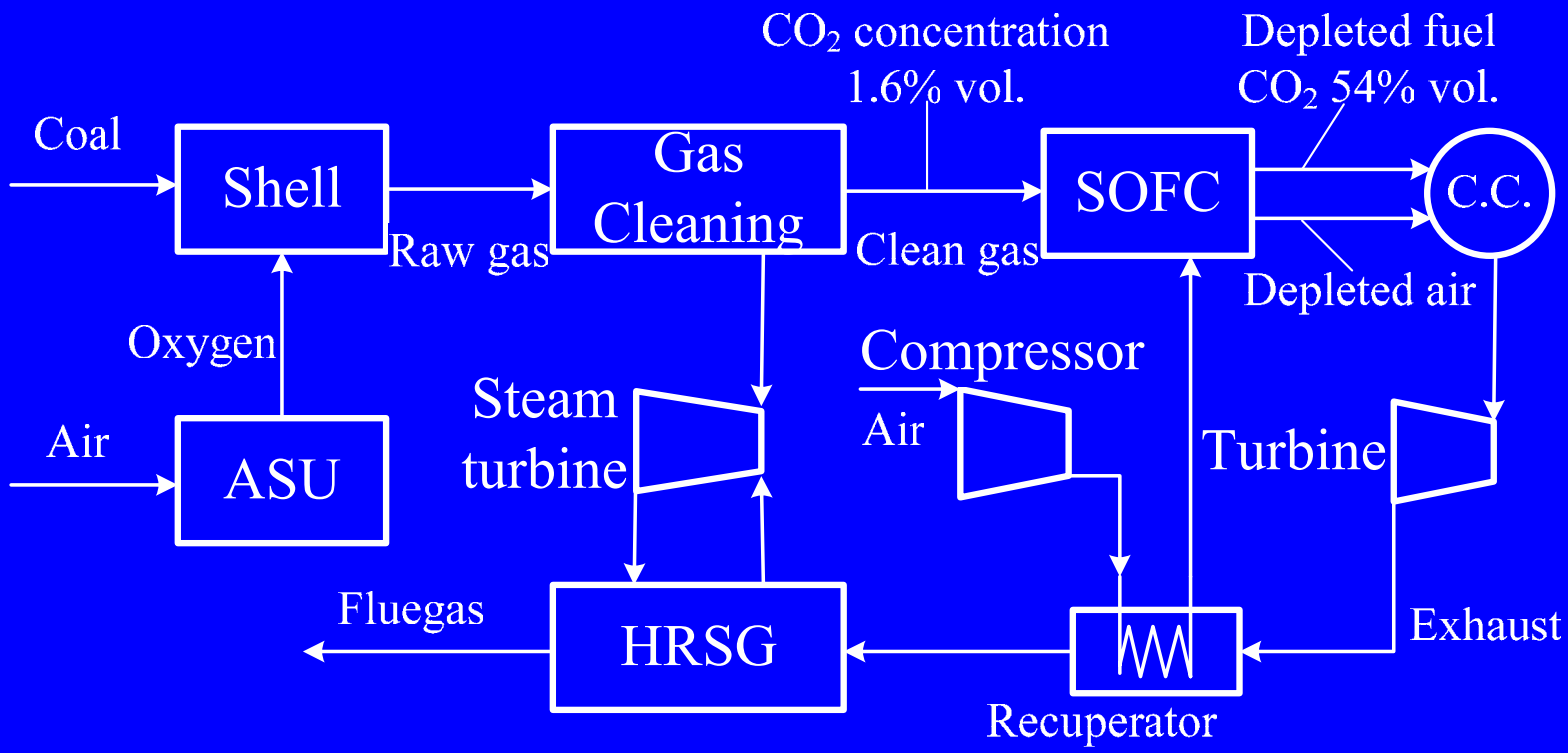


Coal Gasification System Ready for Large-Scale H_2 production and Utilization



清華大學

Coal Gasification is the Core of Future New Thermal Cycles



- **When coupled with High Temperature Solid Oxide Fuel Cell (SOFC), the efficiency of IGCC-SOFC could be up to 60%~65%.**
- **SOFC has the similar function like Water Gas Shift for increasing CO_2 concentration in syngas**

清華大學

General Conclusions

- **According to the projection of energy demand and supply, coal will still play the dominant role (50%~60% in 2050)**
- **Coal utilization will contribute about 70%~75% of CO_2 in China (at present 76.8%)**
- **Coal mainly will be used for power generation in future (up to 80%, at present about 45~50%)**
- **It means coal fired power plants will contribute 60% or more CO_2 of total**

清華大學

Genetic characteristics of polygeneration system

- **Heritage of all environmental virtues of IGCC**
  - **SOx, NOx, dust, Mercury**
- **Simplicity and higher efficiency**
  - **once through→reduce the size and energy consumption of recycling**
  - **CO-rich gas synthesis →saving shift reactor**
  - **more flexibility for balancing energy recovery and simplicity of the system**
- **Nature of easy CO_2 capture**
  - **concentrated CO2+diluted CO_2**
  - **meets time progressive CO_2 reduction requirements by different configuration (e.g. w. or w/o shift reactor)**

清華大學

Conclusions

- **Polygeneration has the nature of easy CO2 capture**
- **Different configurations could meet time-progressive CO2 reduction demand and can evolve up to near zero CO2 system.**
- **When coupled with CO2 sequestration, coal derived synthetic fuels has the prospect to be competitive with other fuels.**
- **Polygeneration is the sustainable, technically consistent, technologically realistic, economically beneficial, and ecologically friendly way for CO2 mitigation, capture, and further sequestration. It is really the most important strategy in China.**

清華大學

END

Thank you!