Where CCS will Go?
after Demonstration

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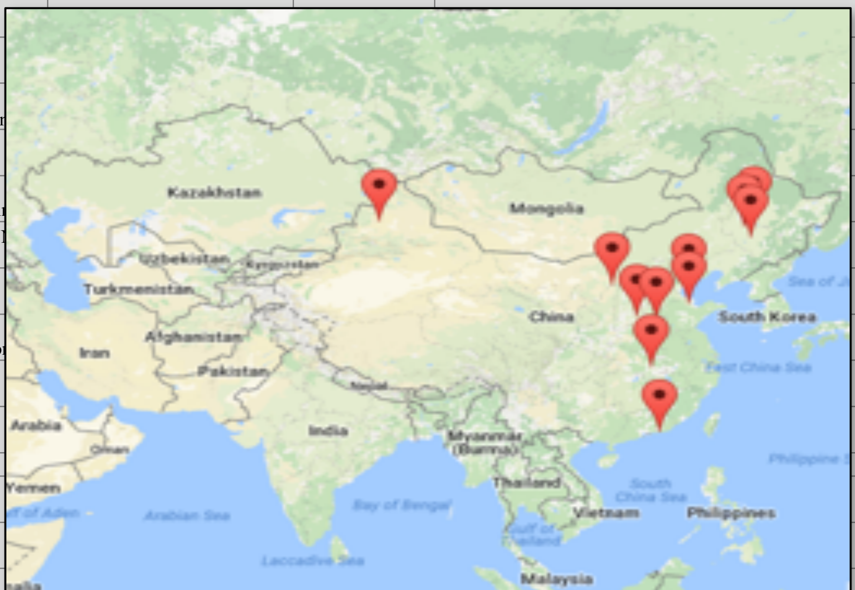
Outline

1. **Progress of CCS demonstration in China**
2. **What we get from demonstration**
3. **Summary**

Overview CCS demonstrations in China

Capture:
~120 Mta (in total)

Storage:
~120 Mta (in total)



Project name	Project stage	Location	Industry	Capture capacity	Capture type
Project	Operational	Shandong Province	Power generation	tpa	Post-combustion
Sinopec Zhongyuan Carbon Capture Utilization and Storage Pilot Project	Operational	Henan Province	Chemical production	120,000 tpa	Industrial separation
Beijing Gaojing NGCC power plant	Construction finished	Beijing	Power generation	1300~1500 tpa	Post-combustion

- Capture covers post-combustion, pre-combustion and oxyfuel combustion;
- Storage covers EoR, ECBM and Saline aquifer;
- One large scale full chain demo in construction.

Huaneng Beijing Thermal Power plant
Post-combustion CO2 capture demonstration project

Location: Beijing;
Scale: 3,000 tons/year
Investment cost: 28 million RMB

CO2 product was sold to food industry	
Capture rate	3,000 tons/year
Pressure	1.3MPa
Purity	99.9%

Performance of CO2 capture unit	
Steam consumption	3.3~3.4GJ/tonCO_2 (1.3~1.5MPa 140~150°C)
Electricity consumption	150~200kWh/ton CO_2

The **first CO_2 capture pilot plant** in China operated in 2008 and shutdown by 2016

Huaneng Shanghai Shidongkou power plant
Post-combustion CO_2 capture demonstration project

Location: Shanghai
Scale: 120,000 tons/year
Investment: 15,000 million RMB
Flue gas treatment: 66,000 Nm³/h (4%)

CO_2 product was sold to industry	
CO2 capture rate	120,000 tons/year
Pressure	1.3 MPa
Purity	>99.99%

Performance of CO2 capture unit	
Steam consumption	1.84 kg/kgCO_2, 3.0 GJ/ton
Power consumption	75 kWh/ton CO_2
Solvent consumption	6 kg/ton-CO_2

The **largest CO_2 capture demo in power sector**, operated in 2010

Datang Beijing Shijingshan Combined Cycle power plant Post-combustion CO_2 capture demonstration project

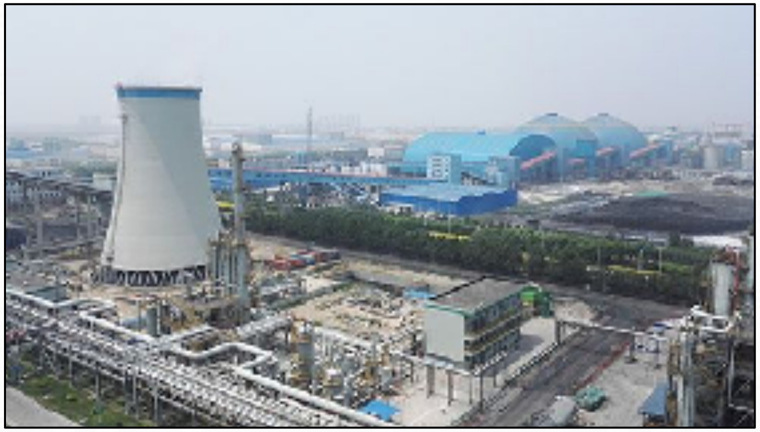
Location: Beijing
Scale: 1,000 tons/year
Investment: 15,000 million RMB
Flue gas treatment: 3,000 Nm^3/h

CO_2 product was sold to industry	
CO2 capture rate	1,000 tons/year
Pressure	1.3 MPa
Purity	>99.99%

Performance of CO2 capture unit	
Steam consumption	3.9~4.3 GJ/ton
Power consumption	258 kWh/ton CO_2
Solvent consumption	2.12 kg/ton-CO_2

The **first CO_2 capture demo in natural gas based power plant,** operated in 2014

Huaneng Tianjin IGCC power plant
Pre-combustion CO_2 capture demonstration project



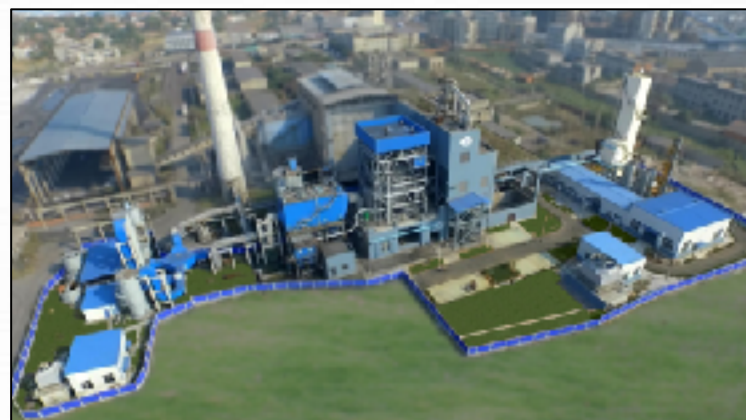
Location: Tianjin
Scale: 100,000 tons/year
Efficiency: ~41%
Fuel gas treatment: 2,372Nm3/h

Performance of CO2 capture unit	
Steam consumption	≤2.0t/ton CO_2 0.3MPa, 144°C
Power consumption	≤ 92 kWh/ton CO_2
Solvent consumption	≤1.5 kg/ton-CO_2

The **only pre-combustion CO_2 capture demo,** operated in 2016

35MW Oxyfuel Combustion demonstration project

Location: Hubei Province
Scale: 100,000 tons/year
Pilot plant for science and technology research



The **only Oxyfuel combustion demo,** operated in 2015

Large scale full chain CCUS project in construction
Shaanxi Yanchang project

The largest full chain CCUS project

Location: Shaanxi Province, China

Scale: 0.41 Mt/year

0.05Mt project in operation in 2012, and 0.36Mt project will be operated by 2018.

CO_2 capture: high purity resource (from 83% to 99%), 50,000 tonnes from gasification facilities of the Yulin Coal Chemical Co. Ltd, and 360,000 tonnes from gasification facilities of the Yulin Energy Chemical Co. Ltd, Jingbian Industrial Park

Capture method: Absorption physical solvent-based process - Rectisol

Transportation: Tanker trucks plus pipeline (in planning)

Storage: Enhanced oil recovery, Primary injection site is the Jingbian producing unit of the Yanchang oil field (>100 kilometres southwest of Yulin).

Large scale full chain CCUS project in construction
Guohua Jinjie project

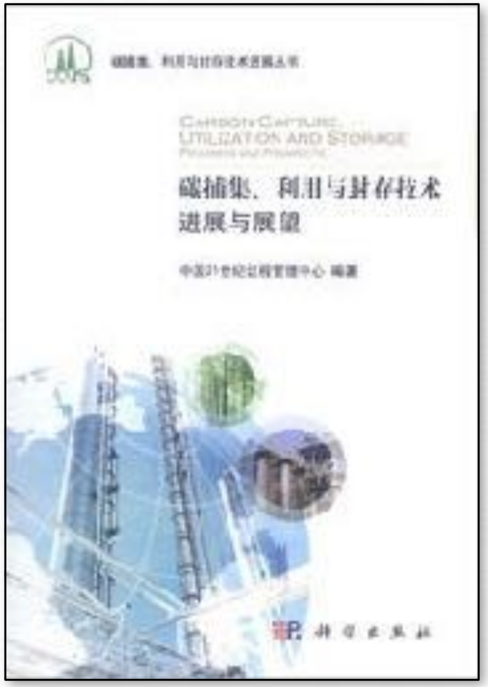
Location: Shaanxi Province, (200 miles to Yanchang project)

Scale: 150,000t/year

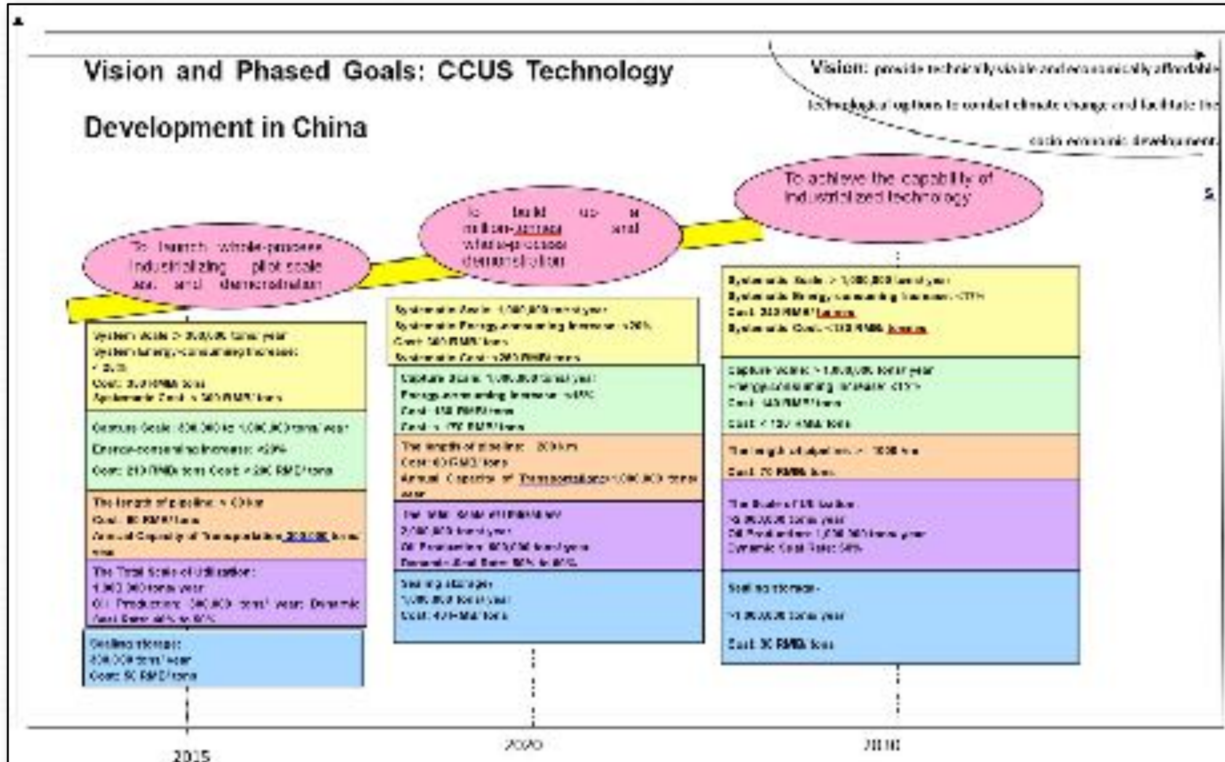
CO_2 capture source: flue gas of 600MW subcritical power plant

Storage: to be combined with the CO_2 storage project in Erdos, Saline aquifer.

Technology Roadmap Study：
Carbon Capture, Utilization, and Storage (CCUS) in China



Issued by MoST in 2012



Will be updated and issued by 2018.

国家重点研发计划 National Key Research Program

Leading by the MoST

科技部主导，2016年共支持737个项目，总经费216亿。

政策背景：

《国家中长期科学和技术发展规划纲要(2006—2020年)》

《能源发展战略行动计划(2014—2020年)》

Clean Coal Utilization

煤炭清洁高效利用和新型节能技术

- 煤炭高效发电
- 煤炭清洁转化
- 燃煤污染控制
- **二氧化碳捕集利用与封存(CCUS)**
- 工业余能回收利用
- 工业流程及装备节能
- 数据中心及公共机构节能

2016~ the present:

3~5 projects, more than 100 million yuan funding per year

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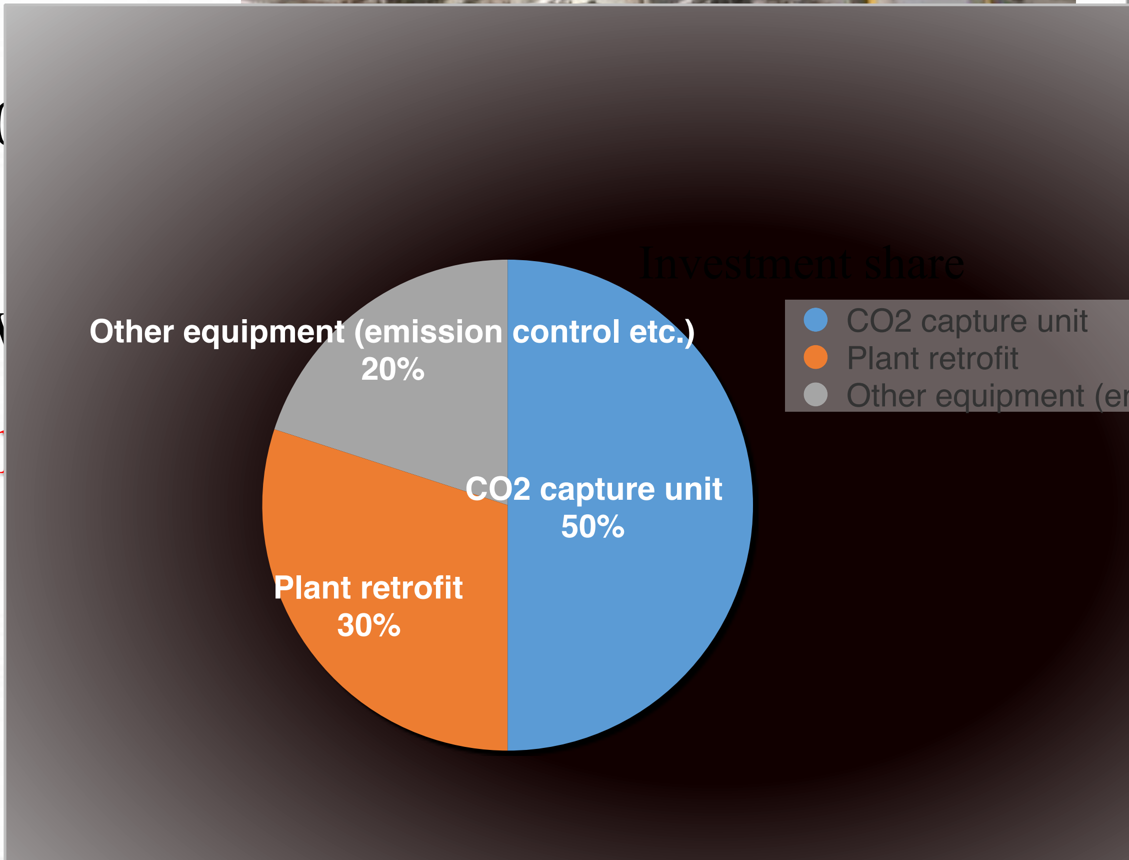
The world first successful large scale demo project Boundary Dam post-combustion CO_2 capture project

Operation in 2014. 10

- Location: Boundary Dam
- Capacity after retrofit: 16(
- Capture rate: 1 Mt/year
- CO_2 utilization: **EOR in** W
- Final investment: $1.5 bil



Boundary Dam post combustion demonstration

Parameters before retrofit	
Fuel type	Saskatchewan lignite
Fuel input, MW	397.1
Boiler type	Subcritical
Steam turbine	150MW
Steam	12.5Mpa/538°C/538°C
Gross power, MW	150
Net power, MW	139
Net efficiency, %	35.5
CO_2 emissions, Mt/y	110
COE, $/kWh[4]	0.091-0.125

Parameters after retrofit	
Fuel type	Saskatchewan lignite
Fuel input, MW	397.1
Steam turbine	Hitachi 160MW
Steam	29Mpa/593°C/621°C
Gross power, MW	162
Net power, MW	150
Net efficiency, %	37.8
CO_2 emissions, Mt/y	110

Retrofit plant with CO2 capture	
Fuel type	Saskatchewan lignite
Fuel input, MW	397.1
CO_2 capture rate	1 Mta
CO_2 capture technology	Cansolv amine-based
Steam parameter w/o retrofit	12.5MPa/565°C/565°C
Net power w/o retrofit, MW	95
Net efficiency w/o retrofit, %	23.9
Steam parameter w retrofit	29 MPa/593°C/621°C
Net power w retrofit, MW	110
Power for CO_2 compression, MW	9
Power for CO_2 capture, MW	14
Net efficiency for retrofit plant, %	27.7
CO_2 storage	Weyburn EOR
Total investment	1.50 billion
Unit investment, $/kW- gross	9375
Unit investment, $/kW- net	13636
Annual investment, M$	180[1]
Annual O &M cost, M$	60[2]
Annual fuel cost, M$	8.6[3]
COE, $/kWh	0.303
CO_2 capture cost, $/t	100-155

Performance of post-combustion CO_2 capture projects in China

	Beijing Thermal power plant		Shaihai Shidongkou		Chongqing Shuanghuai	
	Base plant	90% CO_2 capture	Base plant	90% CO_2 capture	Base plant	90% CO_2 capture
Coal input, MW	3945	3945	1444-1573	1444-1573	1500-1544	1500-1544
Boiler type			Supercritical	Supercritical	Subcritical	Subcritical
CO_2 product pressure, MPa		1.3		1.3		
Heat, MW	1556[1]	1307~1315[2]				
Gross power of ST, MW	845[1]	845	660		2×300MW	2×300MW
Net power output for base plant, MW	811[2]	811	634		576[1]	576
Efficiency penalty, %		11.3-12.5				9.1-9.4
COE $/MWh			*42.94-47.81*	*[illegible]0.88-88.61*		
CO_2 capture cost, $/ton		44-66		52-62		59
Total investment, M$			396-462[2]	623-688[3]	459[2]	508-581[3]
Unit investment, $/kW			650-730	1570-1734	796	1167-1335

COE rises from ￥0.26~0.292/kWh to ￥0.493~0.54/kWh

CO_2 capture cost ranges from 44-66 $/ton

Performance comparison between post-combustion projects

Project	Scale, Mt/y	Efficiency penalty	Investment cost $/kW-net	CO_2 Capture cost $/t
Boundary Dam	**1.0**	**10-14**	**~13636**	**100-155**
W.A. Parish	1.6	12.4-13.2	4887-5253	110-120
ROAD	1.1	10.7	2190-2339	52-61
Trailblazer	5.1	13.2-14.5	2422-2886	50-60
China (estimated)	**1.3**	**9.1-16.0**	**1200-1750**	**44-66**

Need deeper understand:

Compared to the first demo, the second will be 30% lower;

Investment Cost will be saved due to localization of key equipment;

Operation cost, including labor cost, may be lower in China;

Different market conditions and policy supporting.

Why the difference is so big? = What is the potential for cost reduction?

Hints:

1. *The cost of demo projects are* ***far beyond*** *the theoretical prediction.*
2. *The cost of international projects are* ***several times higher*** *than that of domestic projects.*
3. *The experiences of the first large scale demo is so valuable, we have to* ***deeply understand*** *them from the aspect of technical, economical, and market, etc..*

How to prevent "Demo to Death"

Kemper County, suspended in 2017

"The world largest CCS project failed!"

Too many ambitious targets:

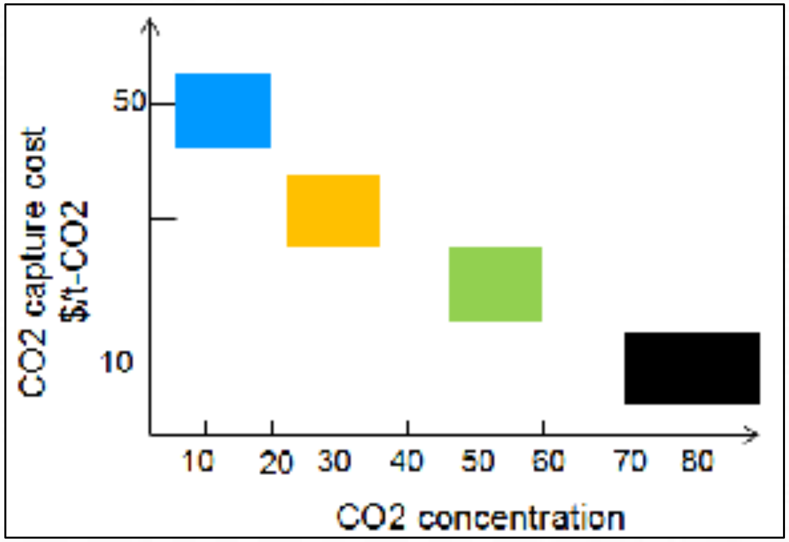
New gasification technology: TRIG technology;

Complex and expensive power plant: IGCC power plant;

Large scale: 350,000t/y, nearly full capture.

Is CCS the reason for this fail?

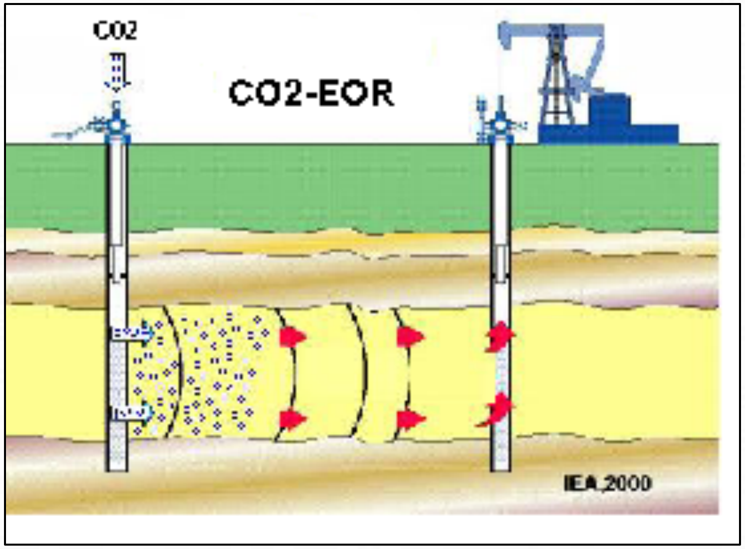
Coal Chemical combined with EoR –
Low cost opportunity for CCS demo in China



High purity resources

Cost for capture: around ￥100/t

Combined with
＋

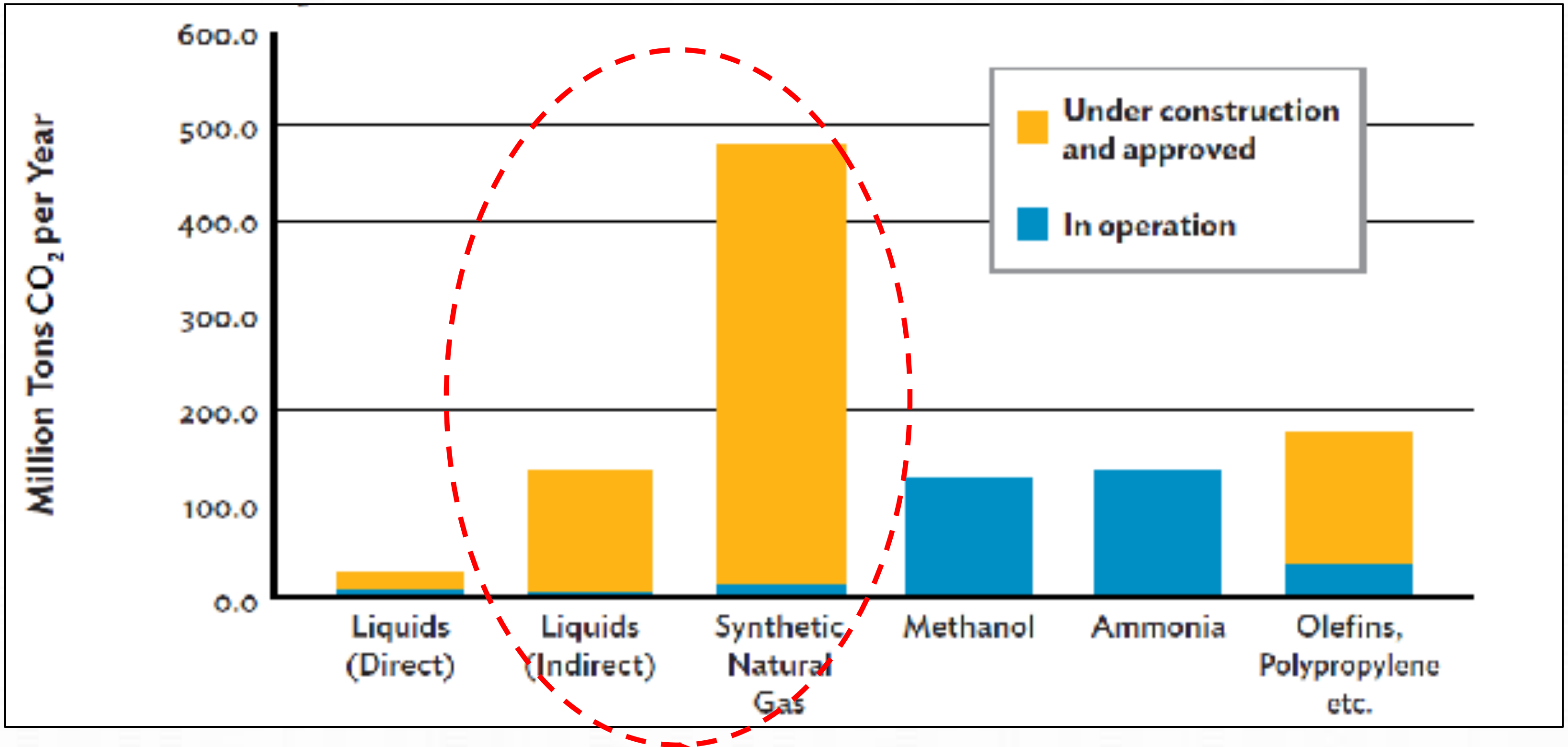


Sinks of EoR

Input output ratio: 1.2~1.5

Benefit business mode for early opportunities

Significant role of coal chemical in China



Opportunity in Coal chemical industry (hundreds millions tones),

especially in alternative fuel production

Experiences of Shaanxi Yanchang project

1. Low cost of Capture:

High purity resource (from 83% to 99%) leads to 120yuan/t-CO_2 (<$20/t)

2. Benefit from EoR: success in pilot sets

Qiaojiawa Pilot: CO_2 injection 7000t
increased oil amount is 2402.7t.

Yougou Pilot: CO_2 injection is 19200t
increased oil amount is 2741.8t.

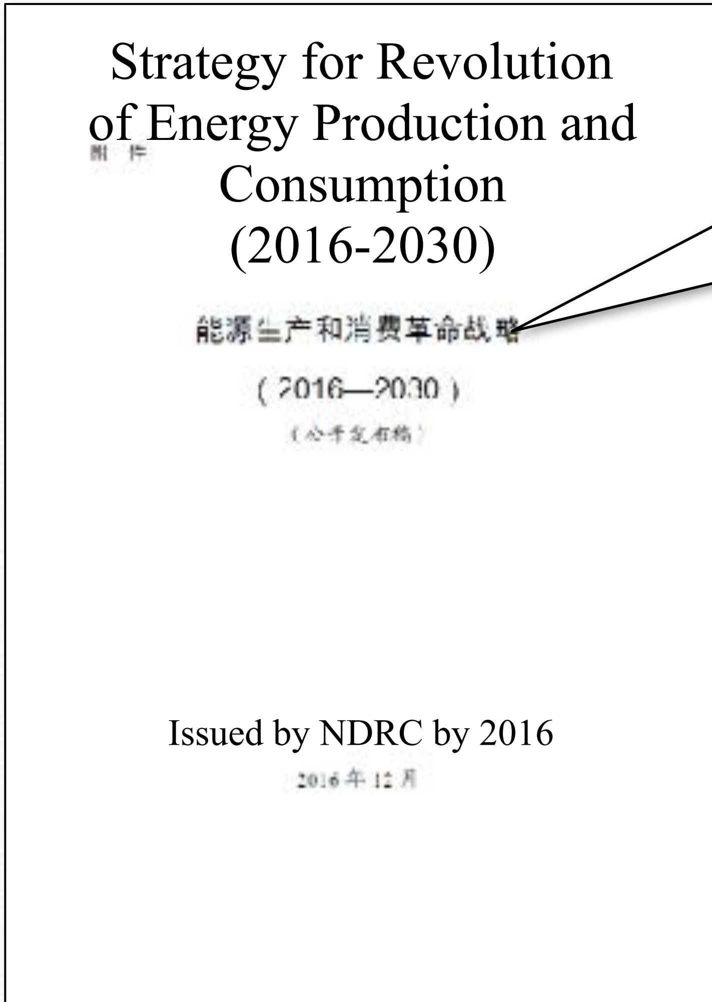
3. Project Owner owns both source and sink

Hints:

1. *Rather* ***high cost*** *is the* ***main barrier*** *for CCS deployment, especially in power sector;*
2. *Low cost should be* ***the first criterion*** *for early demo selection;*
3. *Early demo should gather the experiences, and more important,* ***build confidence*** *and save time for new tech..*

Pressure from renewable energy

Strategy for Revolution of Energy Production and Consumption (2016-2030)


附 件

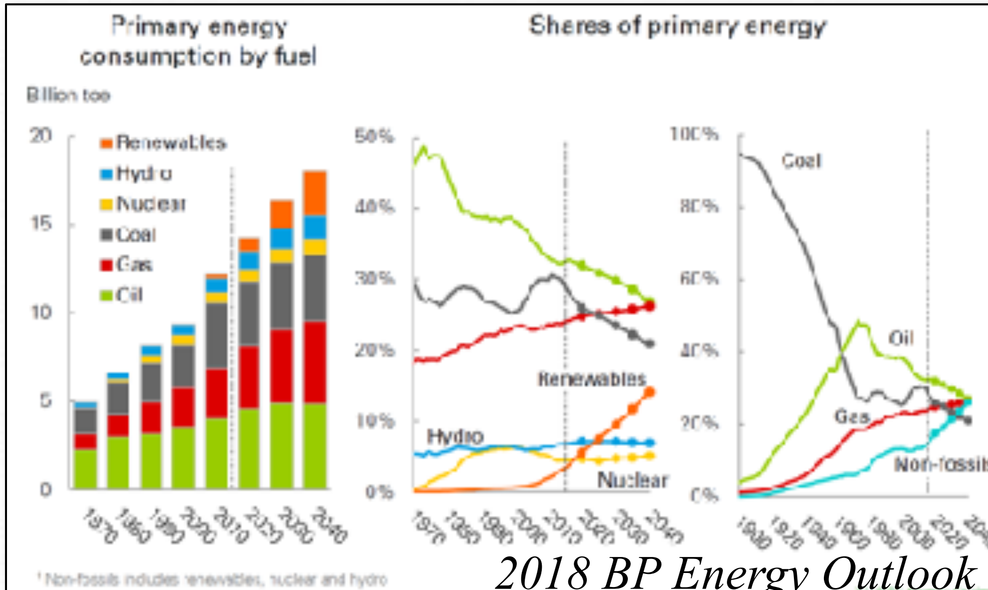
能源生产和消费革命战略

（2016—2030）

Issued by NDRC by 2016

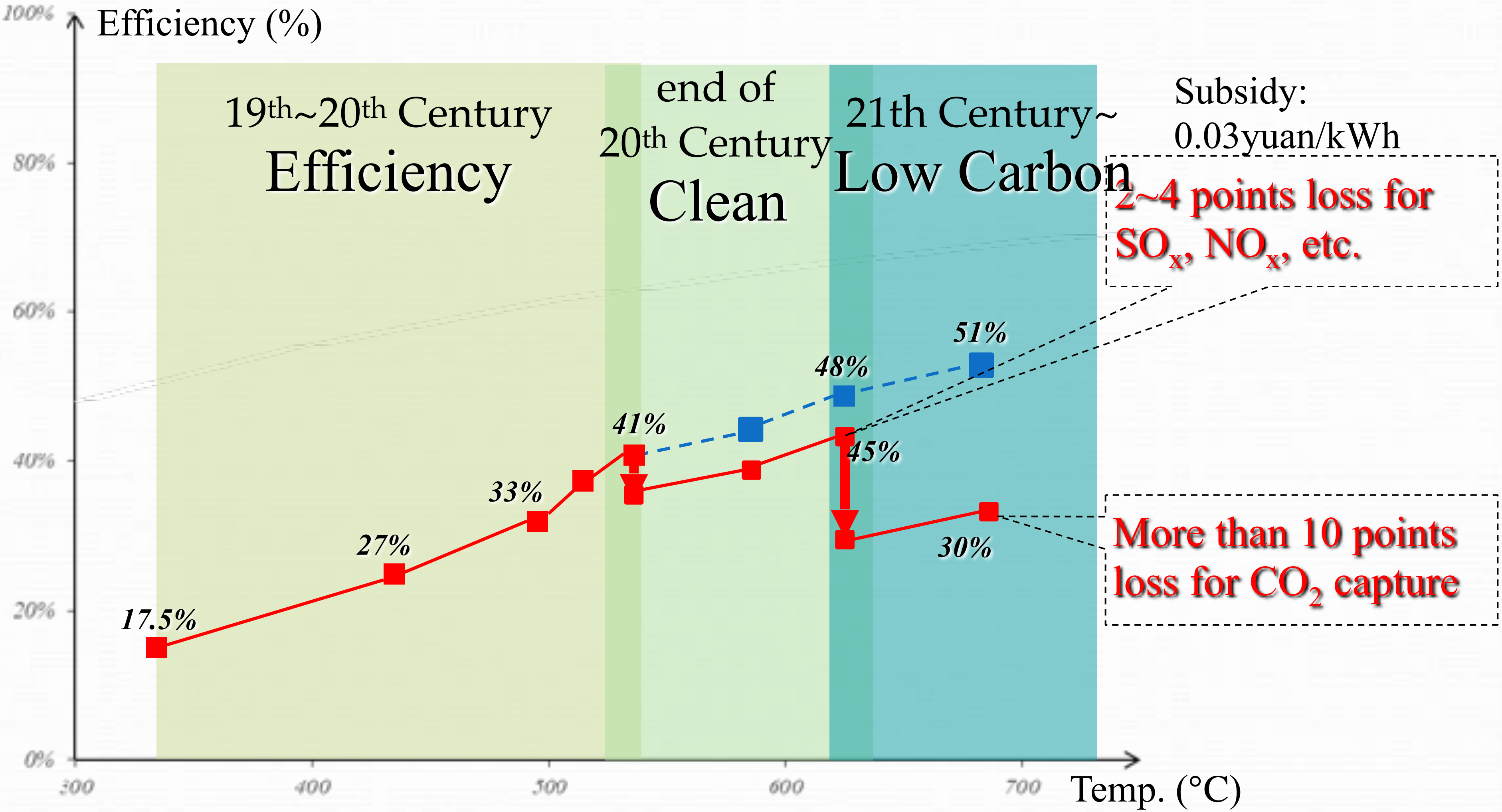
展望 2050 年，能源消费总量基本稳定，非化石能源占比超过一半

Look into the future, non-fossil fuel will account more than 50% of energy mix of China by 2050.

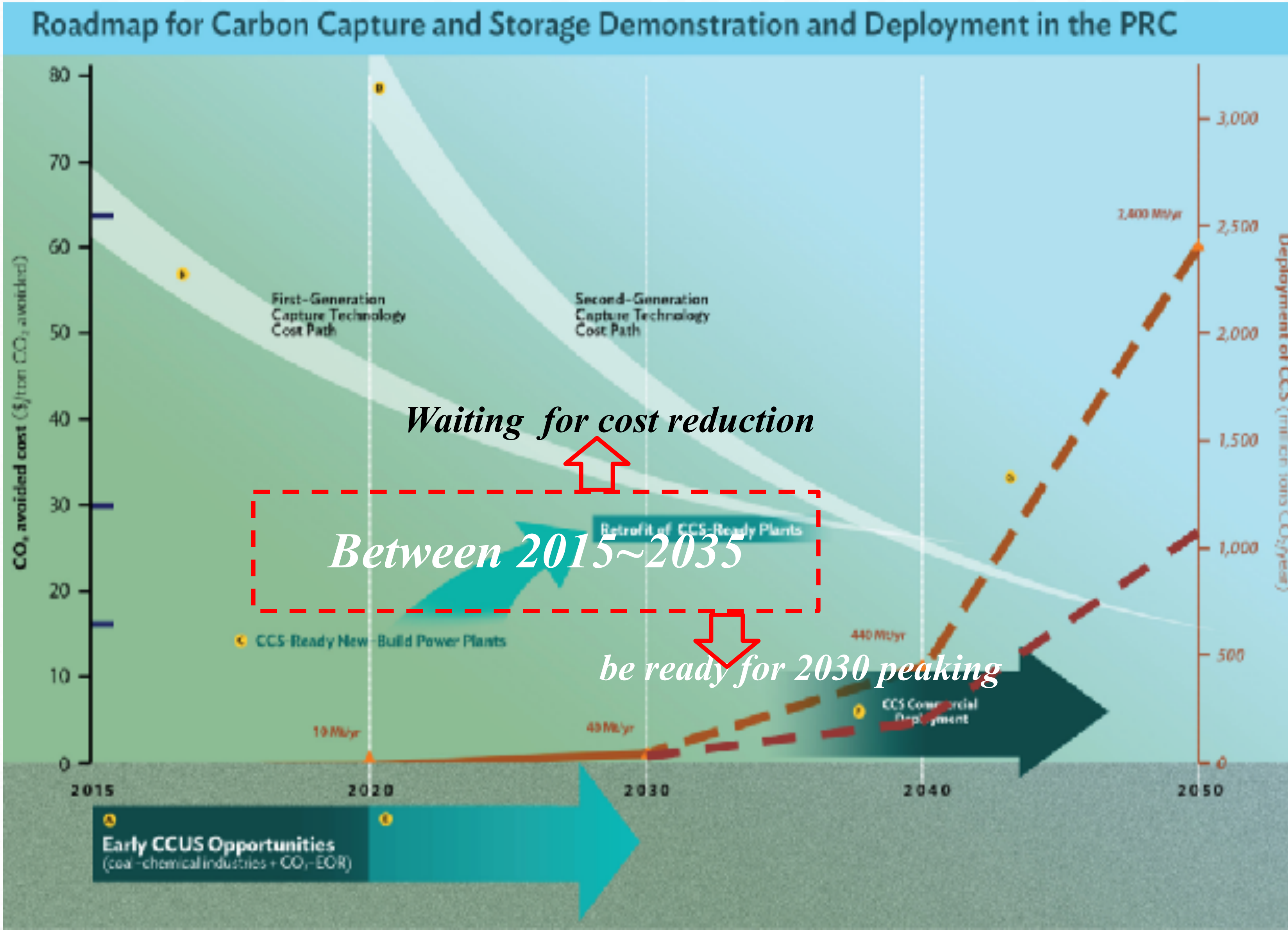


2018 BP Energy Outlook

Concerns of industry



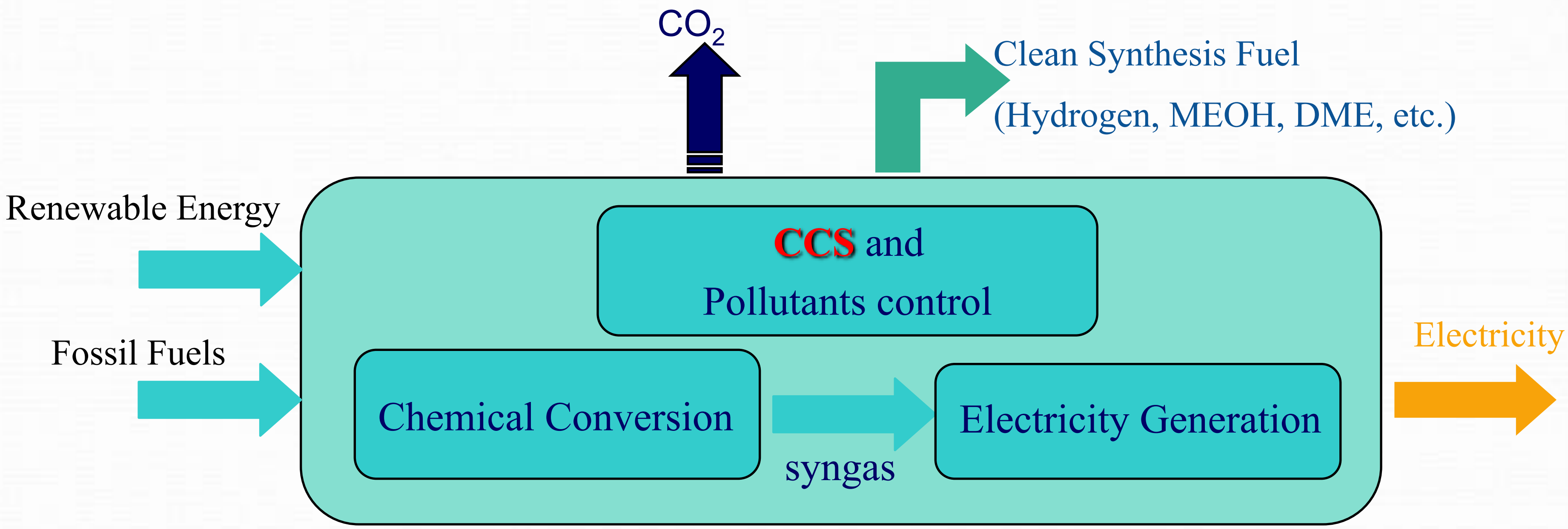
National CCS Roadmap for China
issued by Dec. 2015, COOP21, Paris



Multi-functional energy system (MES)

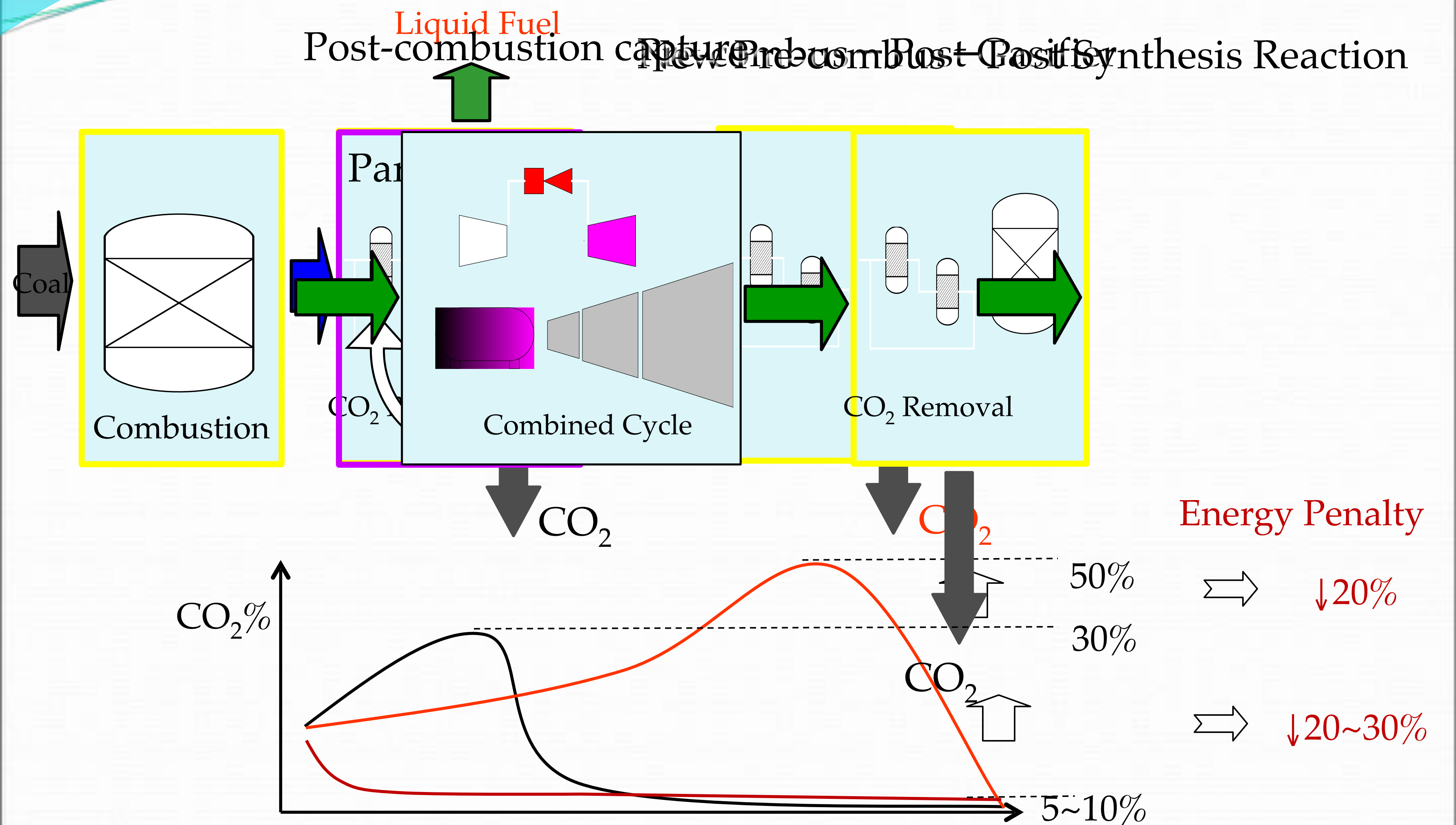
Multiple Inputs (fossil fuels and renewable energy)

Multiple Outputs (Power, Clean Fuel, Chemical products)



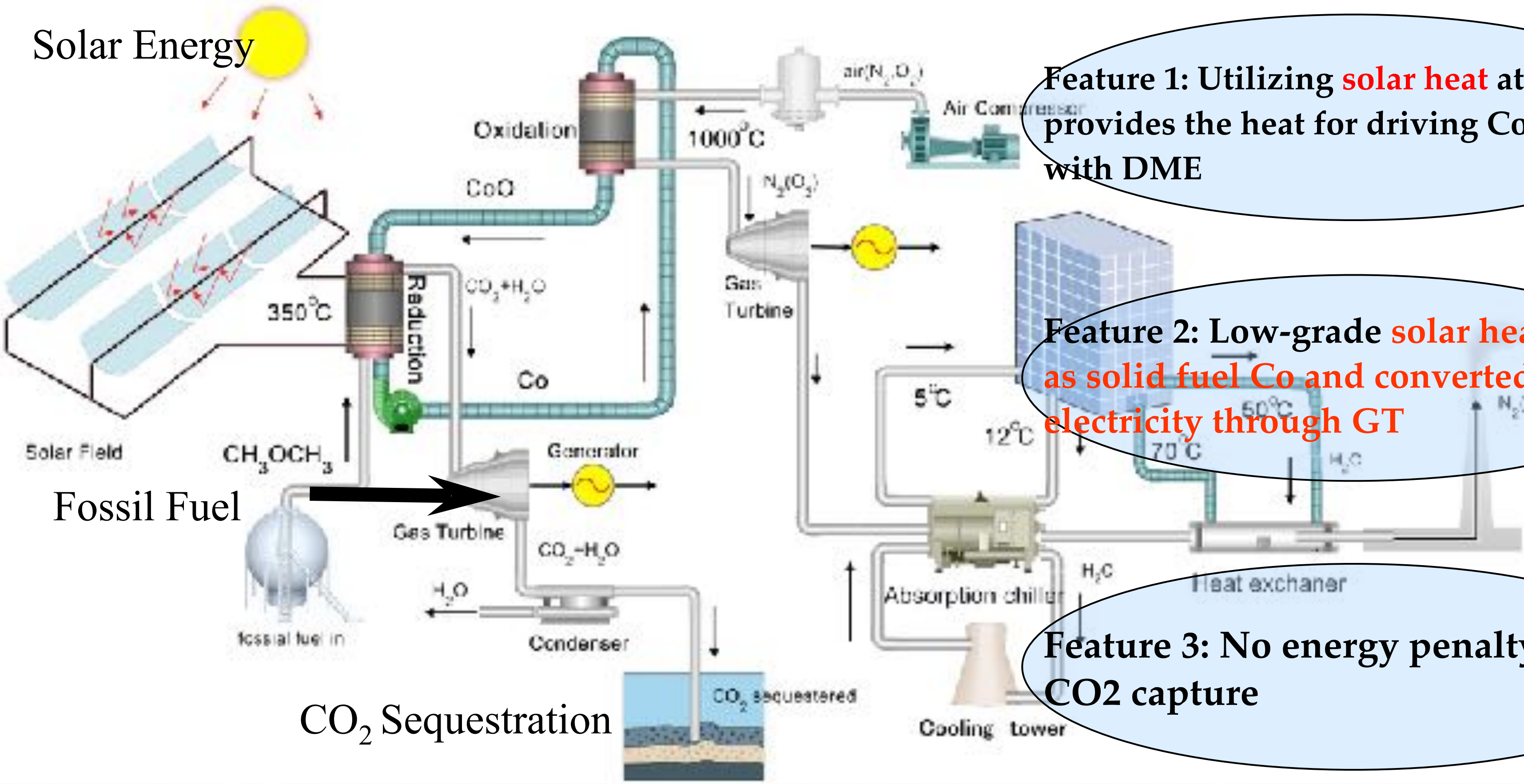
From competitive to compatible!

Coal based Polygeneration system for production of alternative fuel and power with CO_2 recovery



The energy efficiency has been ***increased 3~4 percent points****,*
instead of losing 7~10 percent points.

DME-solar hybridized CCHP using Chemical Looping Combustion



Feature 1: Utilizing solar heat at 450°C provides the heat for driving CoO reduced with DME

Feature 2: Low-grade solar heat is stored as solid fuel Co and converted into electricity through GT

Feature 3: No energy penalty of CO2 capture

Saving energy up to 20% compared with fossil fuel based system

Hints:

1. *The attitude of key stakeholders (industry, public) are **changing**;*
2. ***Hydrogen energy** may provide new opportunity for CCS to catch up;*
3. ***Technology innovation** should be the priority task for CCS in the following decade.*

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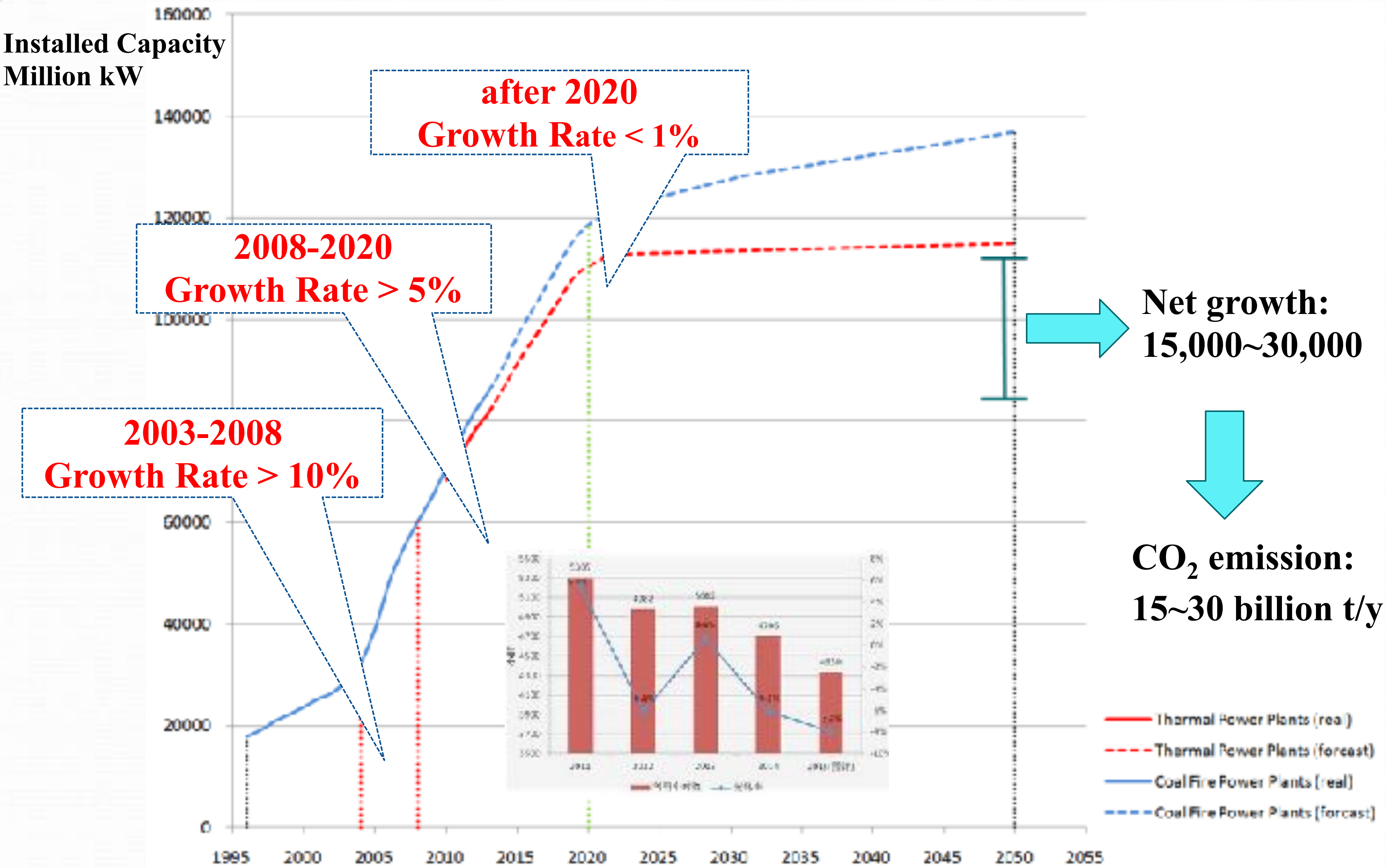
Conclusions

1. *We should understand CCS technology deeper, especially the ongoing successful demonstration project;*

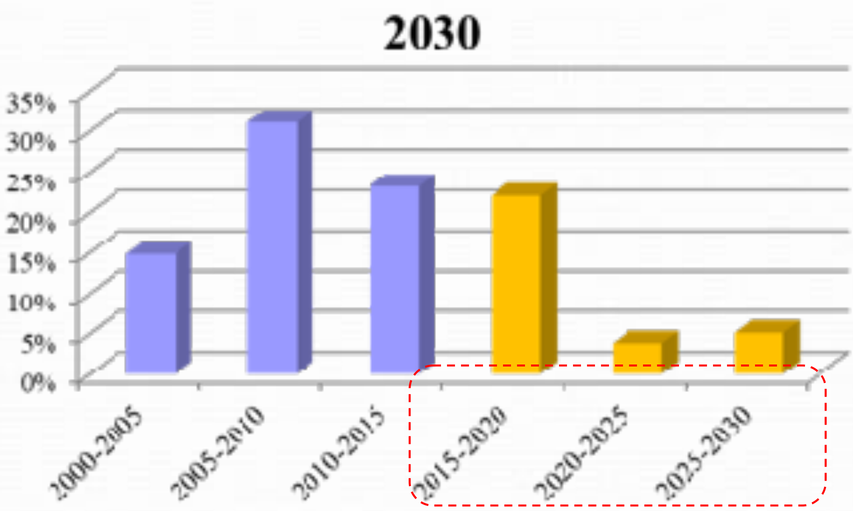
2. *Technology innovation is the key. New generation of CCS technology should solve the problem of energy penalty and cost;*

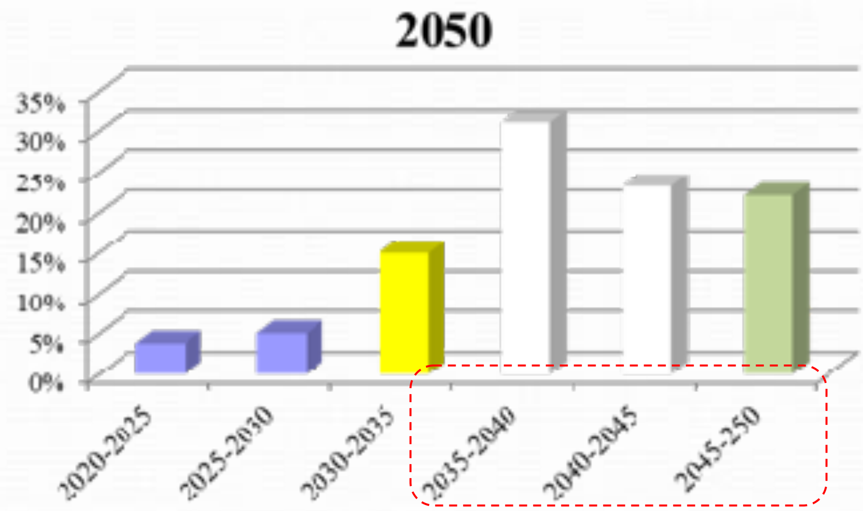
3. *CCS should not only be recognized as the special technology for Climate Change mitigation, but also the breakthrough to build the multi sources energy system integrating fossil fuel and renewable.*

The trend of coal power industry in China



Potential of CCS-Ready before 2050





By 2030:
25% of installed capacity were build between 2015 to 2030

By 2050:
75% of installed capacity were build after 2035

Hint 1: 2015 to 2030 will be the key period for CCS-Ready

Hint 2: by 2035, new generation of CCS tech. should be Ready