CCS Challenges for China

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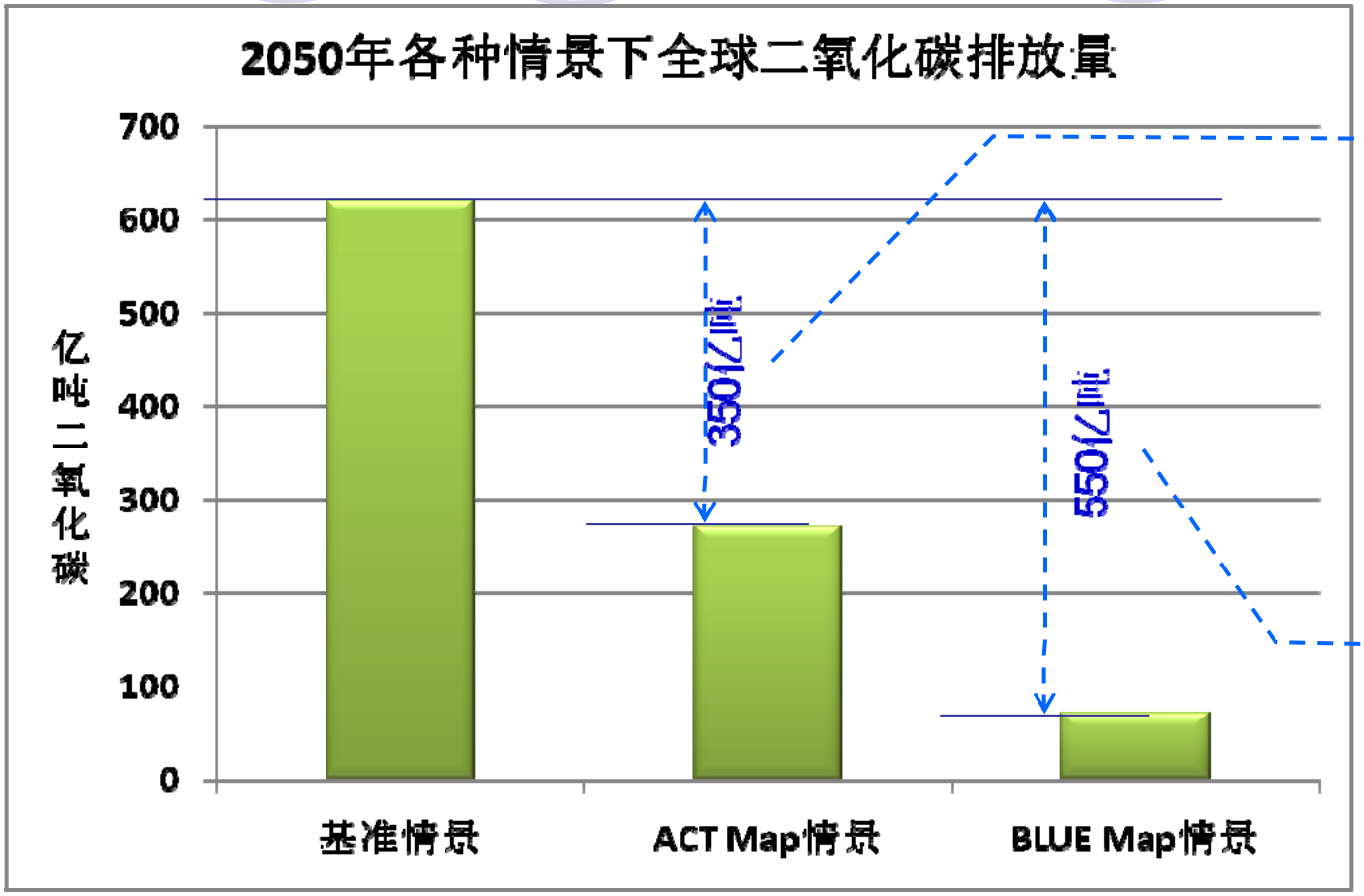
Outline

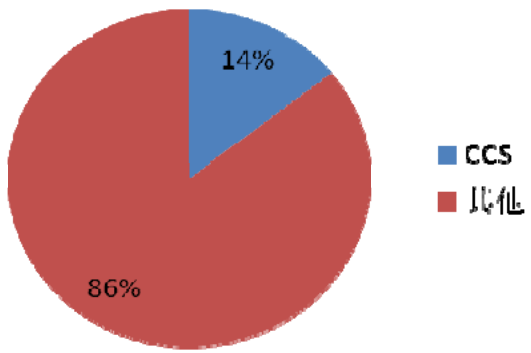
1. Understand CCS
2. The economic and financial issues
3. What kind of CCS is needed by China
4. Recommendations

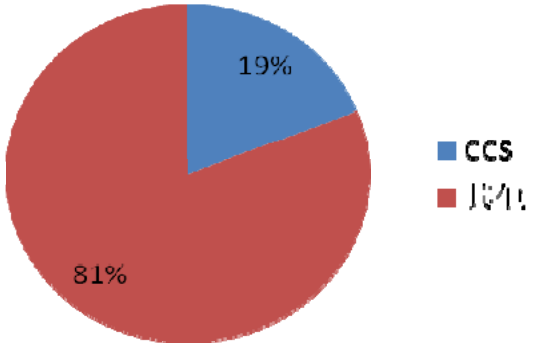
1. Understand CCS

Contribution of CCS in different Scenario



Contribution of CCS





Reference Scenario： without incentive；
ACT Map Scenario： 50 USD/t；
BLUE Map Scenario： 200 USD/t.

IEA. 二氧化碳捕集与封存-碳减排的关键选择. 北京: 中国环境出版社, 2010年.

The Characteristics of Low-Carbon Technologies

CCS	Efficiency and Renewables
Direct CO2 Emission Reduction	**Indirect** CO2 Emission Reduction
Extra Energy **Penalty** and **Cost**	High Cost, but can be reduced in Future
Low-C use of **High-C** Fuel	**Restrict** the use of Fossil Fuel
Limited by **Storage** Conditions	**Hard to meet** the Mitigation Target

As one **Special** Energy&Environment Tech.,

CCS need more **attention** and **deeper understanding**

Argues and Confusions on CCS

CCS is necessary?

Positive	Negative
Reduce total cost for GHG control	Extra energy penalty and cost
Make fossil fuel usable	Limited by storage conditions
Directly reduce the CO_2 emission	Emission reduction is the only profit

Support	Against
IPCC: Important option in the package of emission reduction;	Some Scientists: Unsustainable due to rather high energy penalty&cost
IEA: Reduce the total cost by 70% in specific emission reduction scenario	Green Peace: CCS will keep using fossil fuel, which let more emission

That depends on the urgent of Climate Change problem

Argues and Confusions on CCS

CCS technology is mature?

CCS is technical feasible, but not economic acceptable.

CCUS will be the main direction?

Maybe in the near future. Storage will be the final resort.

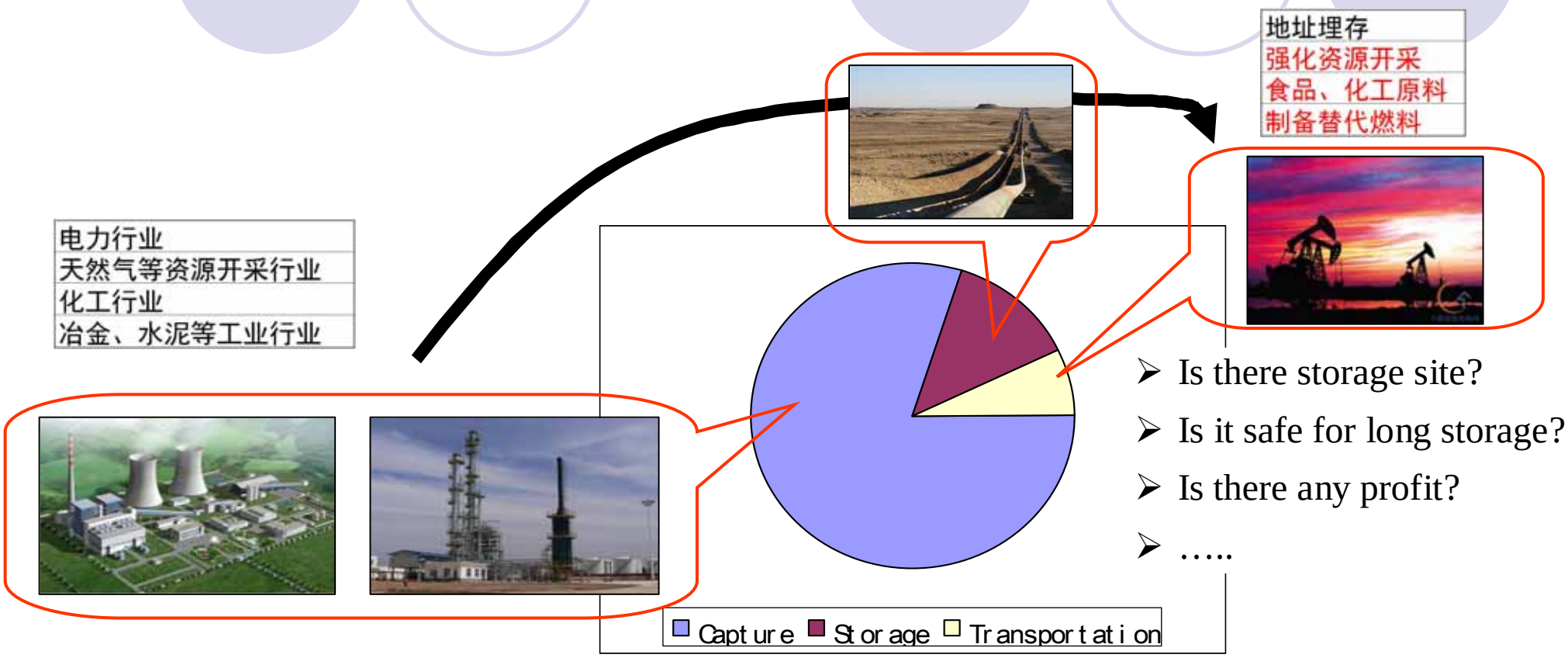
There exists business opportunity in CCS?

Public funding will be the basis for CCS deployment.

CCS will be acceptable to developing countries after cost down

Energy consumption must also be reduced

Complexity of CCS

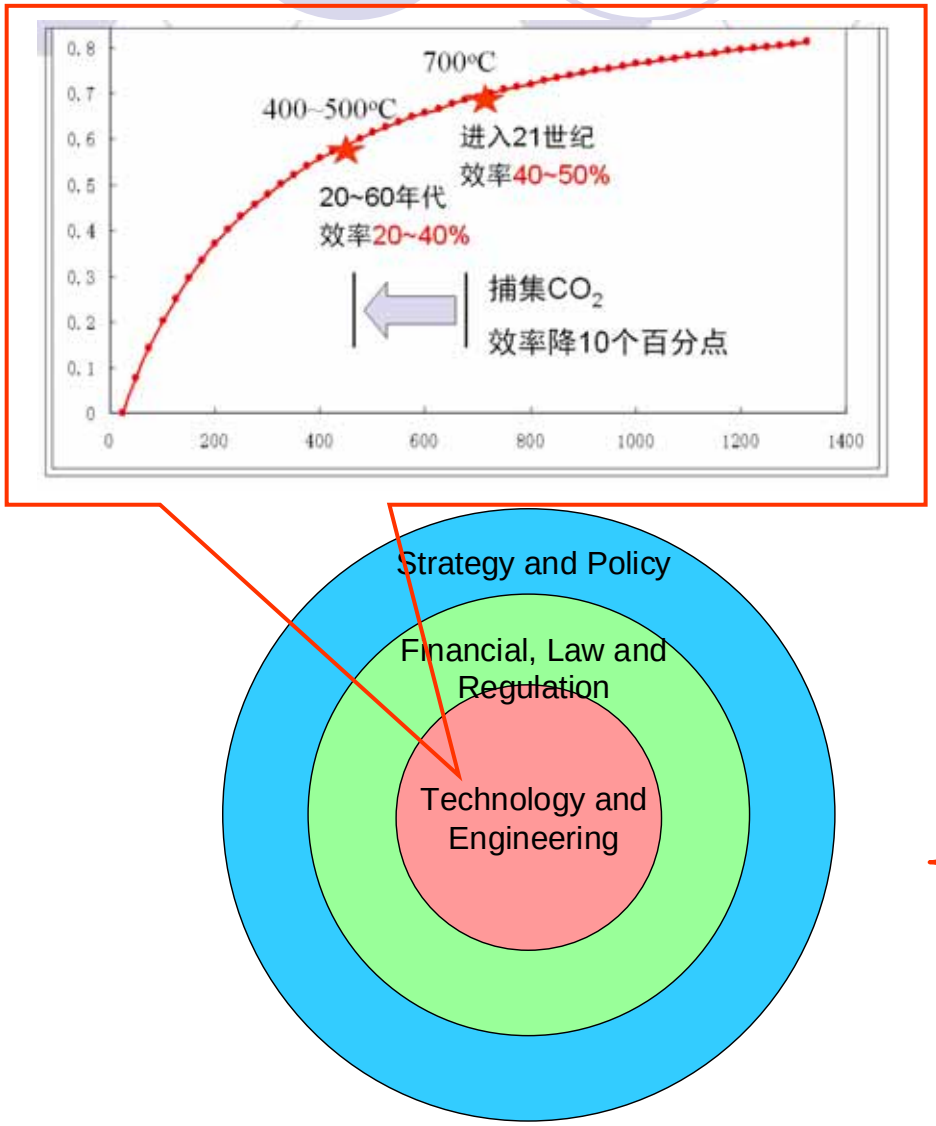


Cost of CCS Chain

- Energy Penalty and Cost is unavoidable?
- When the technology will be mature?
- Is there any edge effect?
- …..

- Is there storage site?
- Is it safe for long storage?
- Is there any profit?
- …..

The core of CCS problem



The efficiency will back to several decades ago, the cost will double

The penalty of **existing CCS** tech. is **unacceptable**

Strategy and Policy	Hard Negation Without Clear strategic positioning
Financial Law and Regulation	Financial： Big Gap, Less Channel Law&Regulation： Without Frame Public Acceptance： Without Deep Understanding International Cooperation： Without Platform
Tech. Innovation	Capture: High Energy Penalty and Cost Transportation: Net Research Storage: Capacity Evaluation, Risk Monitoring and Mitigation
Engineering Practice	Small Scale Pilot and Demo Without full Chain Project

2. The economic and financial issues

Preliminary Economic Analysis

1. Definition of reference case
2. Economic performance
3. Scenario analysis
4. Existing funding resources evaluation
5. Application strategy of existing funding resources

Technical Characteristics of Demo IGCC/CCS

No.	Item	Unit	No CO_2 Capture	60% CO_2 Capture	100% CO_2 Capture
1	Coal type		Shengfu	Shengfu	Shengfu
2	Heat value of coal (LHV)	MJ/kg	22.76	22.76	22.76
3	Coal feed	t/d	3280.8	3235.3	3332.4
4	Plant capacity factor	%	69	69	69
5	Number of operation hour	h/y	6,000	6,000	6,000
6	Gasifier type		TRIP, dry powder feed	TRIP, dry powder feed	TRIP, dry powder feed
7	Gas turbine class		GE, F class	GE, F class	GE, F class
8	HRSG type		3-pressure single reheat	3-pressure single reheat	3-pressure single reheat
9	Gross power capacity	MW	430	430.0	426.3
10	Auxiliary power ratio	%	15.1	25.1	29.0
11	Net power output	MW	365.1	322.0	302.5
12	Net plant efficiency	%	42.3	37.8	34.5
13	CO_2 capture rate	t/h	n.a.	178.9	307.2
14	Mass of captured CO_2	Mt/y	n.a.	1.07	1.84

- ADB Guidelines “Financial Management and Analysis of Projects” (2005) adopted
- A potential demonstration project – Integrated Gasification Combined Cycle (IGCC) power plant (430MW) with three technical schemes: without CCS; 60% CO_2 capture; 100% CO_2 capture
- The return on investment is not regarded as a result from the analysis for gauging the project financial viability, rather it is an assumption
- Upon fixed returns on investments and under other conditions, the required electricity tariff is calculated and considered as the key indicator for CCS project acceptance
- The current tariff for conventional power generation in Tianjin is RMB0.38/kWh. The approved tariff for the first IGCC power plant in China is RMB0.56/kWh, 47% higher

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Economic performance of IGCC/CCS

Investment estimation			
Item	Investment of equipment (M$)		
	IGCC	IGCC+60% capture	IGCC+100% capture
Total static investment	570.5	635.5	676.1
Unit investment $/kW	**1563**	**1974**	**2235**
Fixed charge factor (%)	12	12	12
Total investment	624.7	695.9	740.3
O&M cost estimation			
O&M cost (M$/y)	25.0	27.8	29.6
Fuel cost ($/t)	94.1		
Operating hours (h/y)	6000		
COE ($/MWh)	82.4	94.1	113.2
COE (¥ /kWh)	**0.56**	**0.64**	**0.77**
Cost of CO_2 avoided ($/t-$CO_2$)		**26.1**	**37.3**

Additional investment cost with CO_2 capture: about 25% in 60% capture
about 40% in 100% capture

COE increment: about 15% in 60% capture
about 37% in 100% capture

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Scenarios & Results (60% vs. 100%)

Scenario / Option	Indicator	Unit	60% CO_2 Capture	100% CO_2 Capture
No government incentive	Expected tariff	Y/MWh	640.6	773.4
	% as the benchmark tariff	%	114.2%	137.9%
At the current IGCC tariff, sell CO_2 for EOR	CO_2 price for EOR	$/t	0	7.4
At the current IGCC tariff, sell CO2 through CDM	CO_2 price for CDM	$/t	18.7	27.2
At the current IGCC tariff, subsidize the capital cost	Value for subsidy	$ mil	198.8	498.0
At the current IGCC tariff, subsidize the coal cost	Value for subsidy	$ mil	148.33	371.41
Subsidize only the additional capital cost caused by CCS facilities	Expected tariff	Y/MWh	609.18	727.76
	% as the benchmark tariff	%	108.6%	129.8%
Subsidize only the additional capital cost, and income tax exempted	Expected tariff	Y/MWh	586.33	704.24
	% as the benchmark tariff	%	104.6%	125.6%
Subsidize only the additional capital cost, and CO_2 price at $20/t.	Expected tariff	Y/MWh	500.91	548.17
	% as the benchmark tariff	%	89.3%	97.7%

If financing comes from *20% owners' equity financing, 30% international financing and 50% local bank loan*, CO_2 price and expected tariff are indicated

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Available Funds of CCS Demo

Fund Name	Global Environment Facility	ADB CCS Fund	Global CCS Institute
Prioritized area	Mitigation and adaptation	Mitigation	Mitigation
Target country	Developing countries and countries with economies in transition	Developing countries (China, India, Indonesia and Vietnam)	Some developing countries in Asia, including China
Fund Scale	**> USD 10 bn**	**USD 17 mn (AUD 21.5 mn)**	**USD 42 mn annually**
Average Financing Amount (Mn USD)	**About 4**	**< 5**	**4.2**
Project Example (Mn USD)	**Brazil: USD 2.65 million** Renewable CO_2 Capture and Storage (CCS) from Sugar Fermentation Industry in Sao Paulo State.	**China: USD 5 million** Integrated Gasification Combined Cycle Power plant Financing Project (Climate Change Fund)	The Institute began to finance CCS projects recently, so there is no typical project funded.
Application Scale (Mn USD)	**4**	**10**	**4.2**

Three funds identified, total volume: > USD 10 Mn

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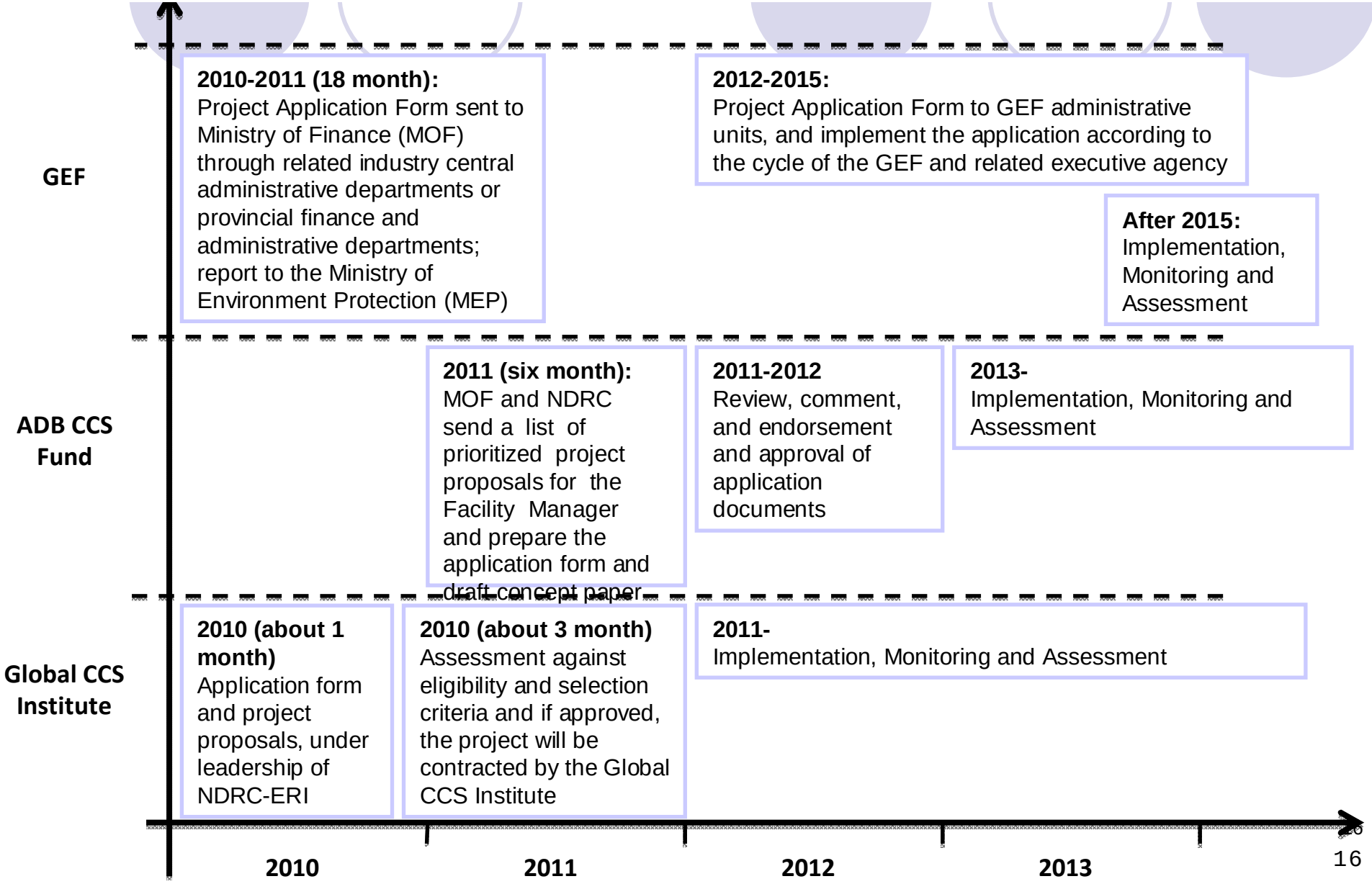
Application Strategy of Existing Funding Resources



Key Findings

The existing fund resources including GEF, ADB and GCCSI can only meeting the ***5~10% of funding gap*** for demo.

Look for new funds, e.g. Copenhagen Green Climate Fund which shall be provided to developing countries for, inter alia, development of low-carbon technologies. For ***2010 to 2012, USD 30 bn is committed***; by ***2020***, this amount will be raised to ***USD 100 bn/y***.

Cost Reduction Potential of CCS Technology

1. The main factors influencing cost reduction
2. Localization issues
3. Potential of cost reduction
4. Specific CCS target for developing countries

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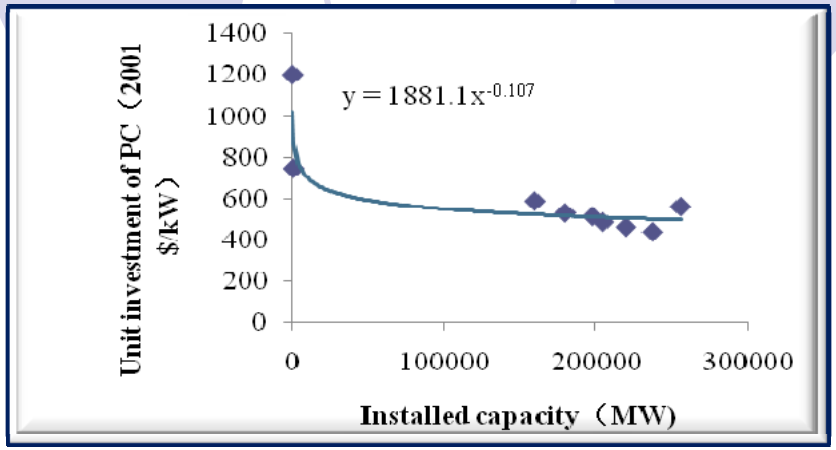
Learning Effect of IGCC/CCS

Empirical observation :
Costs tend to decline with cumulative production



Investment reduction trends of coal pulverized (PC) technology in China

Methodology: Learning Curve

$$C_{cum} = C_0 C^{b}_{um}, PR = 2^{b}$$

Learning through

Initial cost → **Localization** / **Capacity increment** / **Efficiency upgrade** → **Cost after learning**

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Localization of IGCC with CCS

Current localization status of key equipments in IGCC

Unit	GT sets (GE PG5361)	GT sets (9FA)	ASU	Coal slurry gasification	Coal pulverized gasification	CO_2 capture units
Current Localization	Almost localized completely	Auxiliary systems localized totally	R&D, design & manufacture independently	Some individual valves need import	Water-wall of gasifier imported	Imported totally
Cost Reduction	**45%–55%**	**20%**	**50%–60%**	**40%–50%**	**25%**	**5–10%**
Data source	**These data from some related companies and institutes has not been published.*					

Analysis of localization potential of main equipments

	Current localization	Mature level	R&D barriers	Localization potential
AUS	√√√√	√√√	√	**Low**
Coal slurry gasification	√√√	√√	√	**Mid**
Coal pulverized gasification	√√	√√	√	**High**
Gas turbine	√	√√	√√	**High**
CO_2 separation unit	√	√√	√	**High**

Investment reduction of Tianjin IGCC demo with localization

	IGCC		IGCC+CCS	
	Investment decline (￥/kW)	Proportion %	Investment decline(￥/kW)	%
ASU	86	4%	102	3%
Coal Gasification unit	1107	44%	1312	41%
Gas turbine	1330	**52%**	1576	**49%**
CO_2 separation unit	-	-	232	7%
Single project related to site	0	-	0	-
Total reduction	**2523**	100%	**3222**	100%

IGCC: investment maybe reduce by **24%** after **localization completely**

IGCC/CCS: reduce by **26%** after **localization completely**

Gas turbine reveals the biggest potential for localization

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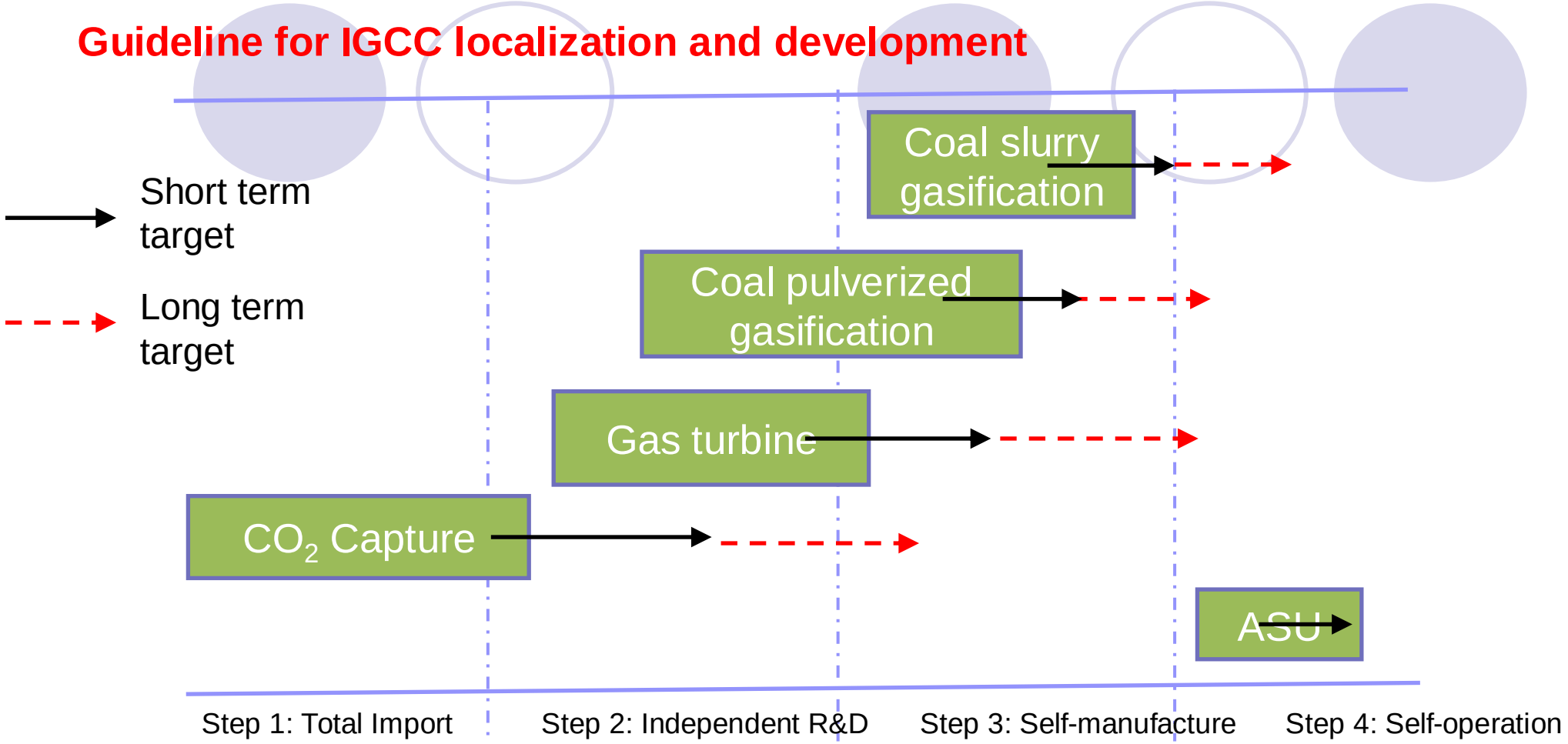
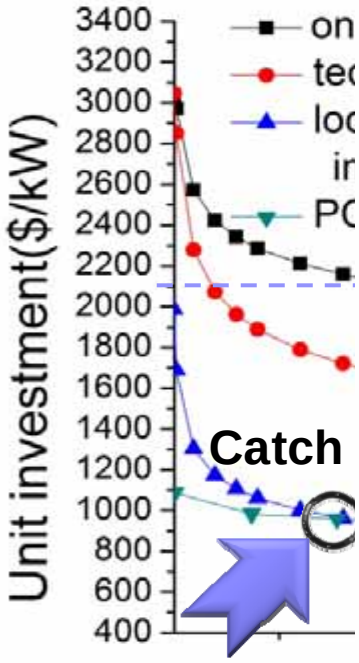
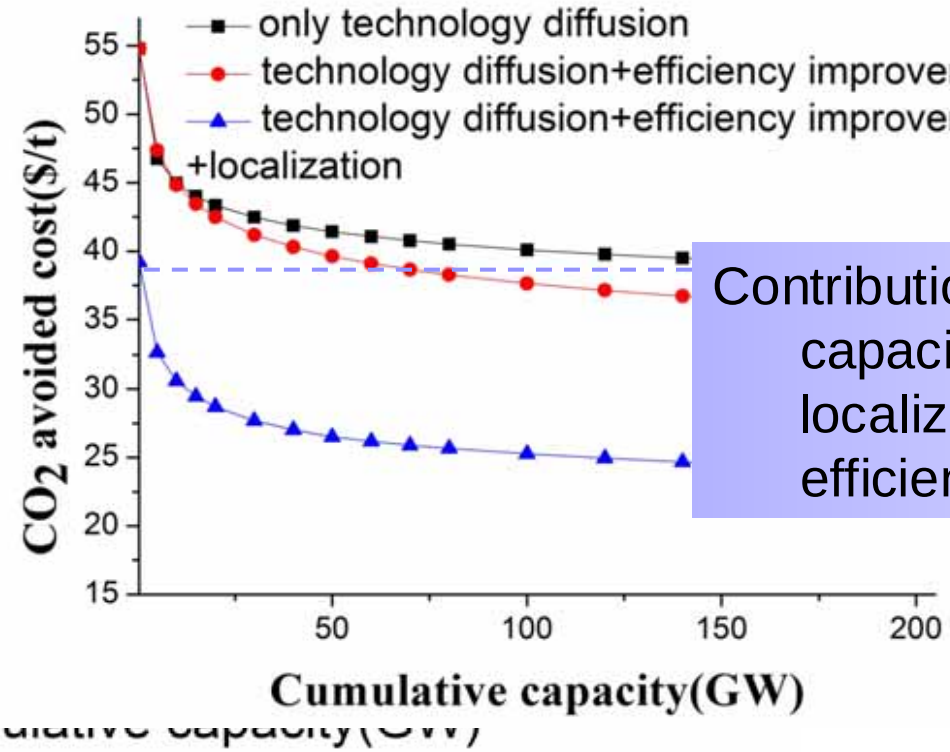
Guideline for IGCC localization and development



- Step 1: Concentrate the equipment purchase to get the license of the patents
- Step 2: Support of national scientific/tech project for the technology research
- Step 3: Government encouragement policy for the purchase of the domestic equipment preferentially

Cost Reduction Potential of IGCC/CCS





Contribution effects:

- capacity increment: 40~50%
- localization: 15~35%
- efficiency upgrade: 10~20%

IGCC/CCS can be economically competitive with PC/CCS

Key Findings

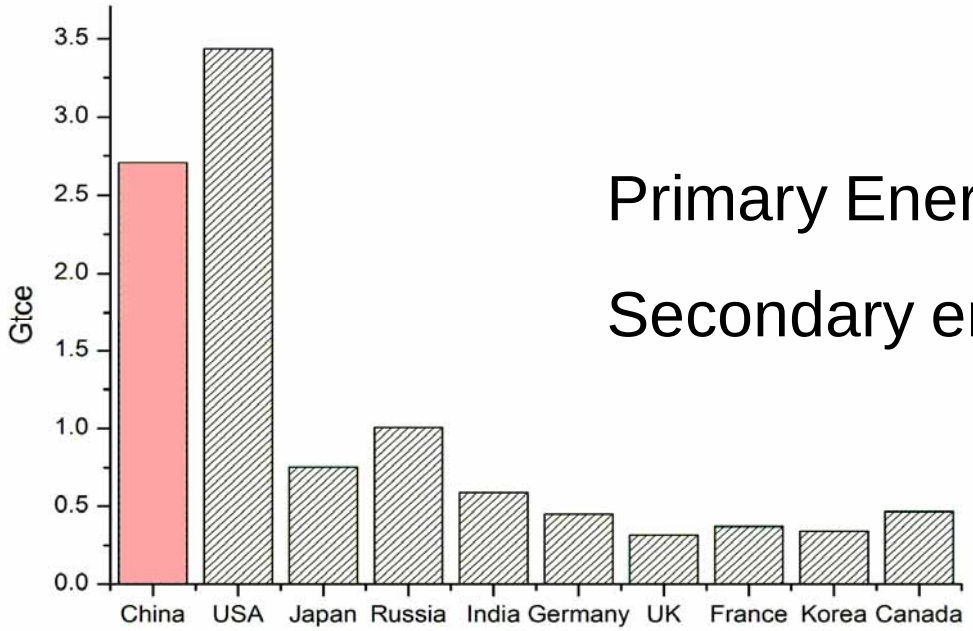
The *learning effect and localization* are the key factors for the cost reduction of IGCC/CCS, which may reduce the CO_2 avoided cost from the current 38$/t to 20~25$/t in China in the future.

IGCC/CCS (when cumulative capacity reaches *40GW*) *can be competitive with PC/CCS*; the investment of IGCC/CCS in China may drop from current 2100 $/kW to around 800 $/kW and the COE can also decline from the current 0.11 $/kWh down to 0.06 $/kWh.

With lower energy penalty and bigger potential for efficiency upgrade compared to that of PC/CCS, *IGCC/CCS may save billion tons of coal*, which will promote IGCC/CCS become the dominating CCS technology of China in future.

3. What Kind of CCS is Needed by China

Huge amount of energy consumption but with low efficiency

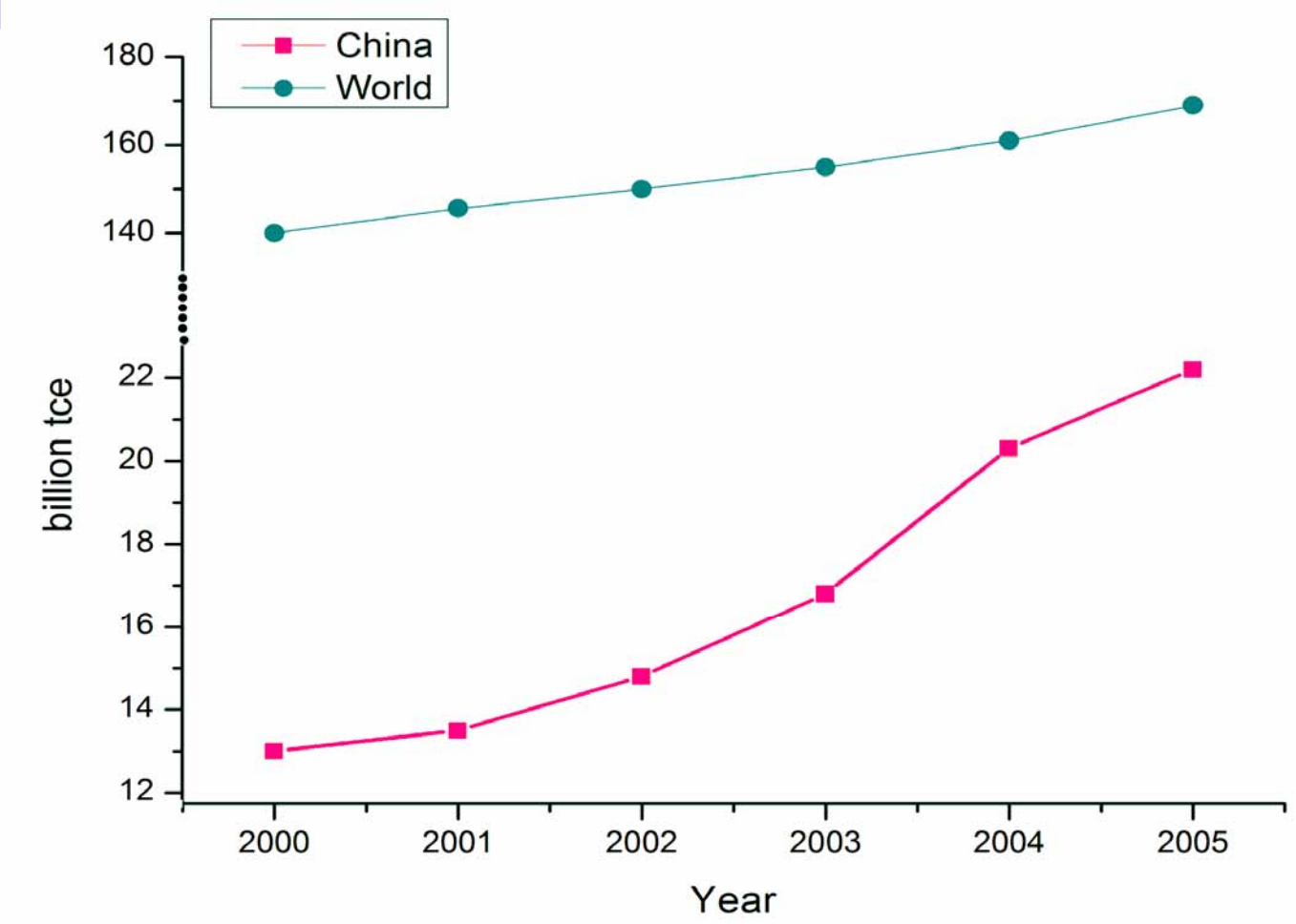


Primary Energy Consumption in 2007

Secondary energy consumer

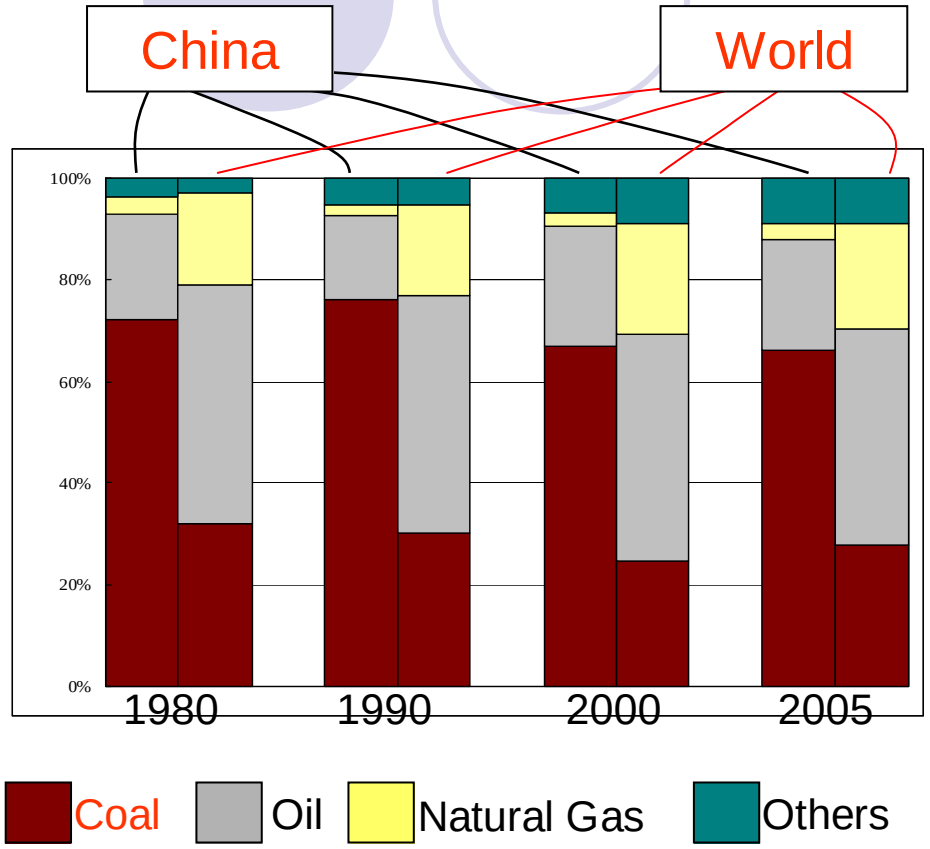
Energy Consumption	year of 2000		
	China	West Countries	Gap
for Electricity Generation (kg ce/kWh)	392	316	*24%*
for Steel Production (kg ce/t)	781	646	*21%*
for Concrete Production (kg ce/t)	181	126	*44%*
for Ethene Production (kg ce/t)	1212	714	*70%*
for Vehicle Transportation (Litre oe/t.mile)	7.6	3.4	*124%*

Rapid Growth of Energy Consumption in China

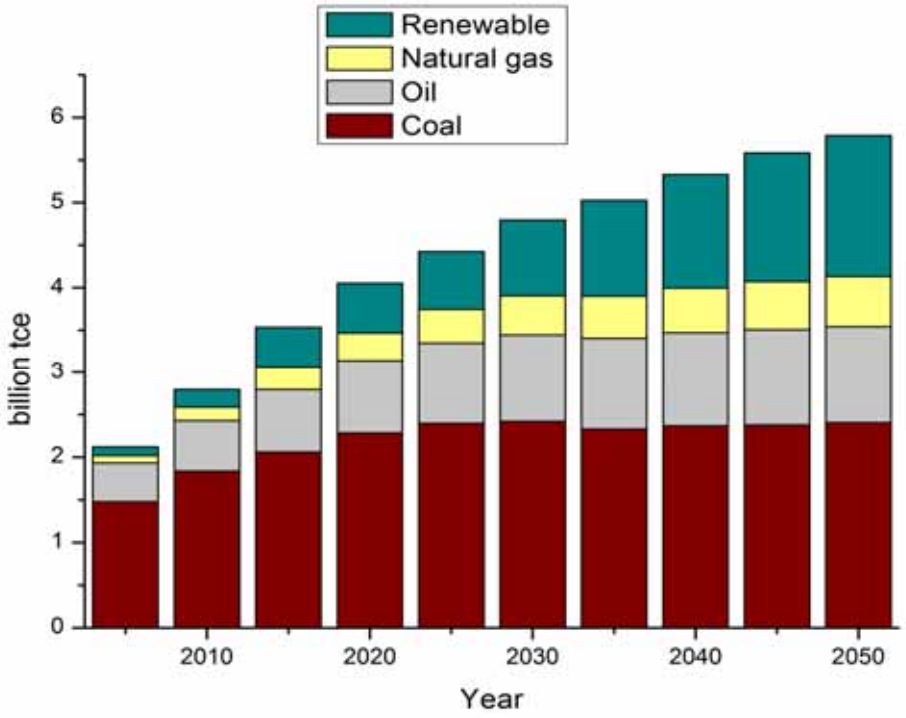


Much faster growth than the average rate of world

Heavy Relying on Coal in a long term



last for a long future



Role of CCS in possible scenario

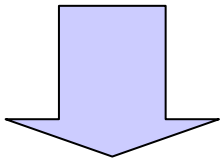
11~13 billions tons/y of CO2 emission in 2050

5~7 billions increment compared to the present

Fuel switch and Efficiency improvement

may contribute 2~3 billions reduction

means *3~4 billions* increment compared to the present



CCS will be necessary for China

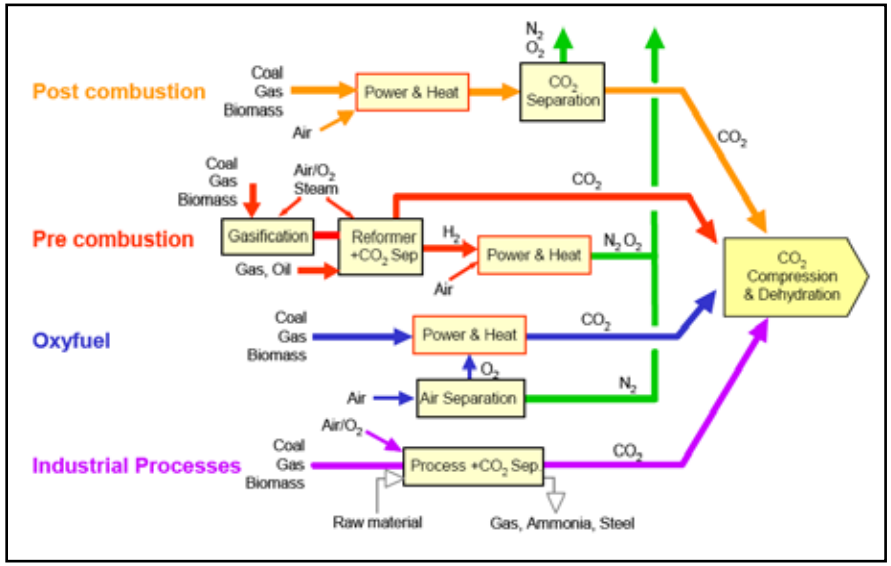
Existing CCS technology

Unacceptable to Sustainable Development China

Existing CCS:

Energy Penalty: 7-15 percent points

Cost: 30-60 USD/tone



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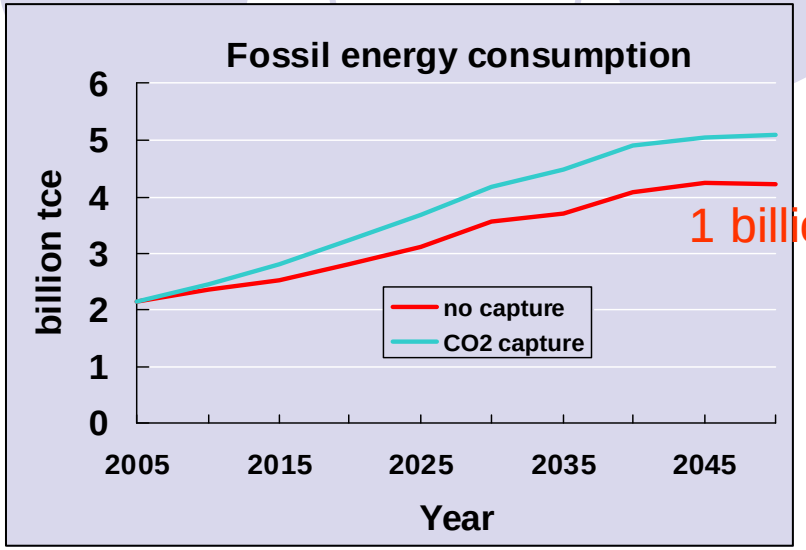
Special Issue of China:

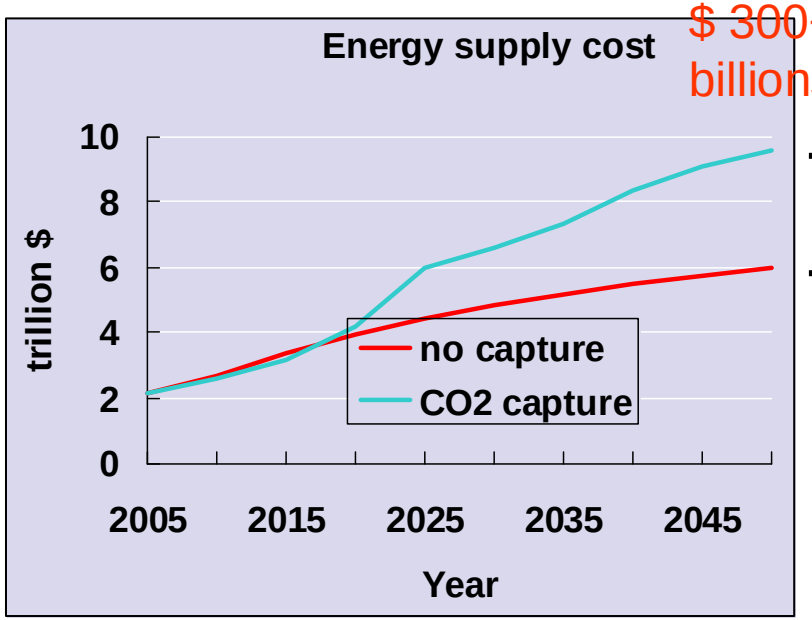
Heavily relying on coal

Huge energy consumption

Resource deficiency



1 billion tce



$ 300~400 billions

Some Thinking

- CCS情景、政策层面与CCS技术层面应紧密融合，而不是相互脱节；

  The Strategy, Policy, Financial and Technology should be integrated and coordinated；

- 国际上现有的CCS技术不符合我国高碳能源低碳技术要求，需要适合我国的革新型CCS技术，而不是老技术解决复杂新问题；

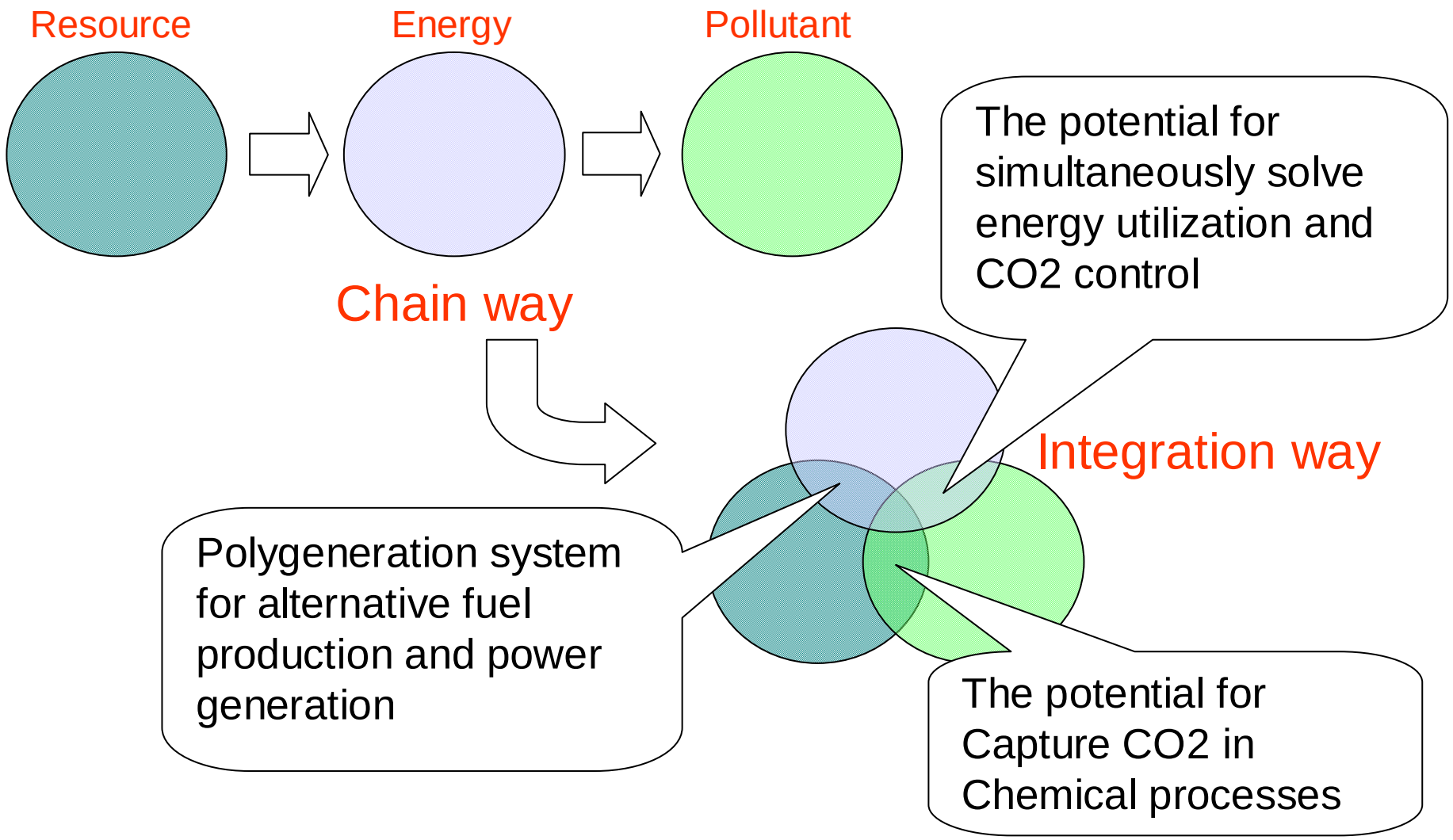
  The existing CCS technologies could not meeting the requirements of China, we need revolutionary CCS technology suitable for China;

- 关注低能耗CCS技术，而不是过于强调零排放。

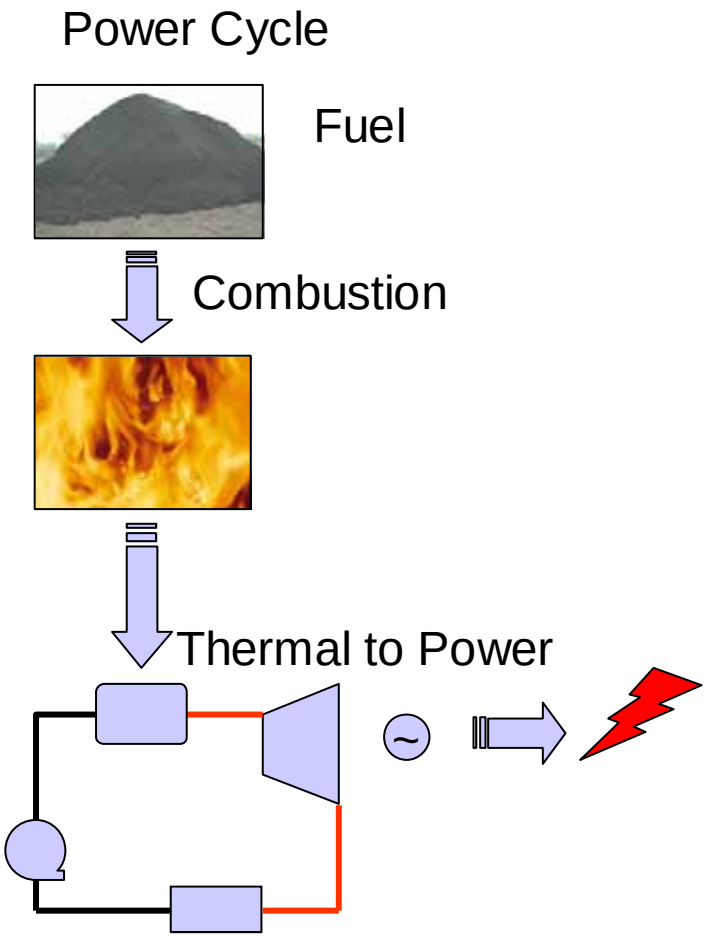
  Focusing on CCS technology with low energy consumption, instead of Zero Emission

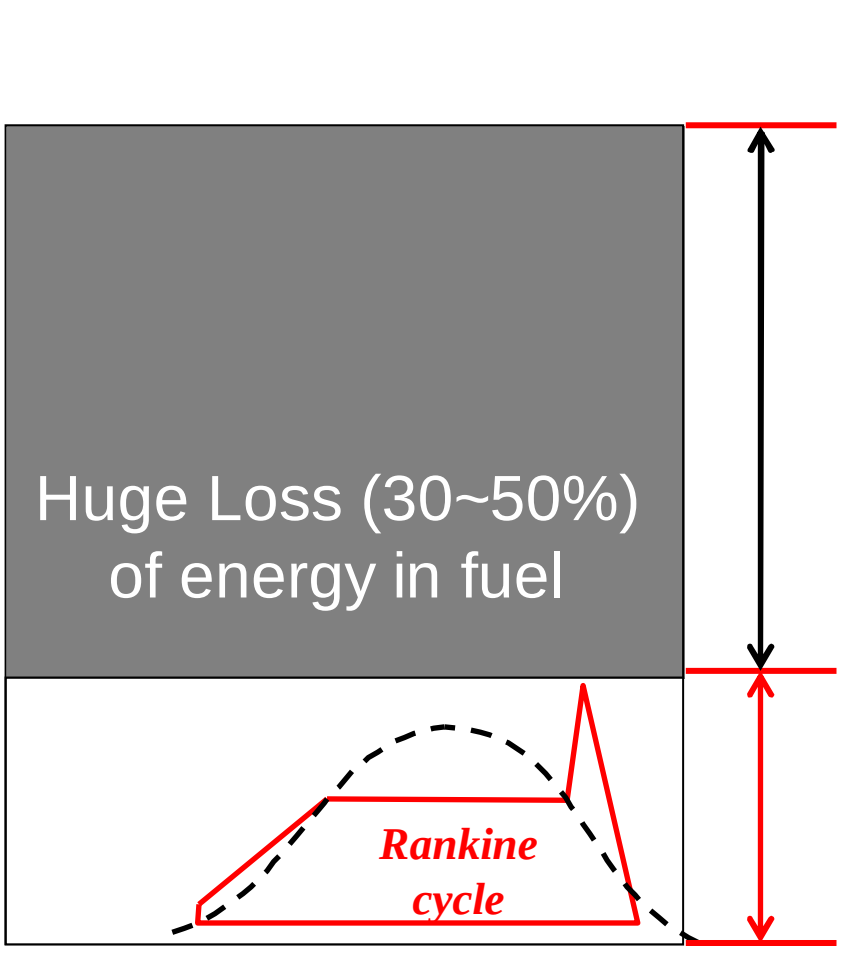
Revolutionary approach for CO2 control:

Integration of Resource, Energy and Environmental



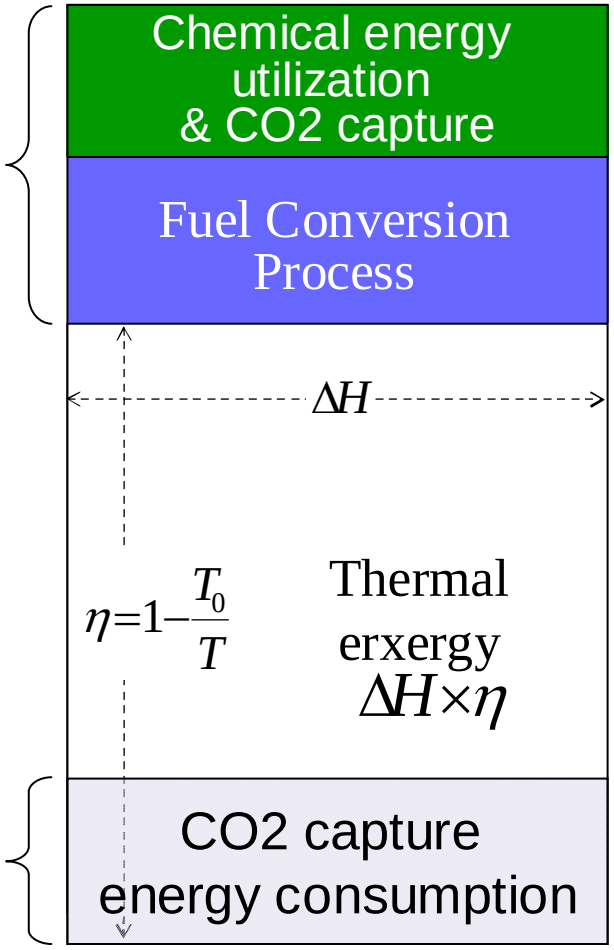
The problem of traditional Power Cycle





Integrating Energy Utilization and CO_2 capture:

Largest exergy destruction



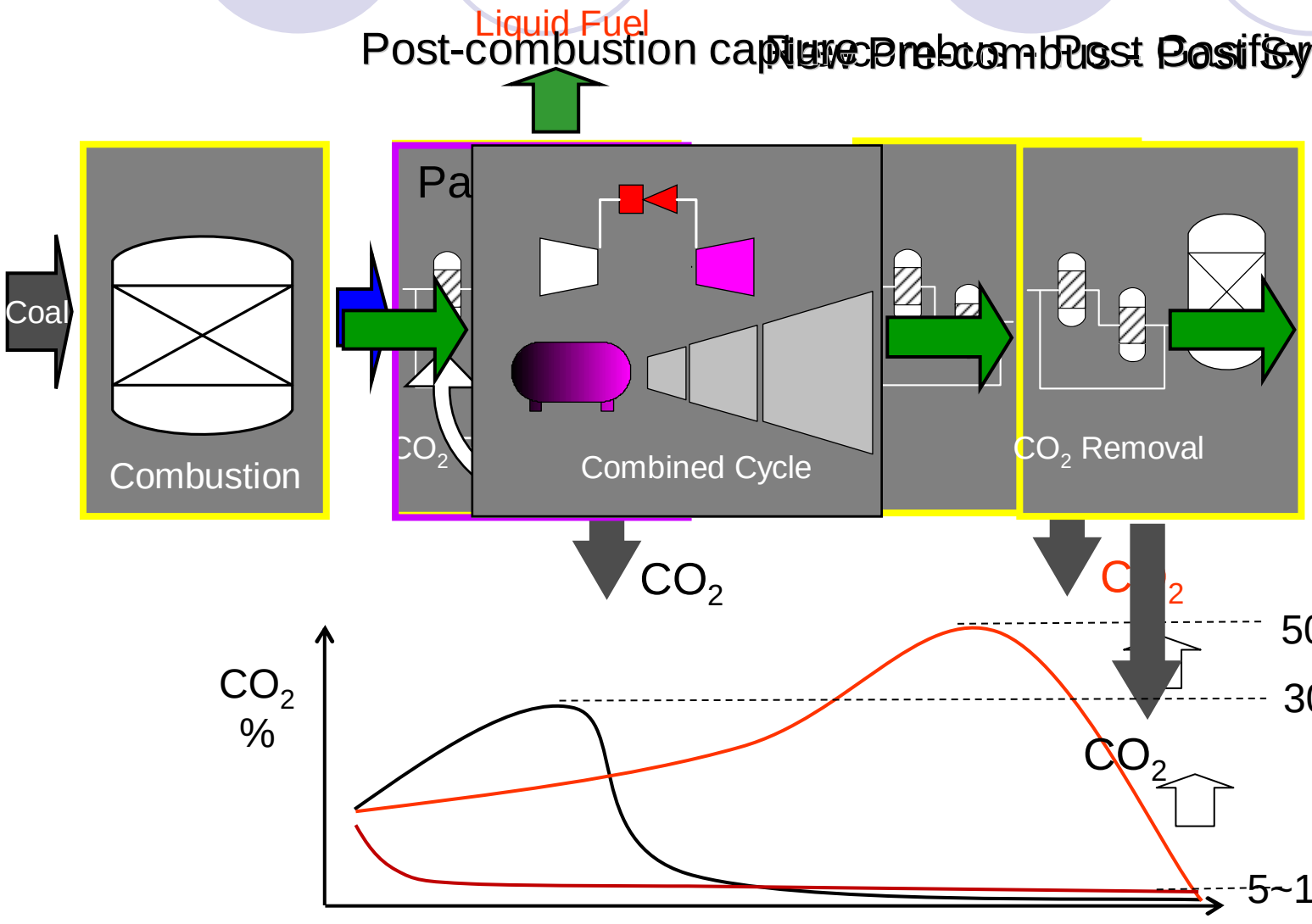
energy penalty

Source Control Technology:

Capture CO2 from the source using the potential of chemical energy utilization

Innovative energy system simultaneously solving efficient energy utilization & CO2 capture

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

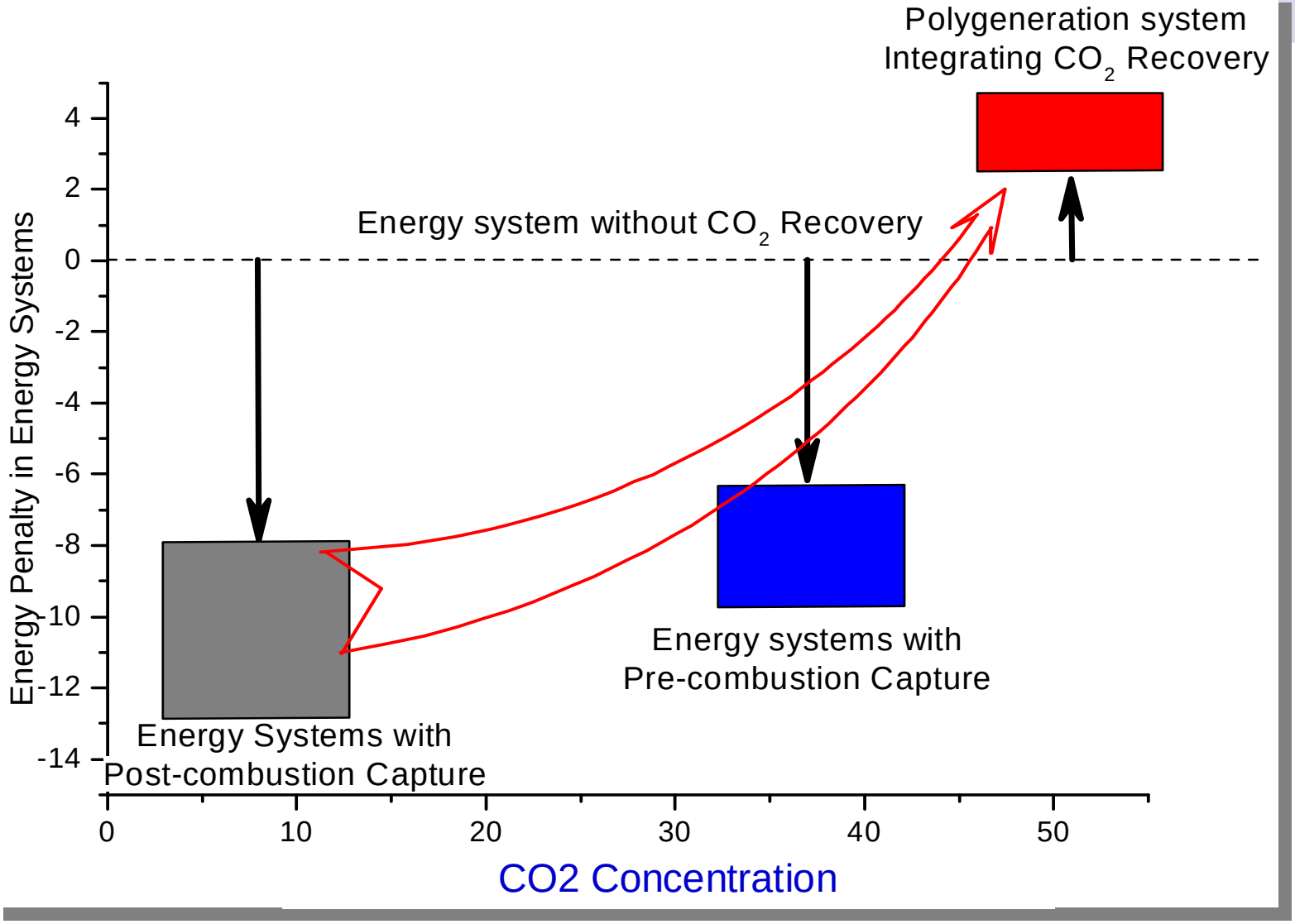


Energy Penalty

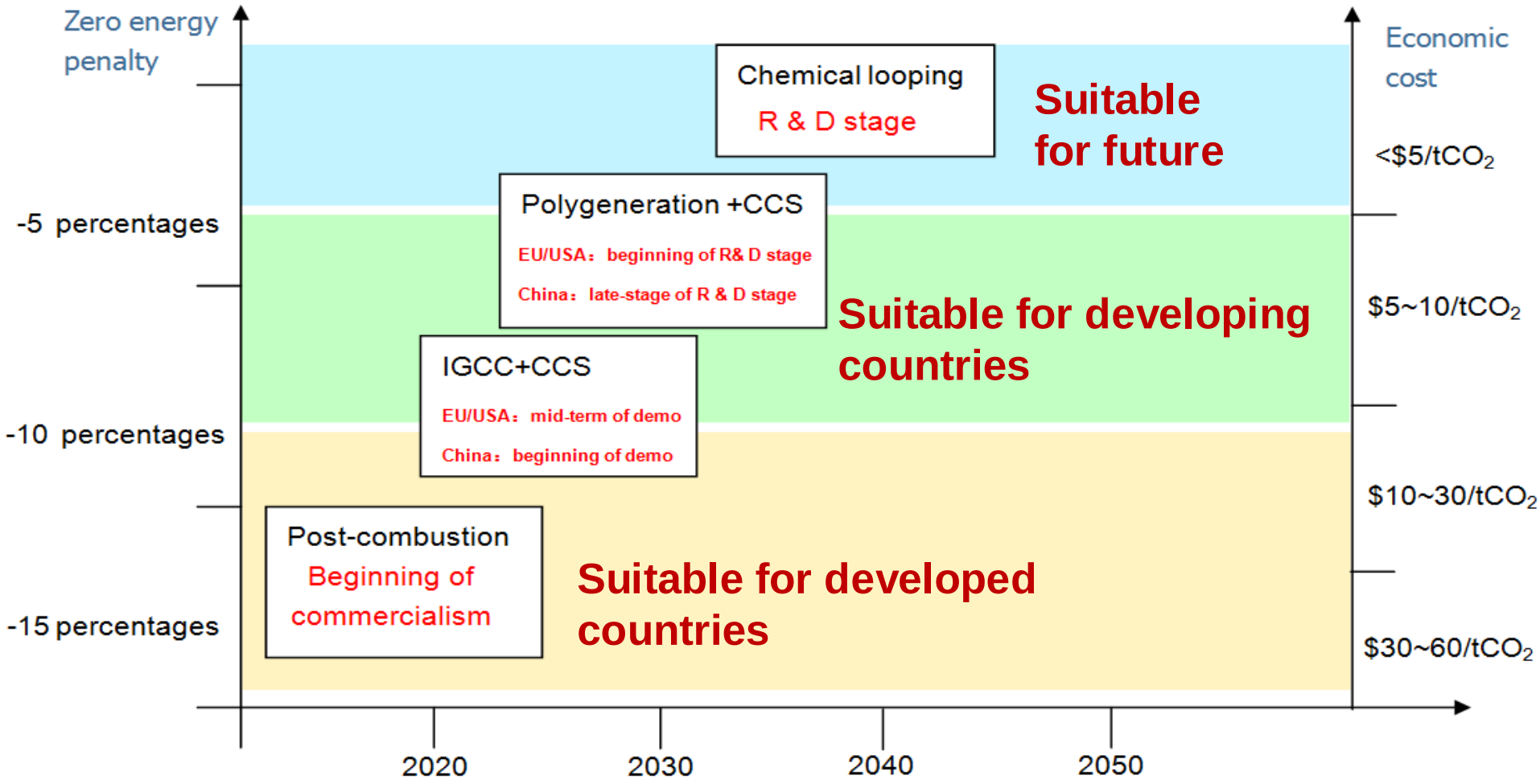
⇨ ↓20%

⇨ ↓20~30%

Breakthrough in CCS technology



Specific CCS target for China



Key Findings

we need ***technical route***, and long-term strategy

The government should coordinate the key stakeholders, define long-term strategy, and clarify the role of CCS

we need CCS technology ***really suitable for China***

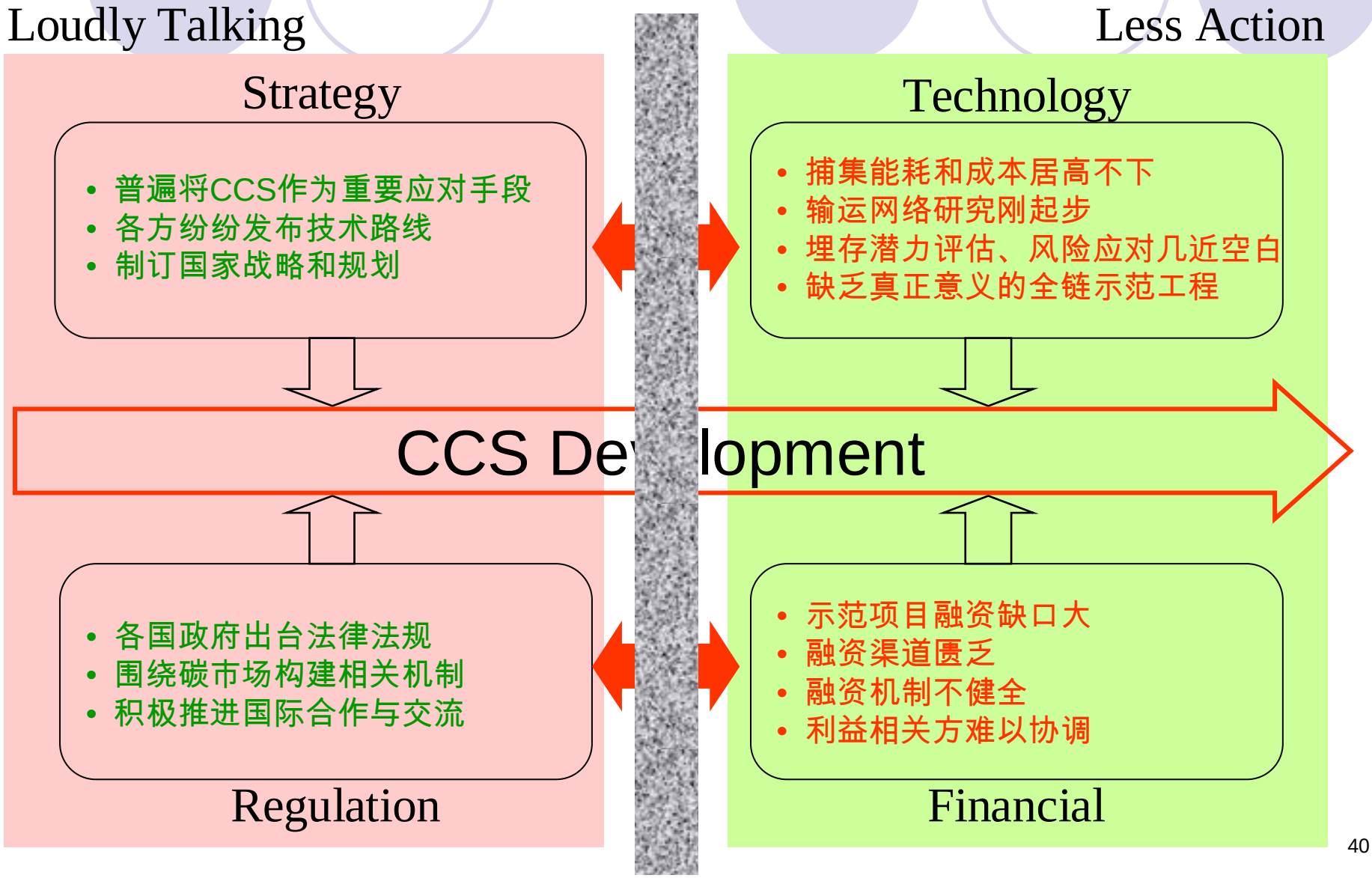
We are still following the existing technology in demo project

we need ***original*** fundamental research and ***technology***

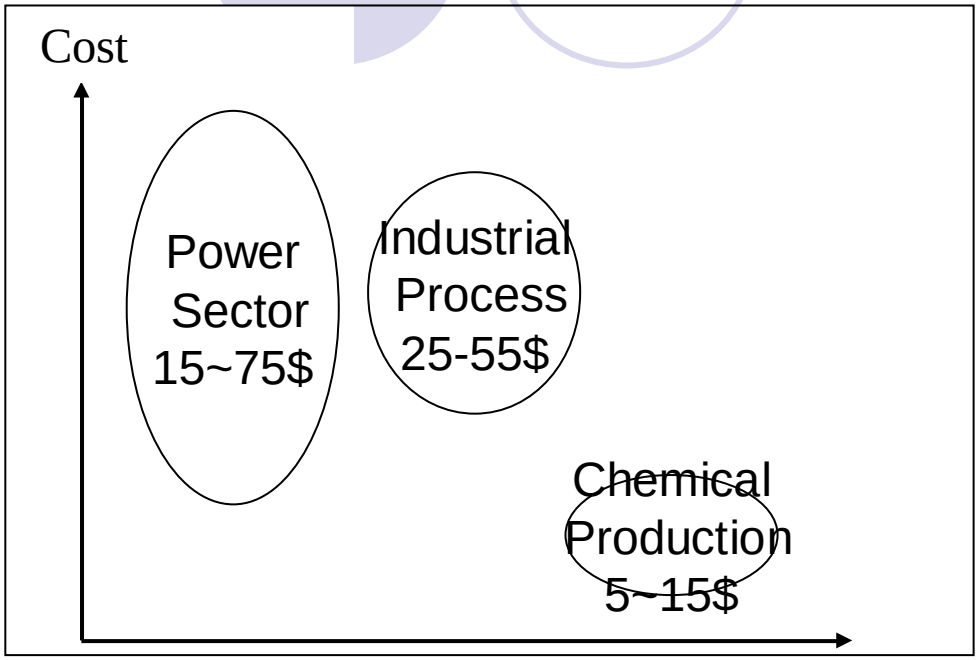
Making research program, and focusing on promising direction

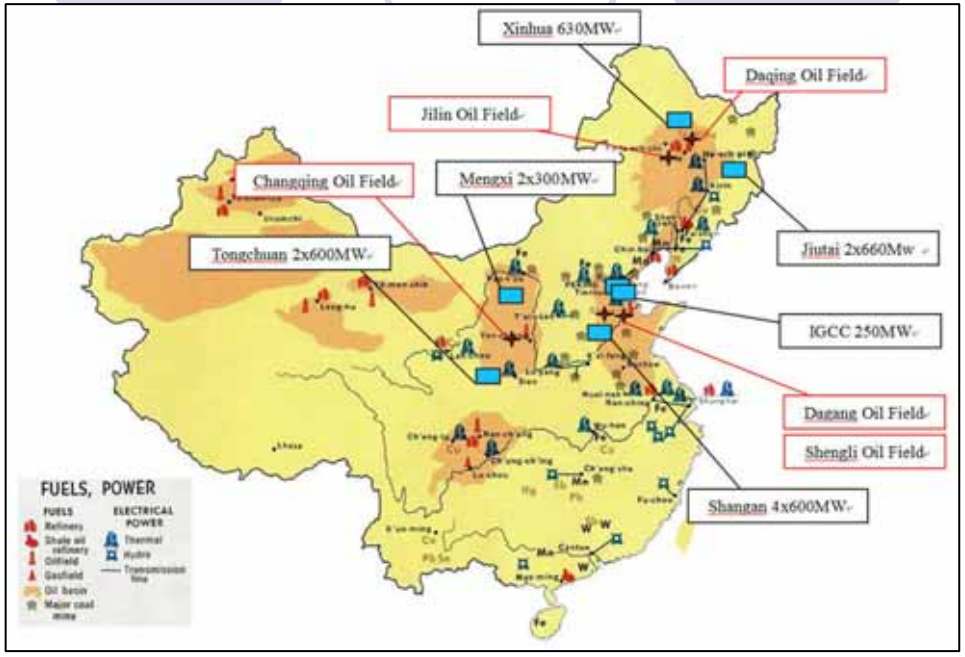
4. Recommendations

The coordination between Different Levels



Identify the early opportunity for CCS demo



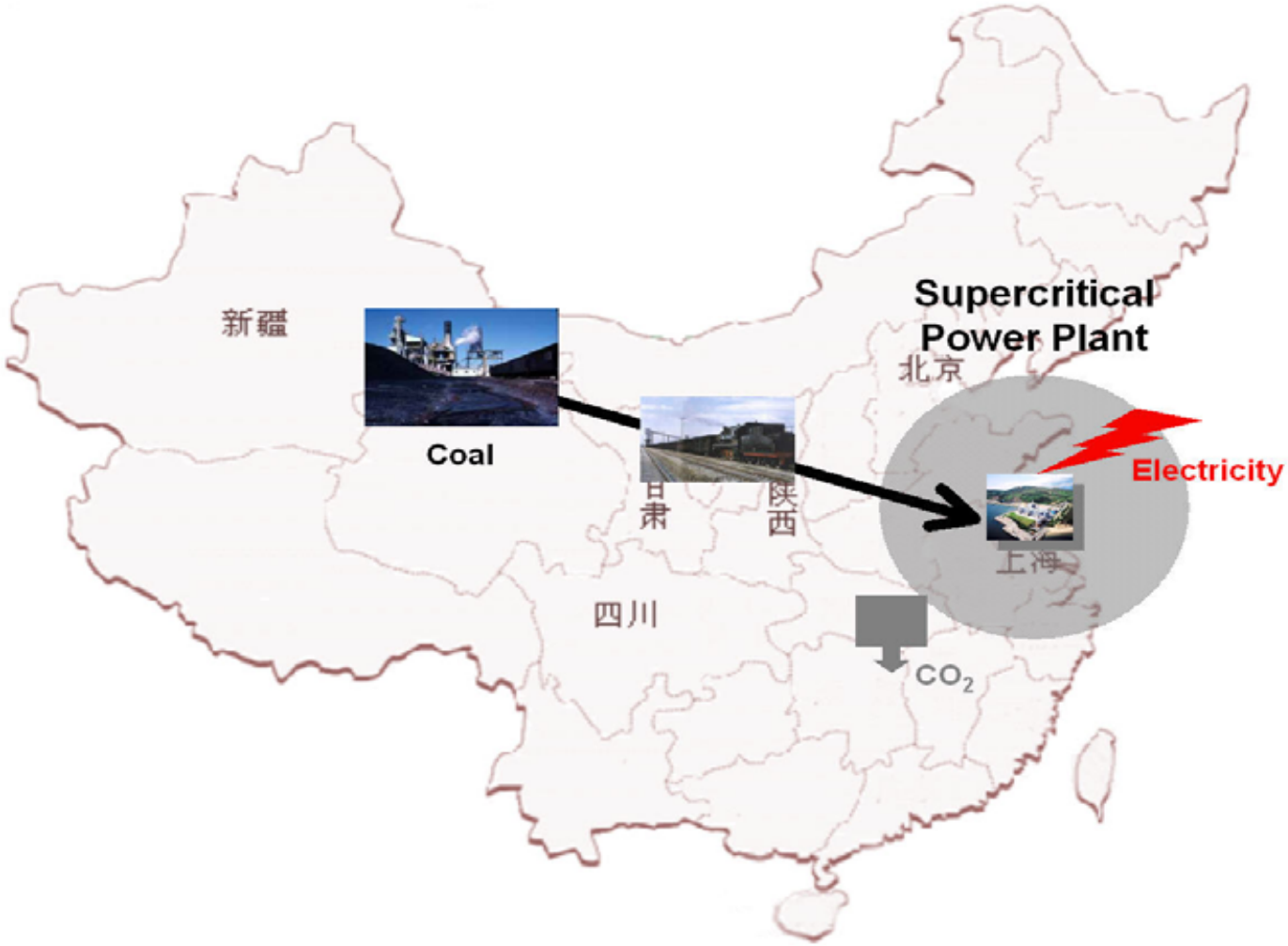


Cost
Scale
Technical Feasibility

Source Sink
Resource Conditions
Economic Condtions

Identify the sector and the area for Low Cost demo

Energy Network in China



Energy Network for China

Upstream (Energy Base) :

Cleanly and effectively convert

the coal to clean energy and electricity

Transportation:

High energy saving

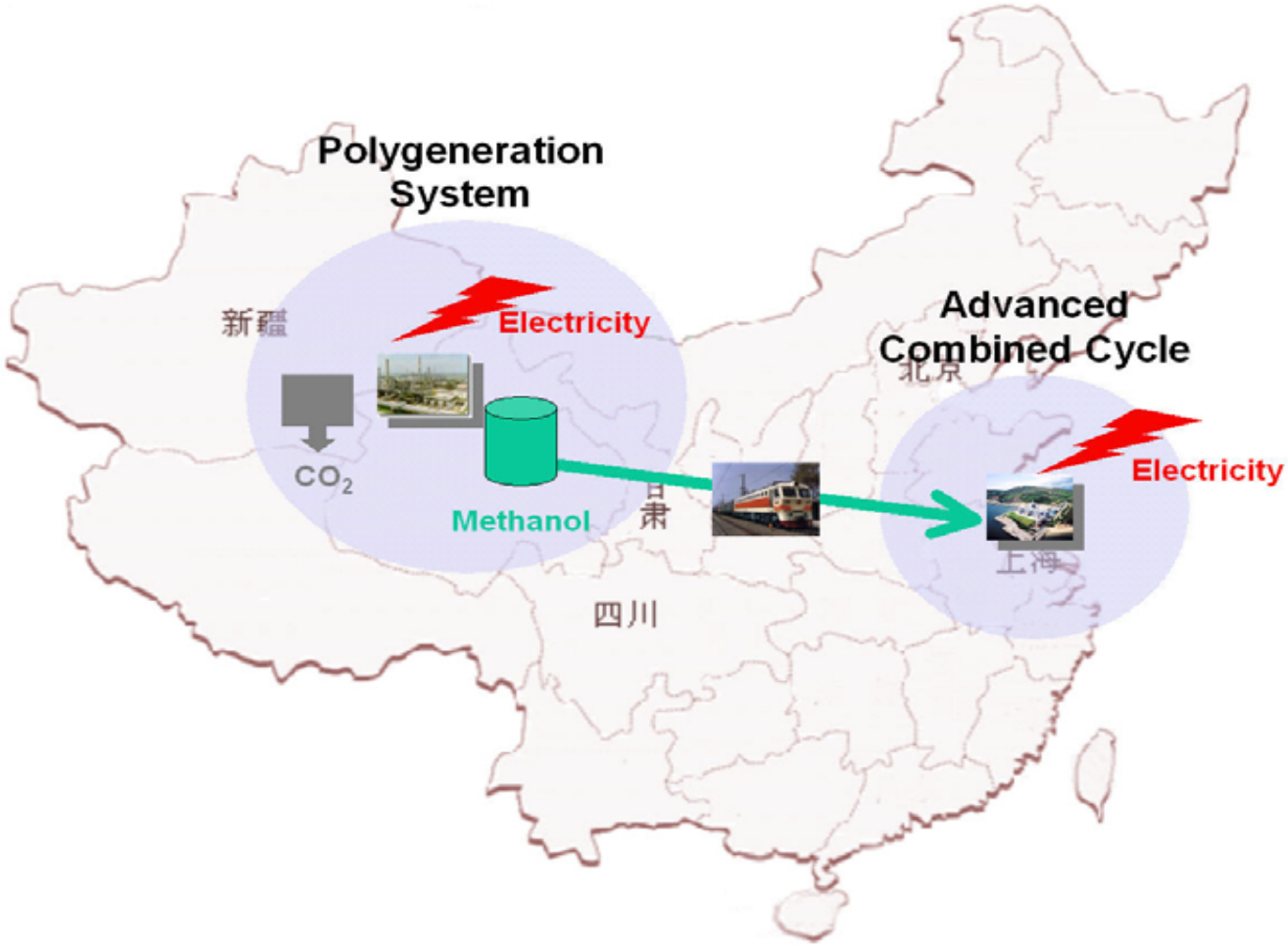
in form of fuel with high energy density

Downstream (City):

Effective use of clean syngas fuel

for power generation or transportation

Energy Network in China



Recommendations

- CCS的技术经济有发展空间，因此应设定捕集技术目标：效率降低少于5 个百分点，成本低于10~15$/tCO2；

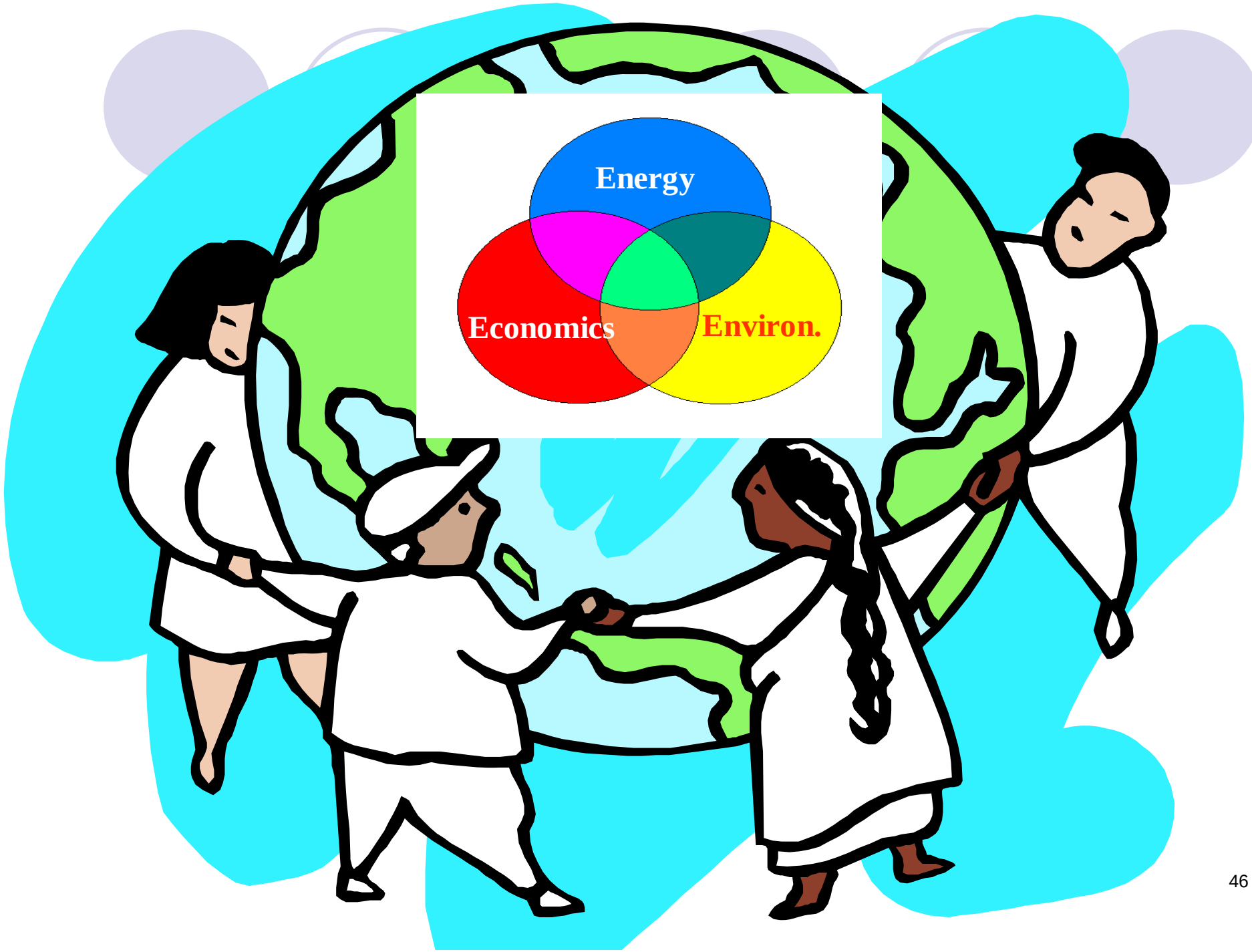
  CCS has potential for technology improvement and cost down, the technical target should be set, for example, energy penalty less than 5 percent points, and cost lower than 10~15 USD/t CO2;

- CCS初期，适合建设代价小、影响大的煤基示范工程：CO2富集行业（煤化工、高炉等）、有效埋存（EOR、ECBM等）；

  The coal based CCS demo project with low cost and good effect, like coal chemcial, coke oven, EOR and ECBM, should be select as the early opportunity;

- 国家层面应成立CCS委员会，协调基础研究、技术研发和技术推广产业化，并发布选择性激励政策；

  The government should build CCS committee to coordinate the research and development, dissemination and issue incentive policy;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