Financing Carbon Capture and Storage
为碳捕获与封存融资

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3. Evaluate a hypothetical CCS investment
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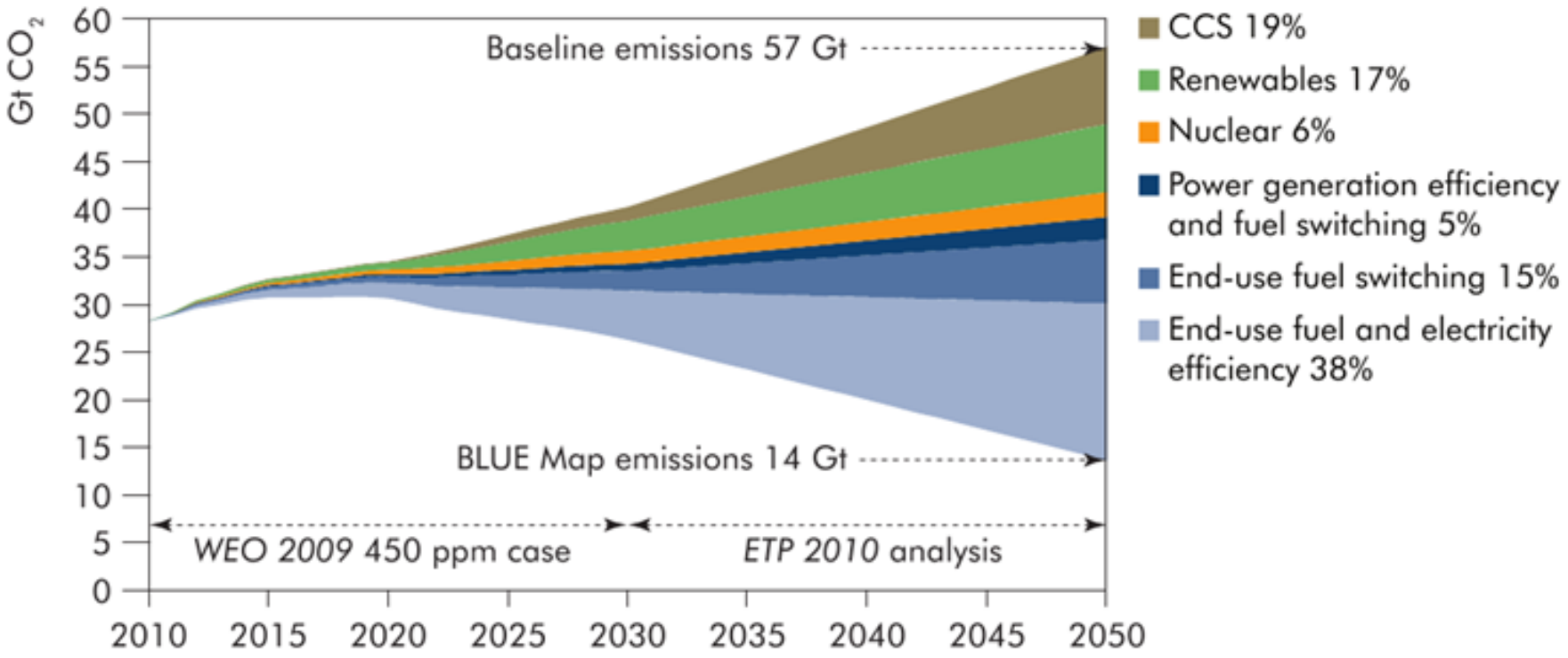
5. Innovative financing model

The Role of CCS / CCS 对全球碳减排的潜在贡献

IEA Blue Map Scenario / 国际能源总署蓝图情景



Source: IEA, 2010.

来源：国际能源总署，2010

1. Key Terms in measuring the cost of CCS technologies

Measure the Costs of Capture

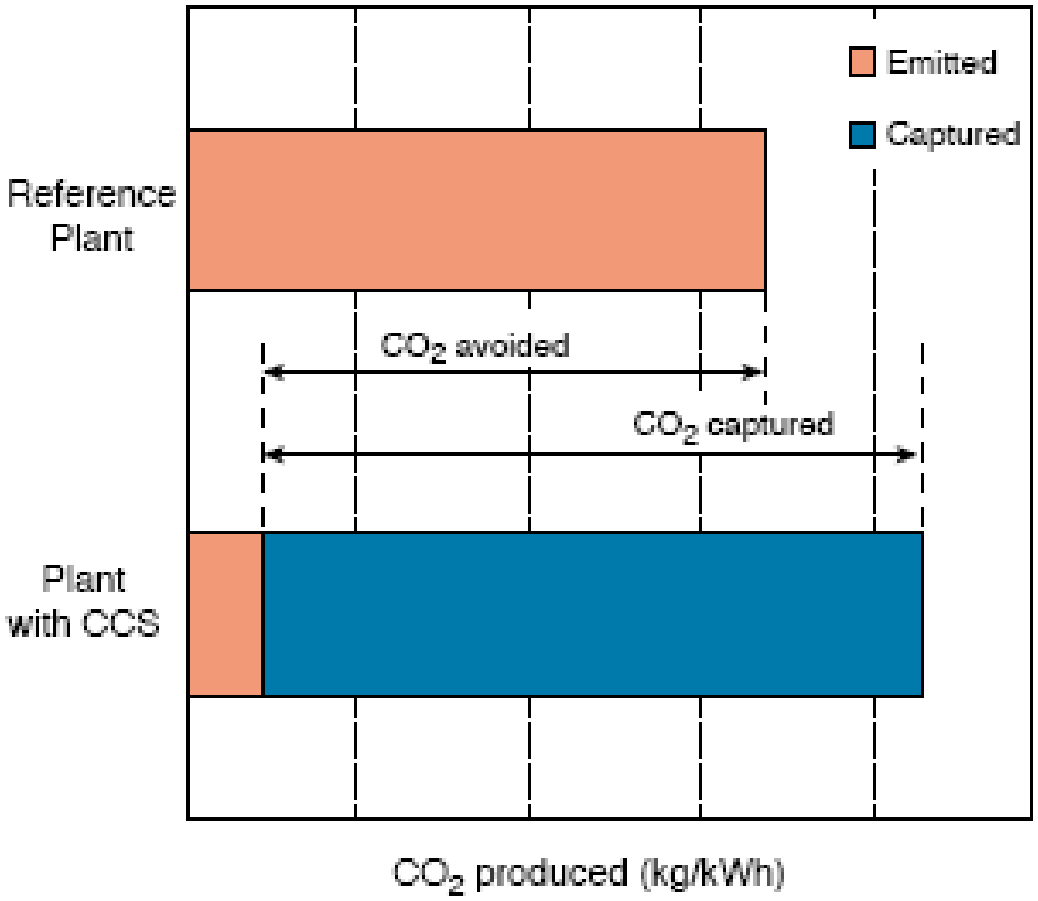
- Cost of electricity ($/MWh)
- Electricity cost increase ($/MWh)
- Cost of CO_2 avoided ($/tonneCO2)
- Cost of CO_2 captured ($/tonneCO2)

Usually through a cost cash flow analysis

Key Components in a Cash Flow Analysis

- Capital investment
- Fixed operational and maintenance (O&M)
- Fuel cost

Understand the difference between the cost of captured versus the cost of CO_2 avoided



Source: IPCC CCS Special Report, Technical Summary: pp32

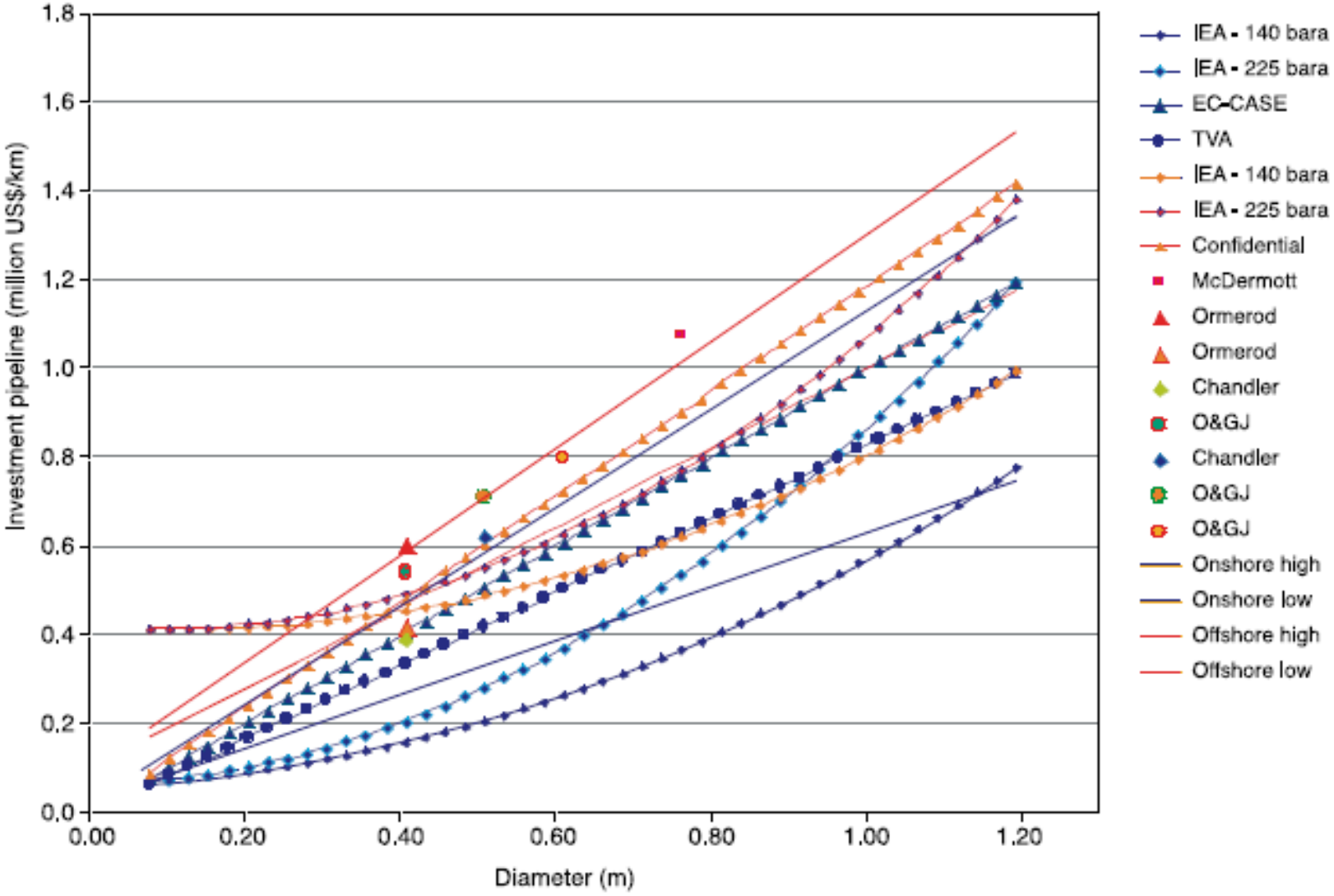
Measure the Costs of Transportation

- Levelised transportation costs ($/tCO2 per km)

Consists of

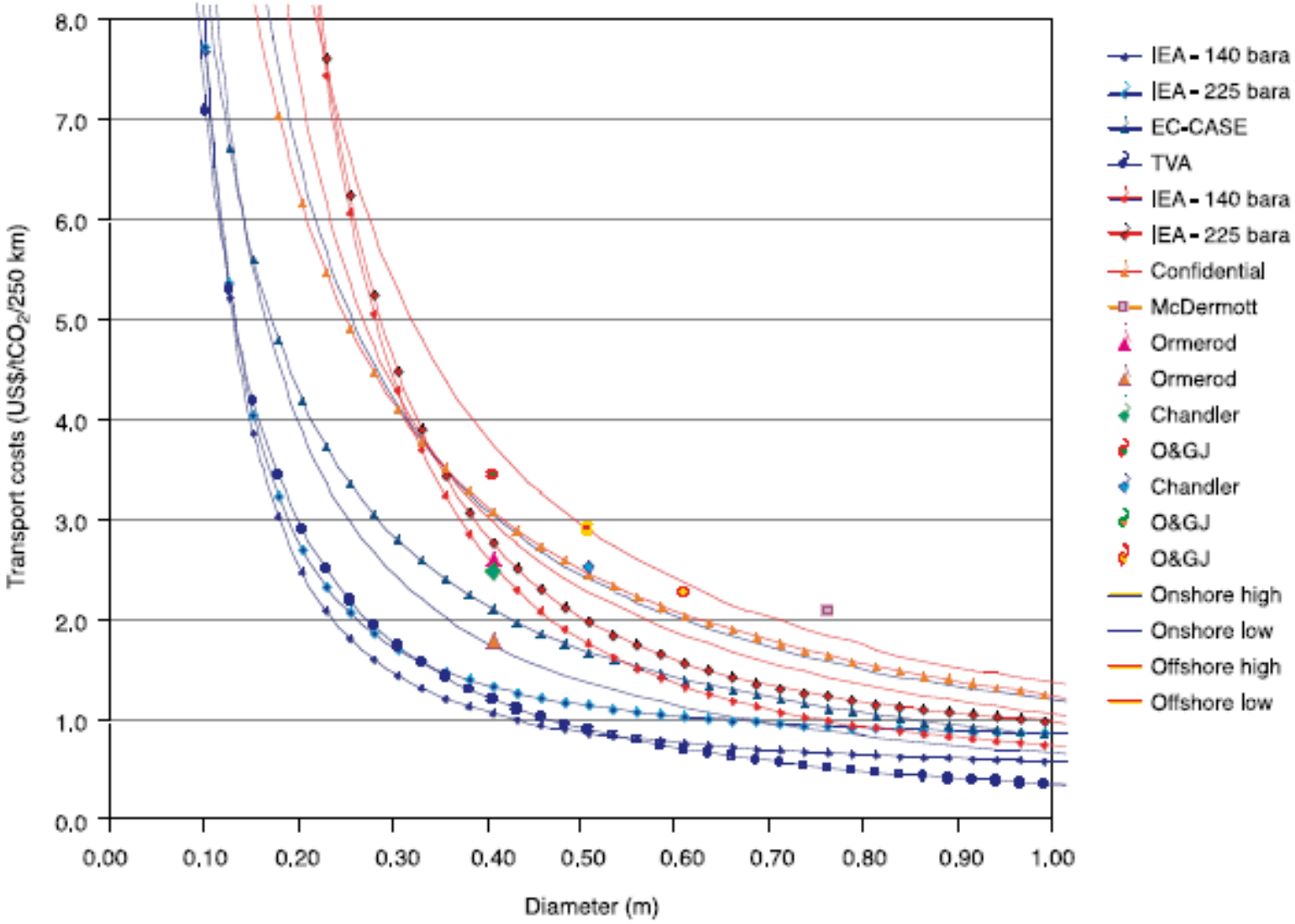
a. Construction cost (material, labour, booster station)
b. Operation and maintenance costs (e.g. monitoring, maintenance, energy cost)
c. Other costs (design, insurance, fees, right-of-way)

Investment Cost versus Diameter of Pipeline



Source: IPCC CCS Special Report: pp191

Transportation Cost versus Diameter of Pipeline



Source: IPCC CCS Special Report: pp191

Measure the Costs of Storage and Monitoring

- Cost per tonne CO_2 stored ($/t$CO_2$)

Consists of

a. Capital cost
b. Operational and Maintenance cost
c. Site characterization
d. Cost of monitoring

Option	Representative Cost Range (US$/tonne CO_2 stored)	Representative Cost Range (US$/tonne C stored)
Geological - Storage[a]	0.5-8.0	2-29
Geological - Monitoring	0.1-0.3	0.4-1.1
Ocean[b]		
Pipeline	6-31	22-114
Ship (Platform or Moving Ship Injection)	12-16	44-59
Mineral Carbonation[c]	50-100	180-370

[a] Does not include monitoring costs.

[b] Includes offshore transportation costs; range represents 100-500 km distance offshore and 3000 m depth.

[c] Unlike geological and ocean storage, mineral carbonation requires significant energy inputs equivalent to approximately 40% of the power plant output.

Source: IPCC CCS Special Report: pp346

Example: CCS Cost based on State-of-art Technology in 2005

	Pulverized Coal Power Plant	Natural Gas Combined Cycle Power Plant	Integrated Coal Gasification Combined Cycle Power Plant
Cost of electricity without CCS (US$ MWh^{-1})	43-52	31-50	41-61
Power plant with capture			
Increased Fuel Requirement (%)	24-40	11-22	14-25
CO_2 captured (kg MWh^{-1})	820-970	360-410	670-940
CO_2 avoided (kg MWh^{-1})	620-700	300-320	590-730
% CO_2 avoided	81-88	83-88	81-91
Power plant with capture and geological storage[6]			
Cost of electricity (US$ MWh^{-1})	63-99	43-77	55-91
Electricity cost increase (US$ MWh^{-1})	19-47	12-29	10-32
% increase	43-91	37-85	21-78
Mitigation cost (US$/$tCO_2$ avoided)	30-71	38-91	14-53
Mitigation cost (US$/tC avoided)	110-260	140-330	51-200
Power plant with capture and enhanced oil recovery[7]			
Cost of electricity (US$ MWh^{-1})	49-81	37-70	40-75
Electricity cost increase (US$ MWh^{-1})	5-29	6-22	(-5)-19
% increase	12-57	19-63	(-10)-46
Mitigation cost (US$/$tCO_2$ avoided)	9-44	19-68	(-7)-31
Mitigation cost (US$/tC avoided)	31-160	71-250	(-25)-120

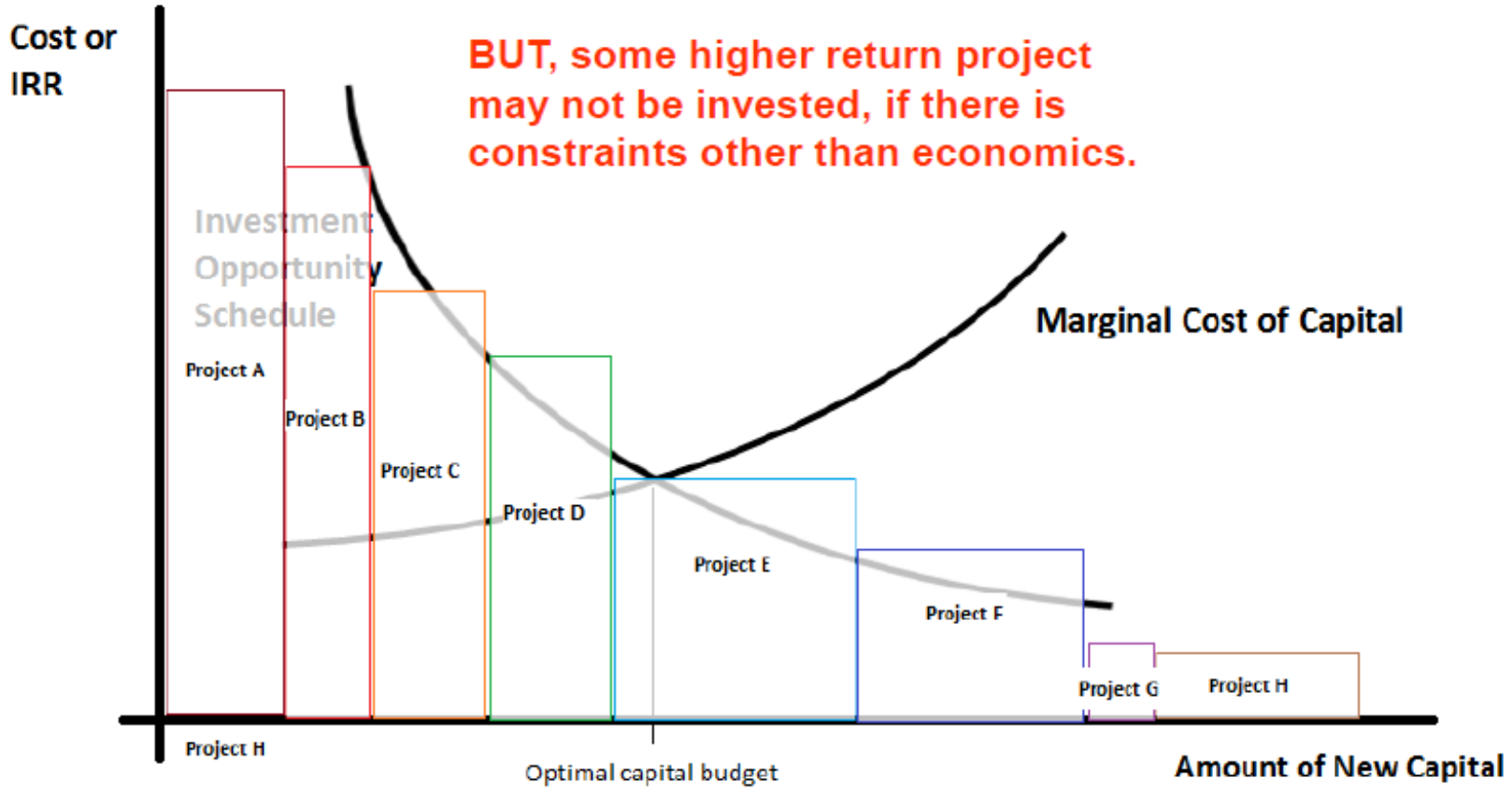
Source: IPCC CCS Special Report, pp347

2. What does an investor care?

Investor concern …

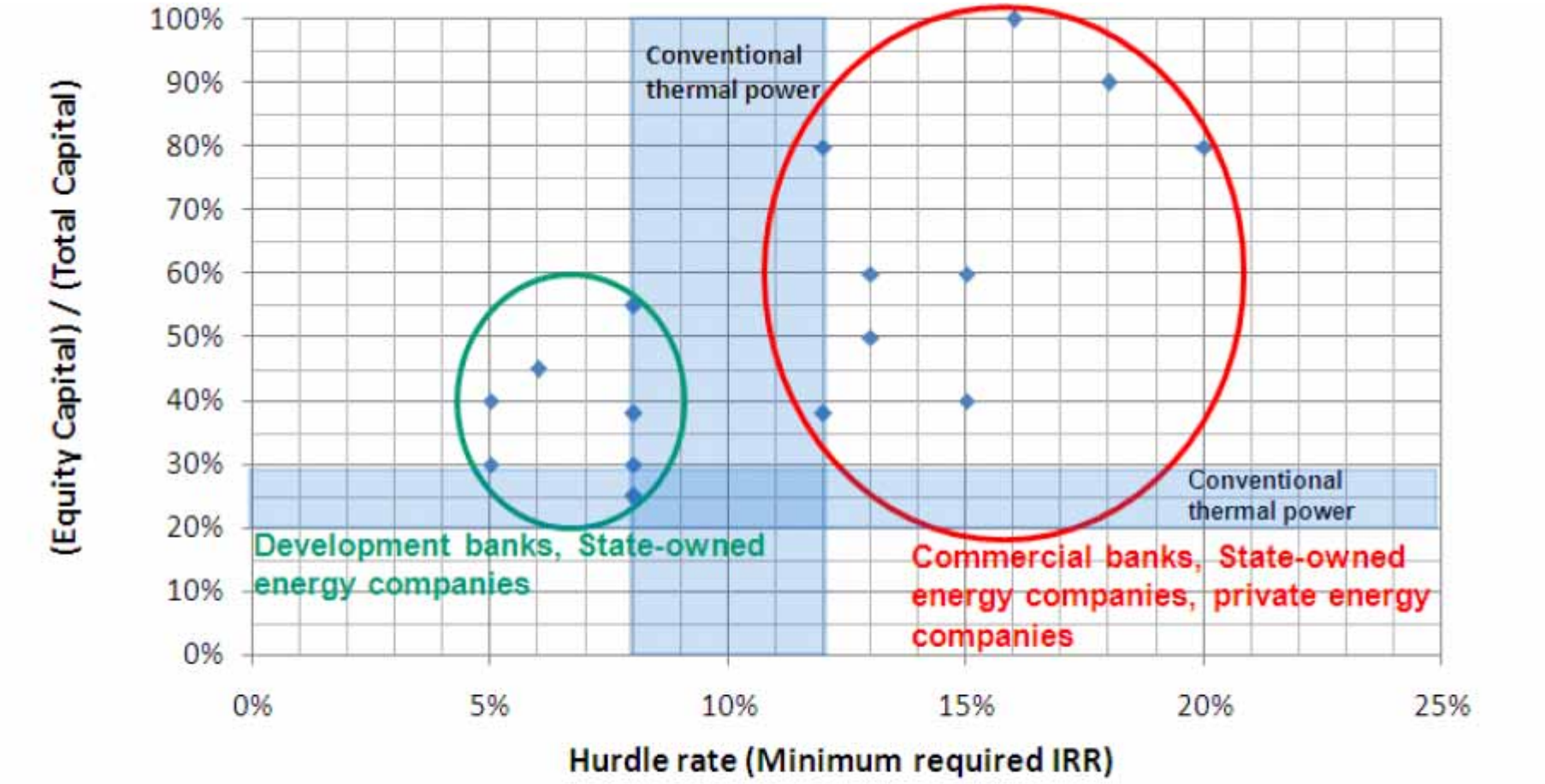
- Potential investment opportunities
- Expected Return (through a free cash flow analysis)
  - Internal rate of return (IRR)
  - NPV
- Perceived Risk
  - Distribution of IRR in a stochastic model
  - Value at risk (i.e. the worst 1% performance)
  - Stress test (what will be the project economics in the worst scenario)
  - driven by market risk, credit risk, operational risk, liquidity risk, legal and regulatory risk.

Investment opportunity schedule



Remark: Risky project demands a higher return and a lower financial leverage

值得注意：高风险项目，需求更高的回报率和较低的负债比率



Scatter diagram of hurdle rate and equity capital ratio for the extra investment needed for capture facilities (based on average response of the 16 financial experts consulted)

Source: Reiner and Liang, 2009; NZEC WP5.2 Report
http://www.nzec.info/en/assets/Reports/CamNZECWP52finalrevisions97-03v28aug09Update.pdf

3. Evaluate a hypothetical CCS investment

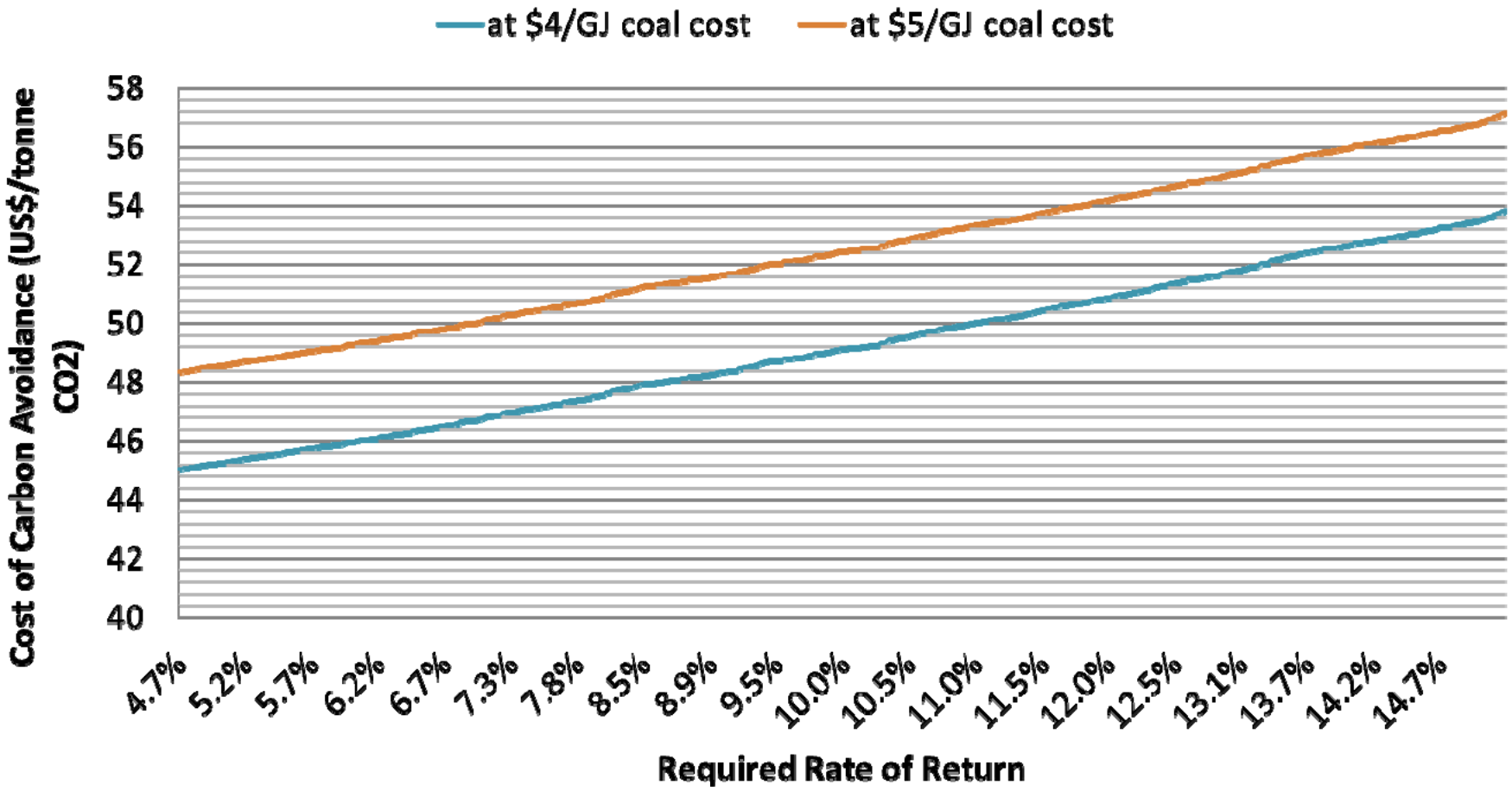
Key question: What is the required electricity tariff or the required electricity tariff to trigger a large scale CCS investment?

Cost Study of a 1GW USCPC Power Plant with CCS in China
中国100万千瓦CCS超超临界燃煤发电厂成本分析

Parameter	Data	Note
Plant Type	USCPC	
Base Real Required Return without Financial Leverage (Discount Rate)	12%	(10% applied for base plant)
Capacity before retrofit	1000	MW
Net Supply Efficiency (LHV) without CCS	41.80%	42.7% at full load
Capacity with 90% capture	799.04	MW
Net Supply Efficiency (LHV) with CCS	34.10%	
Lifetime Degrading factor	1.00%	
Fixed Capital Base Plant	634	M US$ ($6m working cap.)
Fixed Capital for Capture	155	M US$ ($5m working cap.)
Load factor	80%	
Coal Price	4	US$/GJ (eqv. CNY750/tonne metric coal)
Transport, Storage and Monitoring Cost	15	US$/tonneCO2e

Source: Liang and Liu, 2011

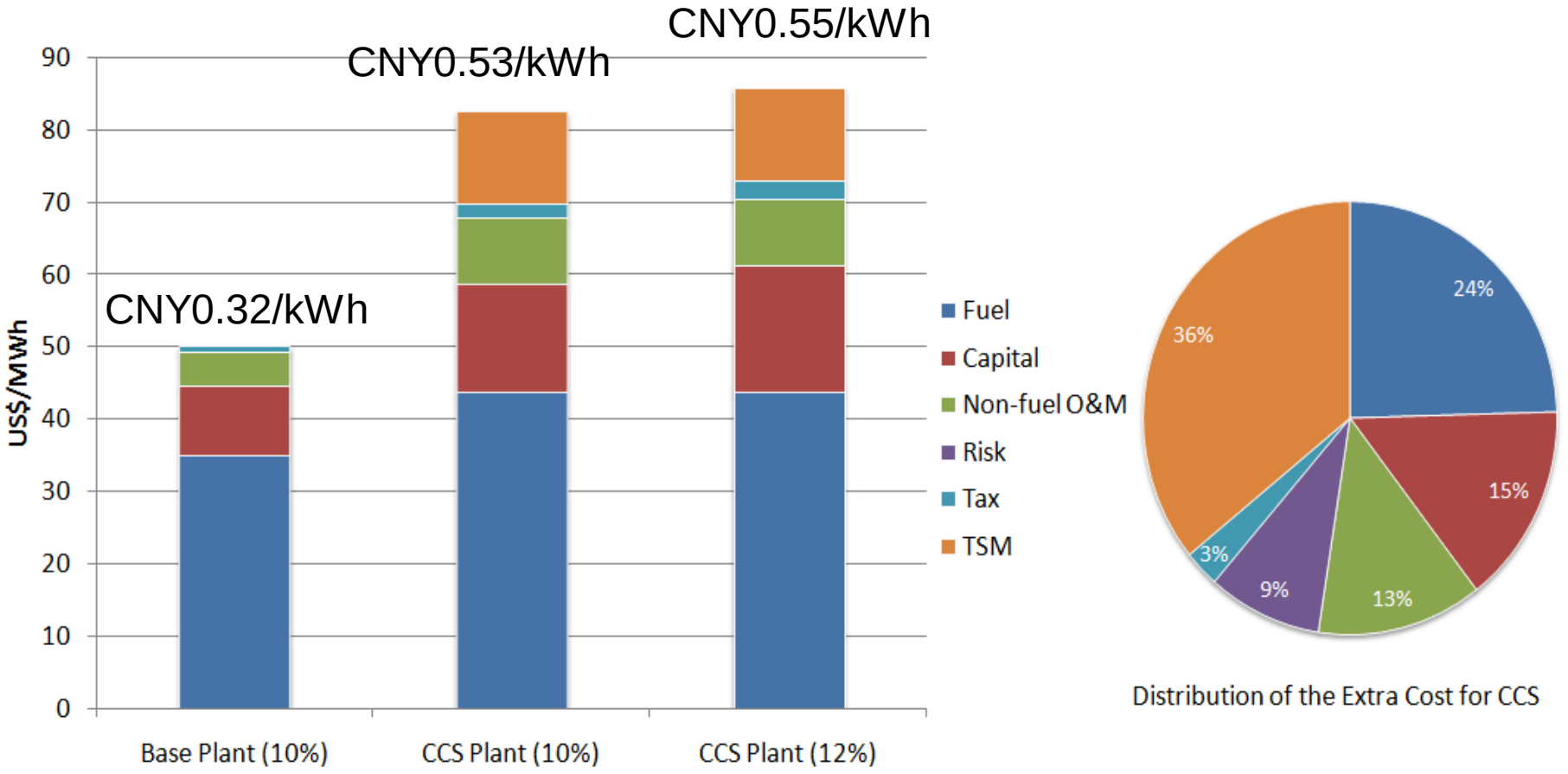
Required Cost of CO_2 Emission for Financing a Hypothetical 1GW USCPC Power Plant with CCS (0.8GW actual output) in China
为一个100万千瓦CCS燃煤发电厂融资所需的碳价格



Note: No premium tariff is assumed.

Source: Liang and Liu, 2011

Required On-grid Tariff for Financing a Hypothetical 1GW USCPC Power Plant with CCS in China
为一个100万千瓦CCS燃煤发电厂融资所需的电价及其构成



Note: Neither carbon price or cost of carbon emissions are assumed.
Fuel costs $4/GJ

Source: Liang and Liu, 2011

4. Financial Sources / 融资渠道

Private Financial Sources

- Energy companies
- Commercial and investment banks
- Venture capital
- Clean Development Mechanism

Source: Liang and Liu, 2011

Public Financial Sources

- National government
- Local/municipal government
- Foreign government
- Development bank
- Multilateral institute

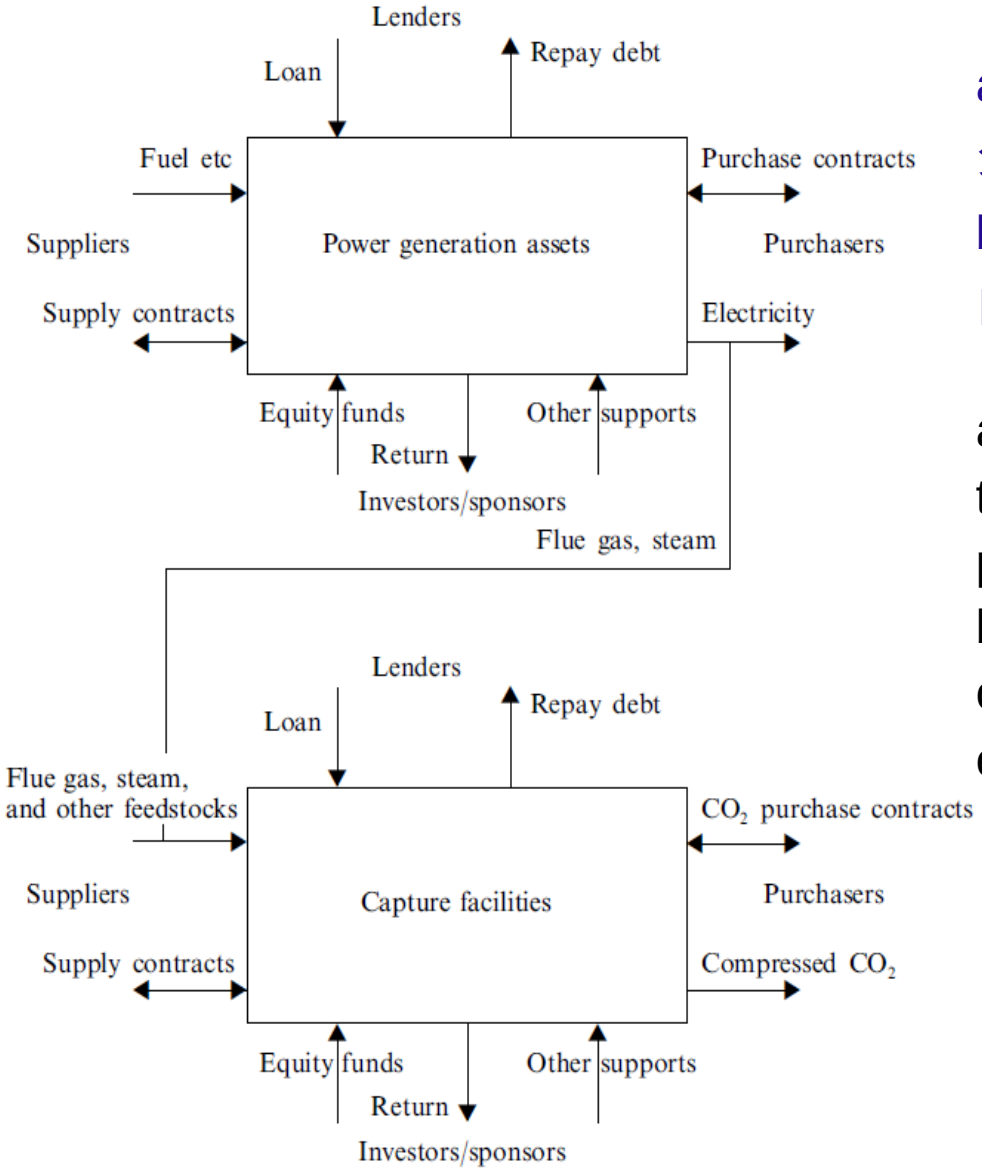
Source: Liang and Liu, 2011

Other Financing Strategies

- Enhanced Oil Recovery
- Special premium electricity tariff scheme
- Investment / operational flexibilities

Source: Liang and Liu, 2011

5. Innovative Financing Mechanism – Capture Option / 开发新的融资方式 – 捕获期权



a. 利用Capture Option（捕获期权）分离电厂与捕获装置的投资。

b. CCS 投资者（捕获装置业主）向电厂购买蒸汽与电力。

a.Apply ‘Capture Option’ concept to separate the investment of power plants and capture units.

b. CCS investors (owner of capture units) purchase steam and electricity from power plants.

Final Remark

- Finance an integrated CCS project in China would require EITHER an USD 3.6 cent/kWh (or CNY0.23/kWh) feed-in-tariff or a US$51/tCO2e carbon price support scheme
- Financing early large scale CCS demonstration in developing countries requires a combination of public and private financial sources with flexible strategies (such as CO_2 utilization)