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Economic Assessment of Deploying Advanced Coal Power Technologies in the Chinese Context

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Feb. 19, 2008

ENERGPOWER

Contents

1. Introduction
2. General Assessment Basis
3. Calculation Results
4. Next Steps
5. Final Remarks

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1. Introduction

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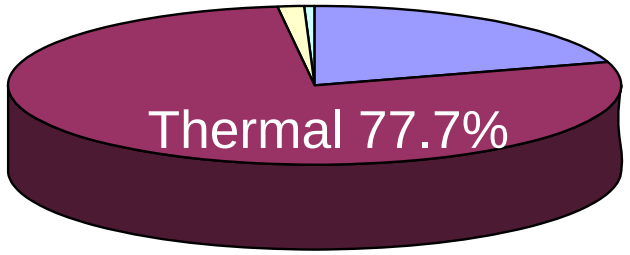
1.1 Power in China

- Total capacity: 713 GW
  - Thermal capacity: 554 GW
  - Coal capacity: 530 GW
- Total electricity generation: 3256 TWh
  - Thermal electricity generation 2698 TWh, 83%
- New added capacity:100 GW
  - Thermal: 82 GW

Power capacity mix, 2007



Hydro 20.4% **Nuclear 1.2%**
Wind 0.6% **Other 0.1%**

- *National Bureau of Statistics of China*
- *China Electricity Council, 2007*

1.2 Some good trends

1. Growth rate of total capacity dropped
   - Installed power capacity: 14.4% higher
   - Growth rate: 6.2% lower
2. Capacity from clean and renewable energy sources increased
   - Wind power capacity: 4 GW, 94.4%
   - Nuclear power capacity: 9 GW, 29.2%
   - Hydro power capacity: 145 GW, 11.5%
   - Thermal power capacity: 554 GW, 14.6%, growth rate, 6% lower

1.2 Some good trends (cont.)

3. More large and advanced coal-fired units went on line
   - 7 1000 MW Ultra-Supercritical (USC) units under operation
     - China Huaneng Group, Yuhuan Power Plant
       - 2006, 2 units
       - 2007, 2 units
     - China Huadian Corporation, Zhouxian Power Plant
       - 2006, 1 unit
       - 2007, 1 unit
     - China Guodian Corporation, Taizhou Power Plant
       - 2007, 1 unit

1.2 Some good trends (cont.)

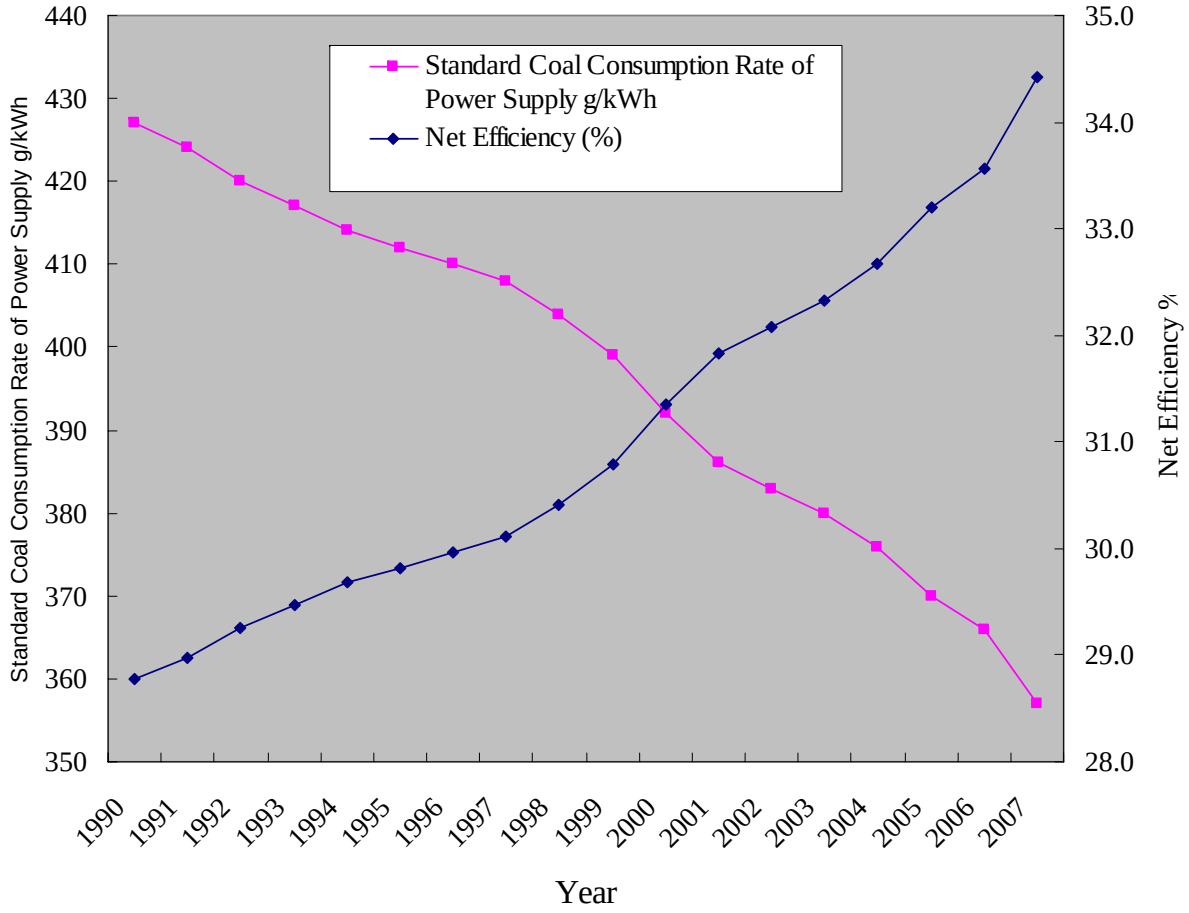
3. More large and advanced coal-fired units went on line
   - 3 600 MW USC units under operation
     - China Huaneng Group, Yingkou Power Plant, 2 units
     - China Power Investment Corporation, Kanshan Power Plant, 1 unit
   - Contracts
     - 80 for 1000 MW USC
     - 50 for 600 MW USC
   - Bids
     - 98 for 1000 MW USC
     - 61 for 600 MW USC

1.2 Some good trends (cont.)

4. Demonstration of new generation technologies was launched
   - 3 IGCC, 2 oil-electricity co-production demonstration plants, under construction
5. Penetration of flue gas desulfurization significantly increased
   - FGD capacity 270 GW, accounting for over 50%
6. Net Efficiency greatly improved
   - 14 GW, closed down
   - Coal consumption rate of power supply: 357 g/kWh (34.4%), 10 g/kWh lower

1.2 Some good trends (cont.)

- *National Bureau of Statistics of China*
- *China Electricity Council, 2007*



- Net efficiency has greatly improved
  - Close down small size units
  - Build large size units
  - Use advanced technology

1.3 Challenges to China's Power Future

- Continued High Electricity Demand
- Low Net Efficiency
- Optimization of Power Mix (dependence on coal)
- Coal Supply
- Environmental Impacts (coal)

1.3 Challenges to China's Power Future (cont.)

Projection of Power Capacity in 2020

	Total installed capacity (GW)	Coal power (GW)	Wind Power (GW)	Nuclear Power (GW)	Addition of coal power (2008-2020) (GW)
Low speed	1241	807	30	41	277
Base	1393	914	50	41	**384**
High speed	1546	1023	70	60	493

1.4 Coal Power Technologies

- Three Pulverized Coal (PC) technologies+ Pollution control technologies
  - Subcritical
  - Supercritical (SC)
  - Ultra-Supercritical (USC)
- Circulating Fluidized Bed (CFB)
- Integrated Gasification Combined Cycle (IGCC)

CASE	Steam Parameter MPa/℃/℃	Gasifier/ Boiler	GT	Sulfur Control	NOx Control	Particulate Matter Control
1	16.7/538/538	Subcritical		-	LNB	Electrostatic precipitation
2	16.7/538/538	Subcritical		FGD	LNB	Electrostatic precipitation
3	16.7/538/538	Subcritical		FGD	LNB/SNCR	Electrostatic precipitation
4	24.2/566/566	Supercritical		-	LNB	Electrostatic precipitation
5	24.2/566/566	Supercritical		FGD	LNB	Electrostatic precipitation
6	24.2/566/566	Supercritical		FGD	LNB/SNCR	Electrostatic precipitation
7	25/600/600	USC		-	LNB	Electrostatic precipitation
8	25/600/600	USC		FGD	LNB	Electrostatic precipitation
9	25/600/600	USC		FGD	LNB/SNCR	Electrostatic precipitation
10	16.7/538/538	CFB subcritical		Furnace Desulfurization	-	Electrostatic precipitation
11	10/510/510	Multi-Nozzle entrained flow	E-class	NHD	Fuel Saturation	Wet Scrubbe
12	10/510/510	Shell entrained flow	E-class	NHD	Fuel Saturation	Candle filter

1.5 Goals

- To compare twelve different power plant configurations
- To evaluate the differences in capital cost and overall cost of electricity (COE)
- To evaluate the performance of all technologies examined
  - Net efficiency
  - Emissions (SO_2, NOx, Particulate Matter, CO_2)

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2. General Assessment Basis

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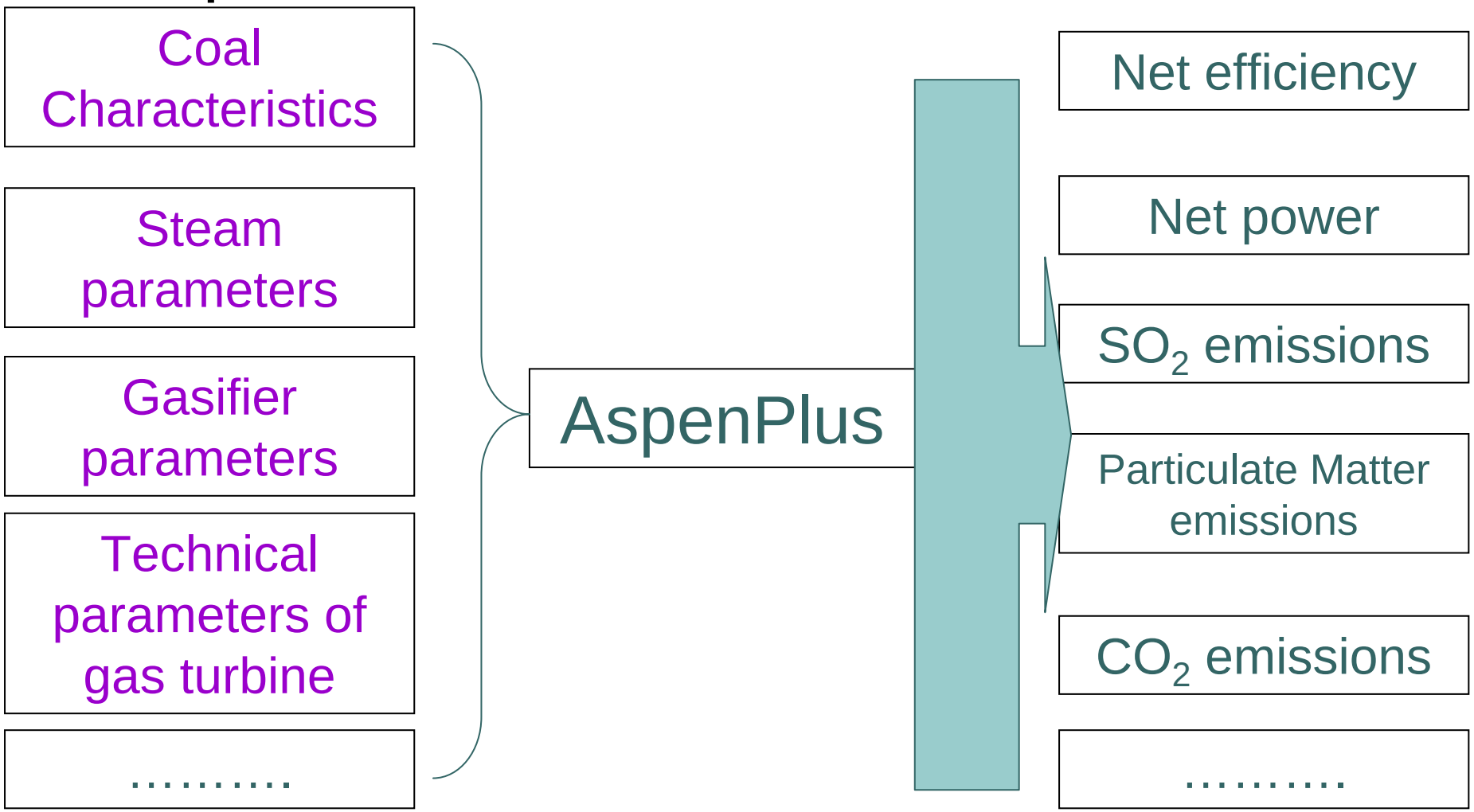
2.1 Calculation of Performance



2.2 Impact Factors for Performance Calculation

- Site Characteristics
- Coal Characteristics
- Emission Standards

2.3 Site Characteristics

Design Air Pressure	1atm
Design Temperature	298K
Relative Humidity	55%
Transportation	Rail access
Water	Municipal

2.4 Coal Characteristics

Heating Values of China Coal (MJ/kg)

<8.5	8.5~12.5	12.51~17	17.01~21	21.01~24	24.01~27	>27	Average
0.4%	1.18%	7.85%	12.69%	25.42%	34.95%	17.51%	22.74 %

Ash Contents of China Coal (%)

⩽ 5	5.01~10	10.01~20	20.01~30	30.01~40	40.01~50	>50	Average
0.4%	8.8%	39.81%	33.56%	13.69%	2.25%	1.49%	23.38%

51%

Sulfur Contents of China Coal (%)

⩽0.5	0.51~1	1.01~1.5	1.51~2	2.01~3	>3	Average
40.17%	31.48%	14.27%	3.37%	4.57%	6.14%	1.06%

28%

2.5 Shendong Coal Characteristics

Shendong Coal

Proximate Analysis（%，wt）		Ultimate Analysis（%，wt，dry basis）	
Moisture	10.56	Carbon	76.99
Fixed Carbon	52.52	Hydrogen	4.58
Volatile Matter	**30.64**	Oxygen	10.07
Ash	6.28	Nitrogen	0.94
		Sulfur	**0.4**
		ASH	**7.02**
As-Received LHV（kJ/kg）		**26110**	

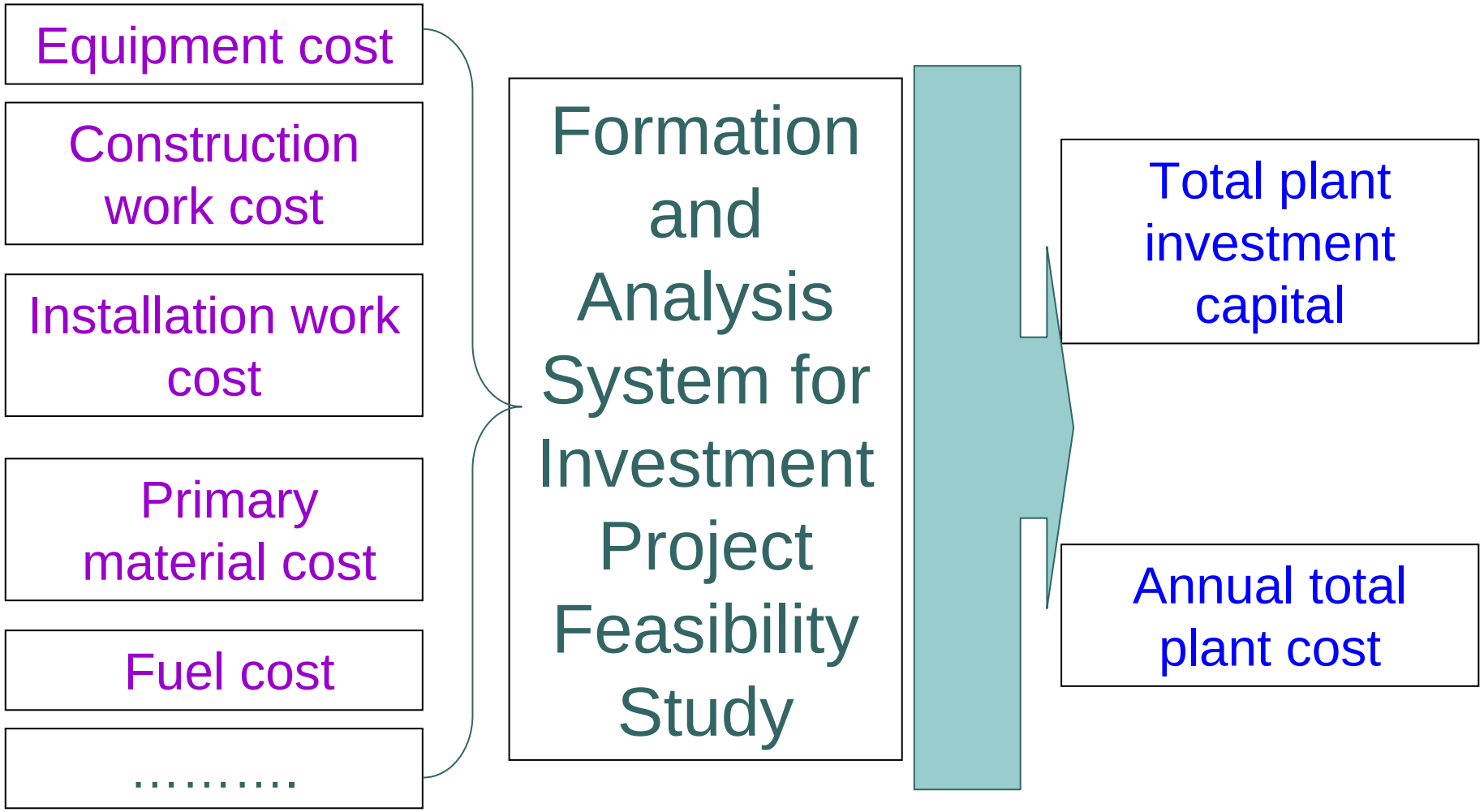
2.6 Emission Standards in China

- NOx:
  - Vdaf ＞20% 450 mg/Nm^3
  - 10%≤Vdaf ≤20% 650 mg/Nm^3
  - Vdaf ＜10% 1100 mg/Nm^3
- SO_2:
  - 400mg/Nm^3, 800mg/Nm^3, 1200mg/Nm^3
- Particulate matter:
  - 50mg/Nm^3, 100mg/Nm^3, 200mg/Nm^3

2.7 Comparison of Emission Limits

Nation / Pollutants	China	USA	EU
SO_2 (mg/Nm^3)	400	135	200
NOx (mg/Nm^3)	450	190	200
Particulate Matter (mg/Nm^3)	50	18	30

2.8 Economic Assessment



2.9 The Composition of Total Plant Investment Capital (Yuan)

No.	Items		
1	Fixed assets	Overnight construction cost	Construction engineering cost
			Original equipment cost
			Installation engineering cost
		Other engineering cost	Management cost for project construction
			Technical service cost
			Extra costs for imported technology and equipment
			Site preparation
			Other costs
2	Intangible assets		Land use cost
3	Deferred assets		Preparation fee for production
4	Fixed assets	Basic contingency cost	
5	Fixed assets	Interests during construction period	

2.10 The Composition of Annual Total Plant Cost (Yuan/Year)

No.	Items	
1	Capital cost	depreciation cost
2		amortization cost
3	Operation and maintenance cost	bought-in primary material cost
4		bought-in fuel cost
5		wage and welfare cost
6		repair cost
7		financial cost
8		charges for emitting SO_2
9		charges for emitting NOx
10		charges for emitting particulate matter

2.11 Basic Parameters for Economic Assessment

Construction period	3 years	Annual operation hours	6000 hours
Depreciation residual rate	5%	Depreciation period	15 years
Amortization of intangible assets	5 years	Amortization of deferred assets	5 years
Loan rate	6.4%	Loan ratio	70%
Basic contingency cost	8%	Loan return period	15 years
Welfare and labor protection coefficient	57%	PC repair rate	2.5%
Operation period	20 years	IGCC repair rate	3.5%

2.12 Two Economic Indicators

- Capital Cost = total plant investment capital / total plant gross power (Yuan/kW)
- COE = annual total plant cost / net electricity generation (Yuan/MWh)

2.13 Data Collection

- Pathways to data collection
  - Plant visits
  - Technology vendor and manufacturer contacts
  - Attendance at conferences
  - Interviews with experts

No.	Title	Contents
1	Shan Xi Fertilizer plant	Fixed bed gasifier (equipment, construction engineering, and installation engineering)
2	Jilin Changshan Fertilizer (Group) Co., LTD.	Fluidized bed gasifier (equipment, construction engineering, and installation engineering)
3	Yankuang Group	Entrained-bed gasifier (new coal-water slurry with opposed multi-nozzles gasifier), sysgas cleanup unit (equipment, construction engineering, and installation engineering)
4	East China University of Science and Technology	Entrained-bed gasifier, including GE, Shell, and new coal-water slurry with opposed multi-nozzles gasifier
5	Sichuan Bluestar Machinery Co., Ltd	Gaisifier manufacturer
6	Air Products and Chemicals (China)	Air Separation Unit (equipment, construction engineering, and installation engineering)
7	Air Liquide (Hangzhou) LTD., CO.	Air Separation Unit (equipment, construction engineering, and installation engineering)China Huadian Corporation
8	Nanjing Turbine & Electric Machinery (Group) Co., LTD.	6B and 9E gas turbines, HRSG , steam turbine, auxiliary system, Control system, electric system, water treatment system, water supply system, fuel supply system, thermodynamic system

9	Harbin Power Equipment Corparation	subcritical, supercritical, ultra supercritical boilers and CFB boilers
10	Shanghai Electric	subcritical, supercritical, ultra supercritical boilers and steam turbines, electric motors
11	Zhengjiang Electric Power Design Institute	loan rate, loan ratio, depreciation period, depreciation residual rate, amortization of intangible assets, amortization of deferred assets, Urban construction charge rate, Extra charges rate of education funs, Operating earning tax rate, Income tax rate
12	North China Power Engineering Co., LTD.	loan rate, loan ratio, depreciation period, depreciation residual rate, amortization of intangible assets, amortization of deferred assets
13	China Huaneng Group	subcritical, supercritical, ultra supercritical PC power plants (capital, operations and maintenance costs), Construction period, Operation period, Load of first year in the operation period, Load of second year in the operation period, Annual operation hours
14	Shenhua Group	Coal price
15	Clean Environmental Protection Engineering Co., LTD.	FGD, flue gas denitrification

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3. Calculation Results

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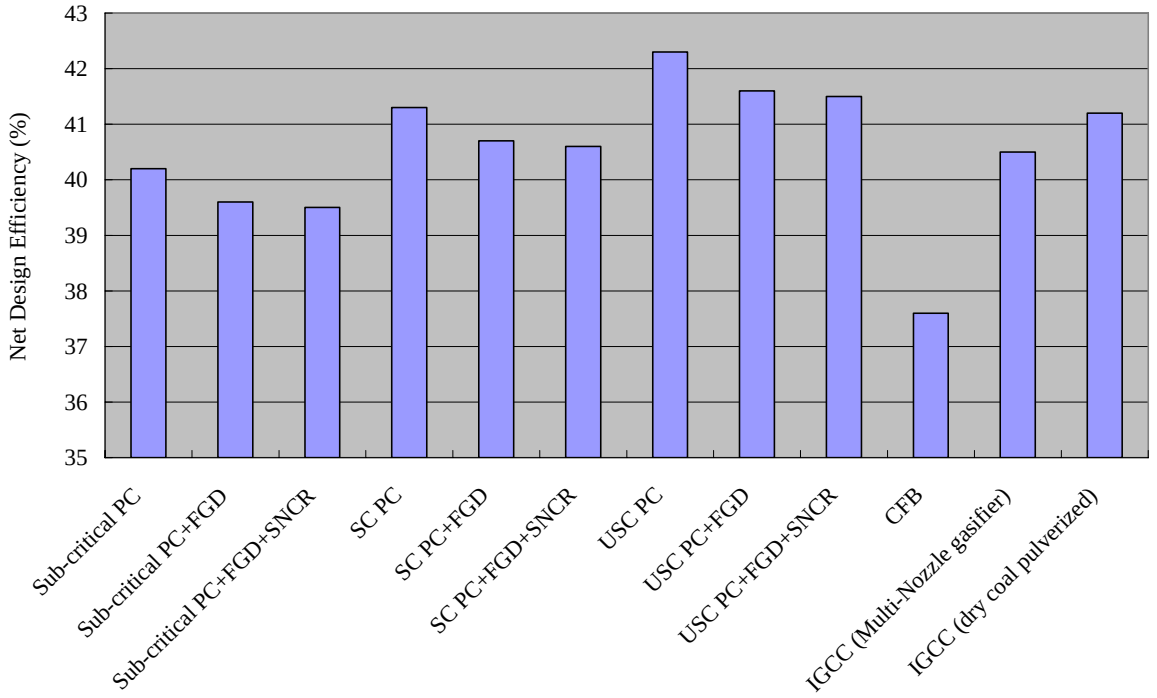
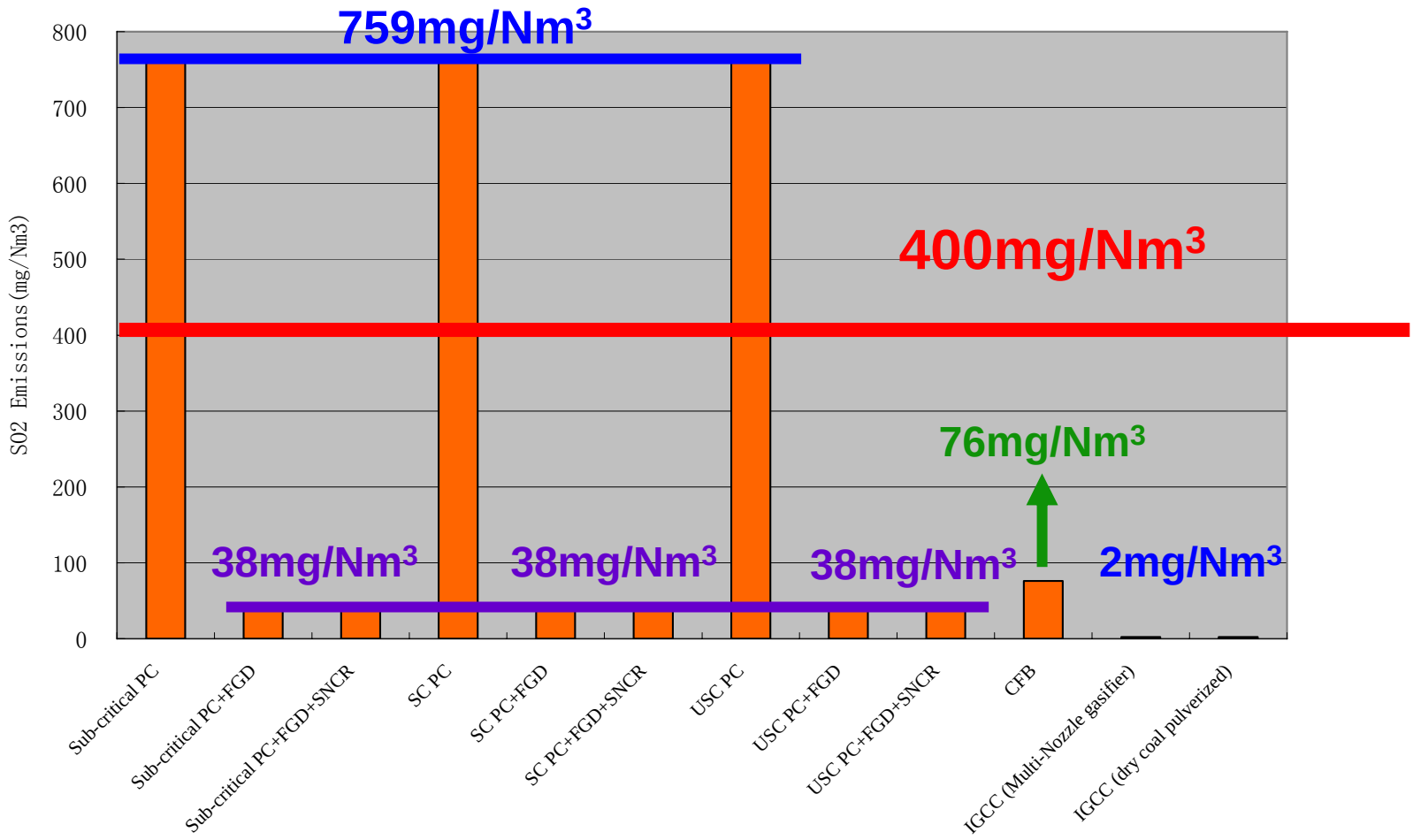
3.1 Technological Performance

CASE	Gross Power (MWe)	Net Design Efficiency (LHV)
3 (subcritical)	1200	39.5%
6 (SC)	1200	40.6%
9 (USC)	1200	41.5%
10 (CFB)	600	37.6%
11 (IGCC)	251.2	40.5%
12 (IGCC)	228.1	41.2 %



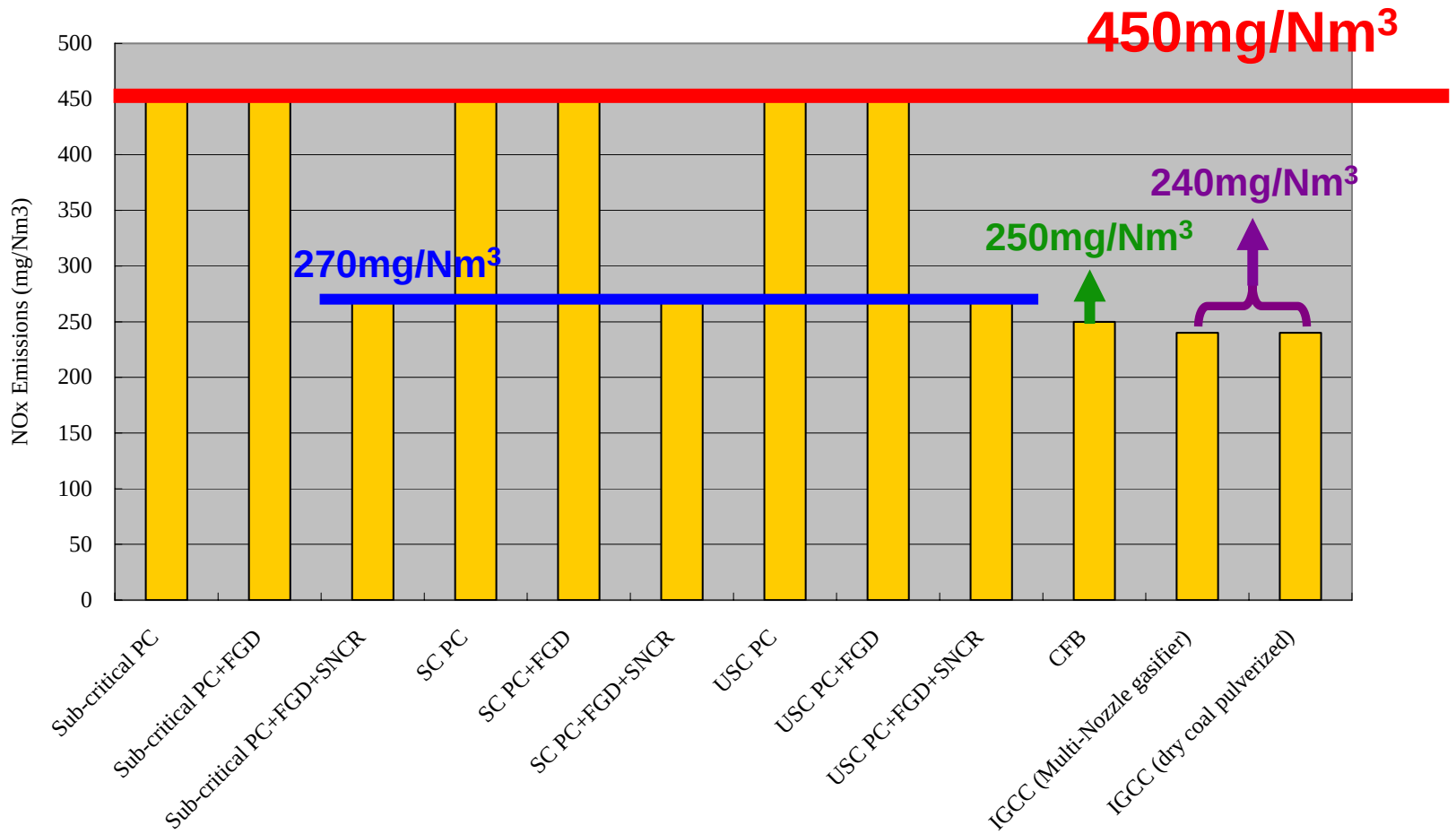
Net Design Efficiency (%)

3.2 Environmental Performance



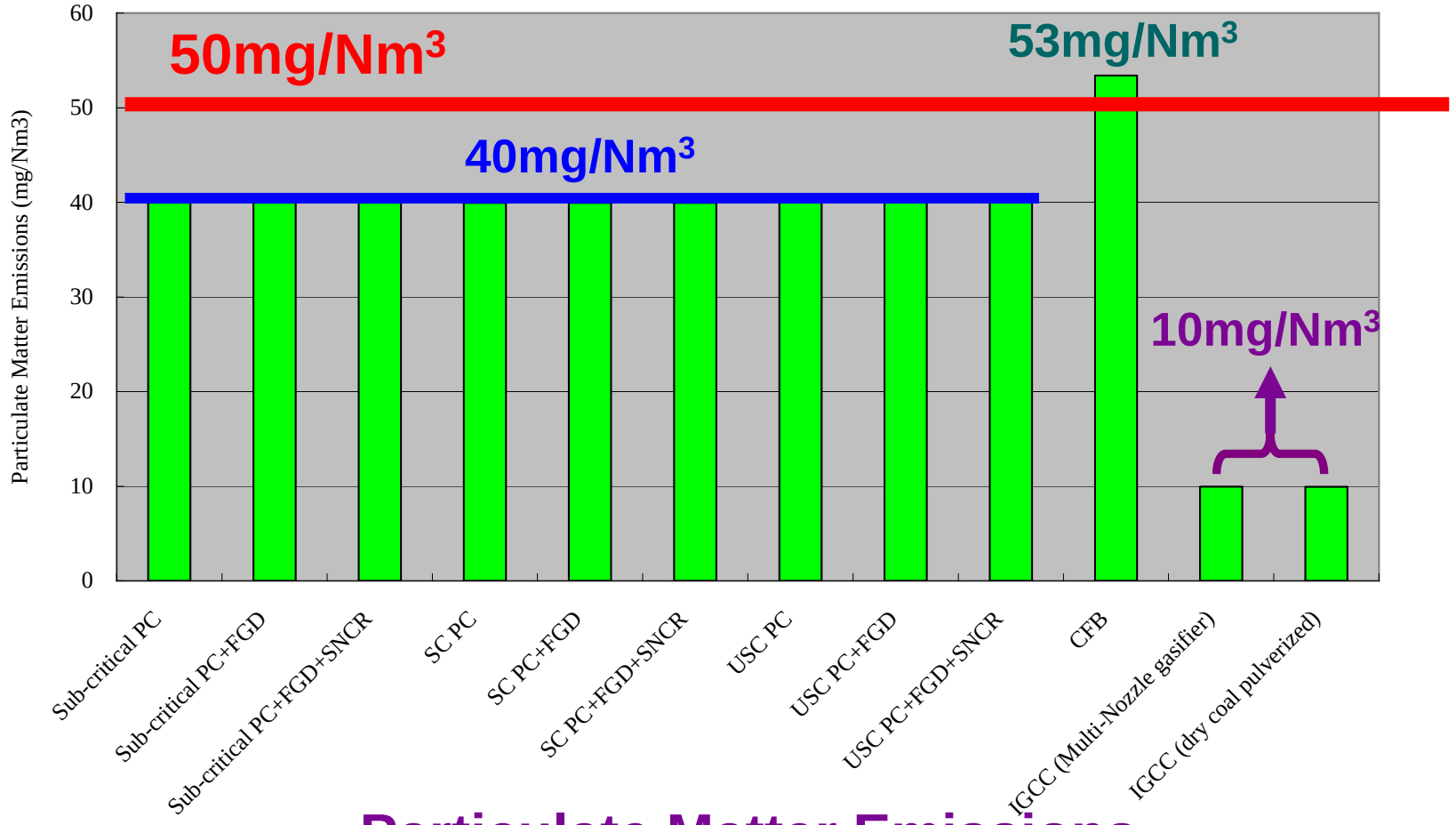
SO_2 Emissions

3.2 Environmental Performance (cont.)



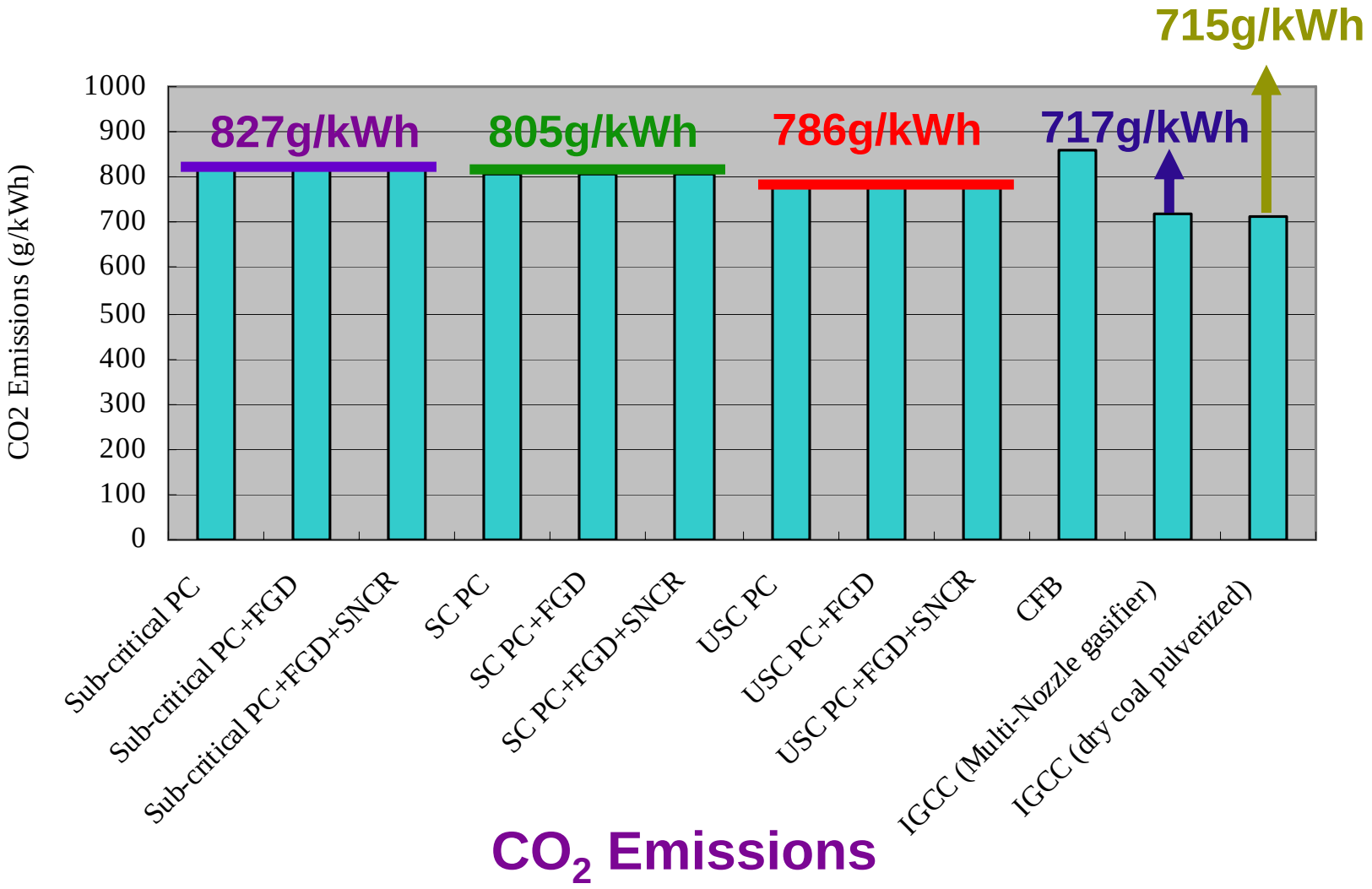
NOx Emissions

3.2 Environmental Performance (cont.)



Particulate Matter Emissions

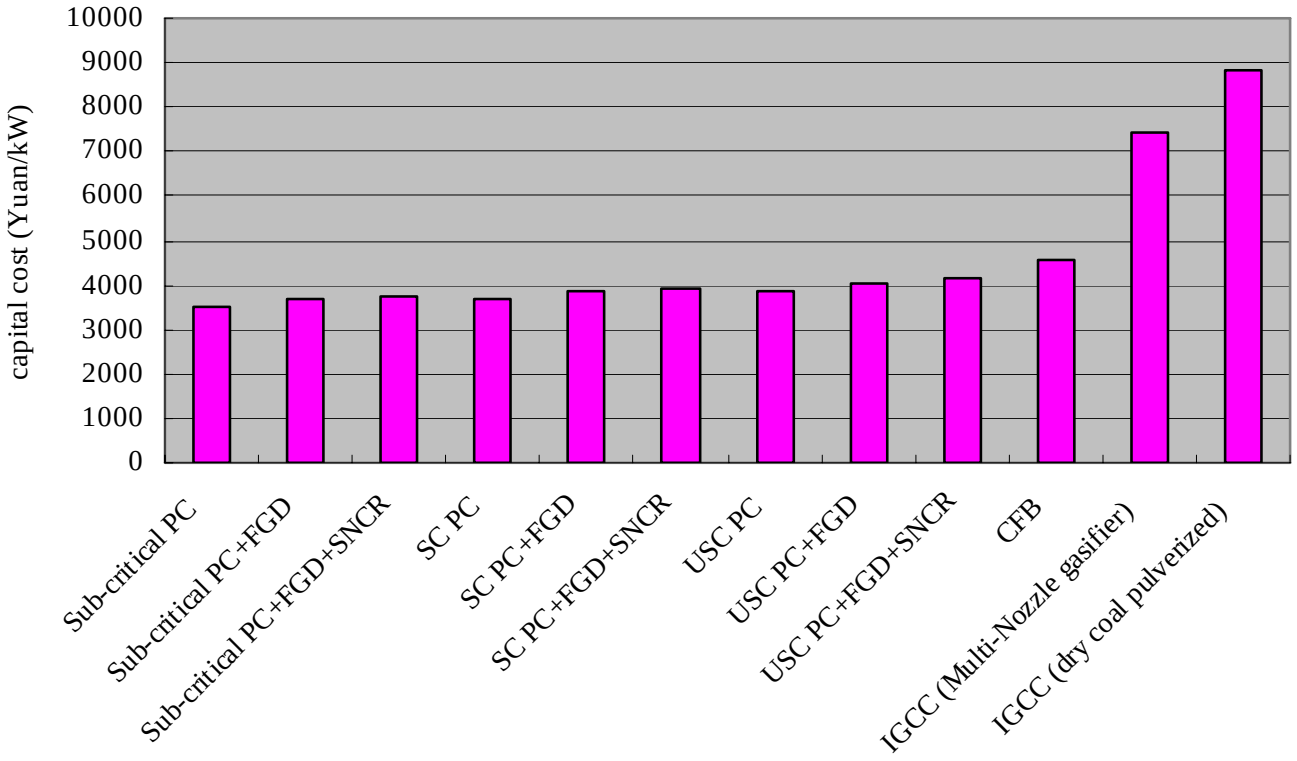
3.2 Environmental Performance (cont.)



CO_2 Emissions

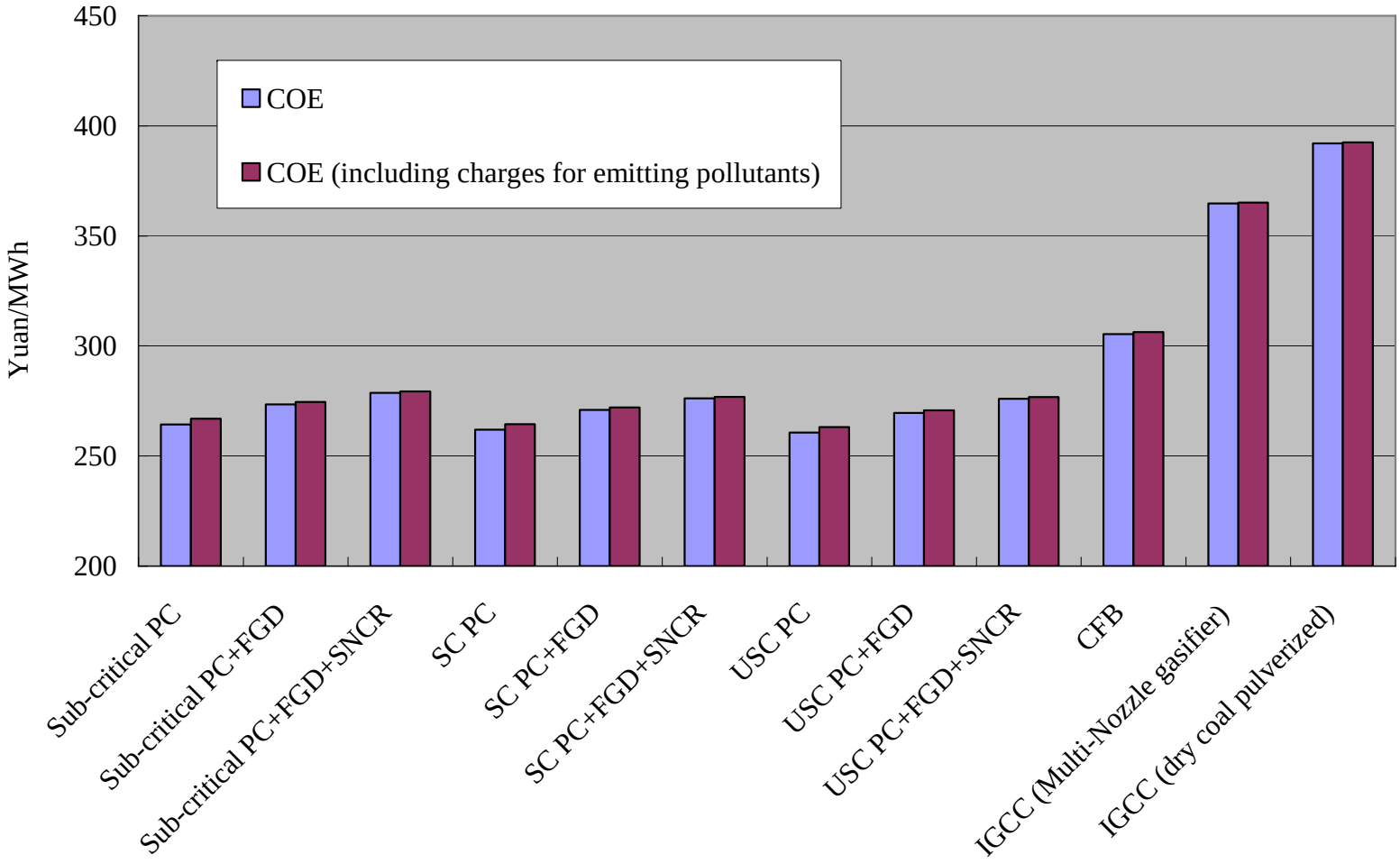
3.3 Economic Assessment

CASE	Capital Cost (Yuan/kW)
3 (subcritical)	3762
6 (SC)	3942
9 (USC)	4137
10 (CFB)	4566
11 (IGCC)	7433
12 (IGCC)	8823



Capital Cost (Yuan/kW)

3.3 Economic Assessment (cont.)



COE (Yuan/MWh)

3.3 Economic Assessment (cont.)

CASE	COE not including charges for emitting pollutants	Cost of Pollutant control unit (not including charges for emitting pollutants)	COE including charges for emitting pollutants	Cost of Pollutant control unit (including charges for emitting pollutants)
4 (SC)	261.95		264.47	
5 (SC+FGD)	270.97	9.02	272.08	7.61
6 (SC+FGD+flue gas denitrification)	276.22	5.25	276.93	4.85

COE (Yuan/MWh)

3.3 Economic Assessment (cont.)

Impacts of Coal Price on COE (including charges for emitting pollutants, Yuan/MWh)

Price of Coal (Yuan/tonne)	180	280	380	480	580	680
Subcritical PC+FGD+SNCR (case 3)	139.75	174.66	209.57	244.48	279.39	314.3
SC PC+FGD+SNCR (case 6)	141.02	175	208.98	242.95	276.93	310.9
USC PC+FGD+SNCR (case 9)	143.97	177.16	210.35	243.55	275.58	309.93
CFB (case 10)	159.57	196.24	232.92	269.6	306.28	342.96
IGCC (Multi-Nozzle Gasifier) (case 11)	226.5	259.89	293.28	326.67	360.06	393.45

3.4 Comparison of cost between the U.S. and China

Plant Type	U.S.		China	
	Capital Cost, $/kW	COE, $/MWh	Capital Cost, $/kW	COE, $/MWh
Subcritical	1549	64	502	37.3
Supercritical	1575	63.3	526	36.9
IGCC-GE	1813	78	991	48.0
IGCC-Shell	1977	80.5	1176	51.5

- Exchange rate: 7.5
- U.S. data source: Cost and Performance Baseline for Fossil Energy Plants, NETL, August 2007

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4. Next Steps

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Next Steps

- Deployment policies (current & options)
- Electricity policies & pricing
- IGCC market demand
- Policy recommendations for IGCC
- Scenario analysis of coal power mix in 2020

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5. Final Remarks

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Final Remarks

- Regarding emissions, PC plants coupled with pollution control technologies, CFB, and IGCC can meet the SO_2, NOx and particulate matter emissions requirements of the Chinese government today
- Only levying charges for emitting pollutants is not enough to encourage power plants to install pollution control equipment

Final Remarks (cont.)

- From the point of view of efficiency, SC and USC units are good choices for power industry
- The cost of IGCC is much higher than that of other power generation technologies
- Incentive policies are needed to deploy IGCC in China

Acknowledgement

- William and Flora Hewlett Foundation
- BP Carbon Mitigation Initiative
- BP Alternative Energy
- the Woods Hole Research Center
- Shell Exploration and Production
- Packard Foundation

Thank you for your attention!

Welcome questions and comments!

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