Economic-environmental effects analysis of process steam supplied by a 200MW NHR using the clean development mechanism (CDM)

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Introduction

- The GDP of China has been growing very rapidly since implementing its opening and reform policy
  - average annual growth rate of about 9.4% in the past two decades years given on Figure 1
- The power industry has seen correspondingly remarkable growth in the past two decades
  - *Shown by Figure 2-3*

Introduction

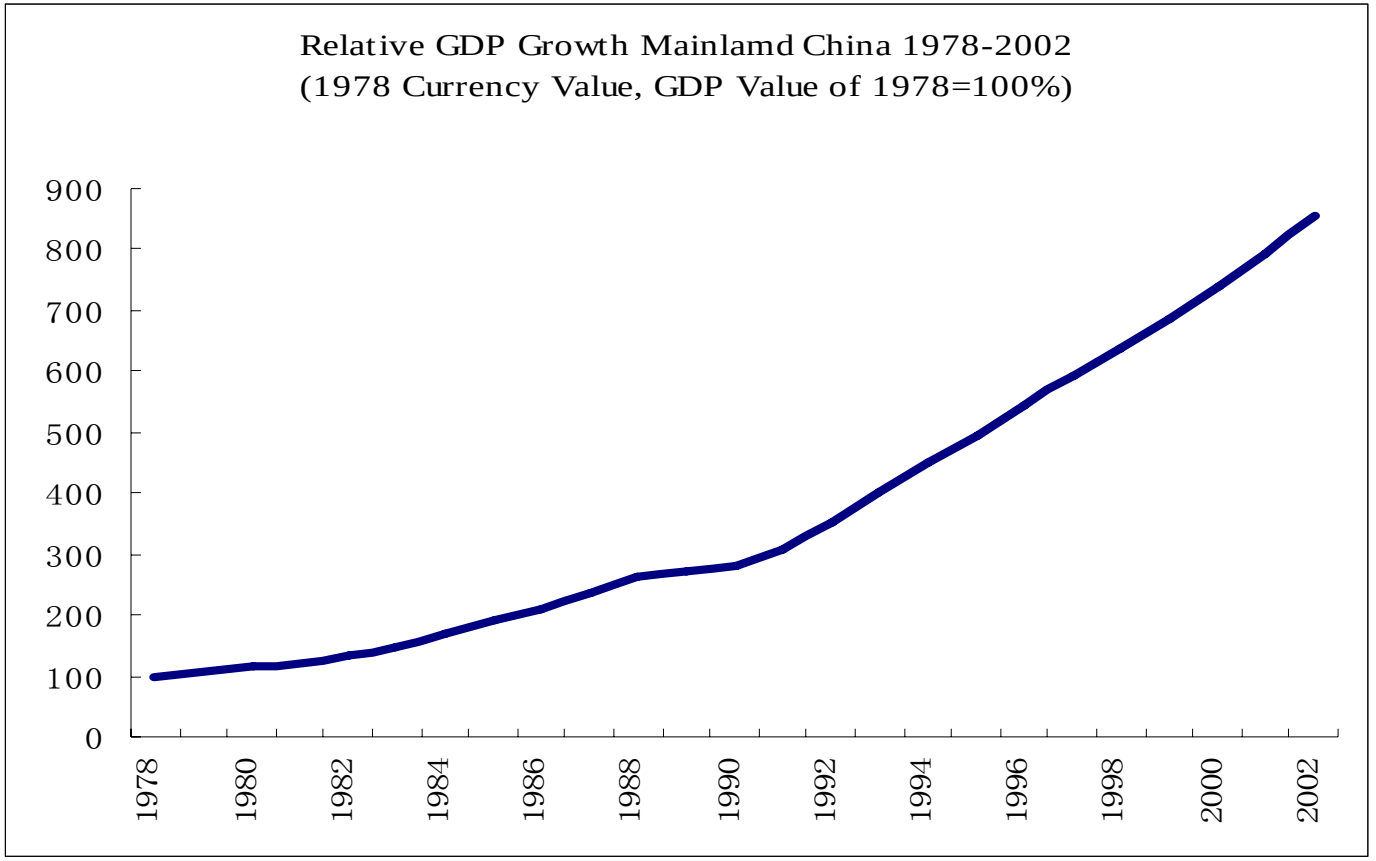

Figure 1 Relative GDP Growth

Introduction

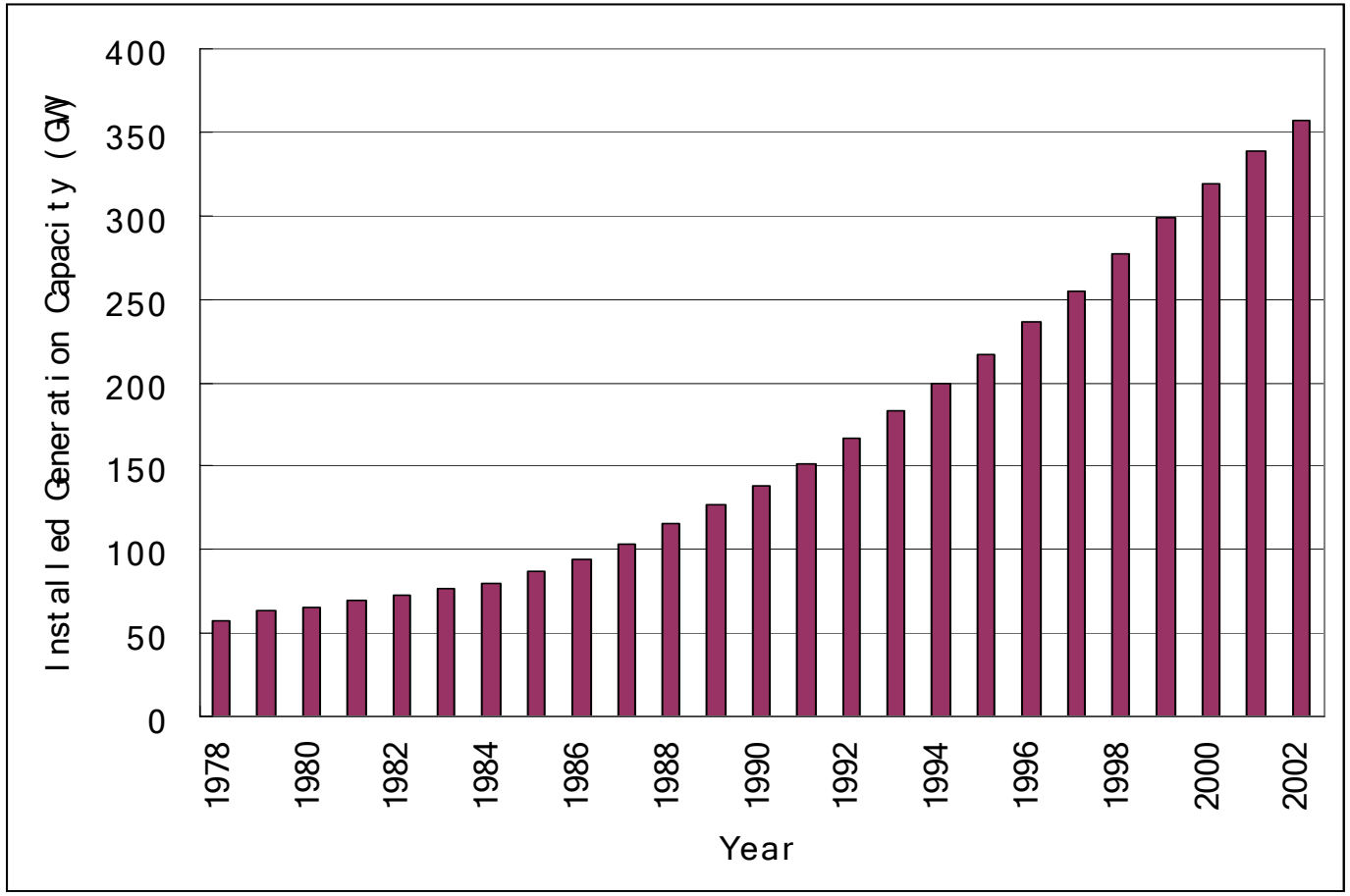

Figure 2 Generation Capacity Growth

Introduction

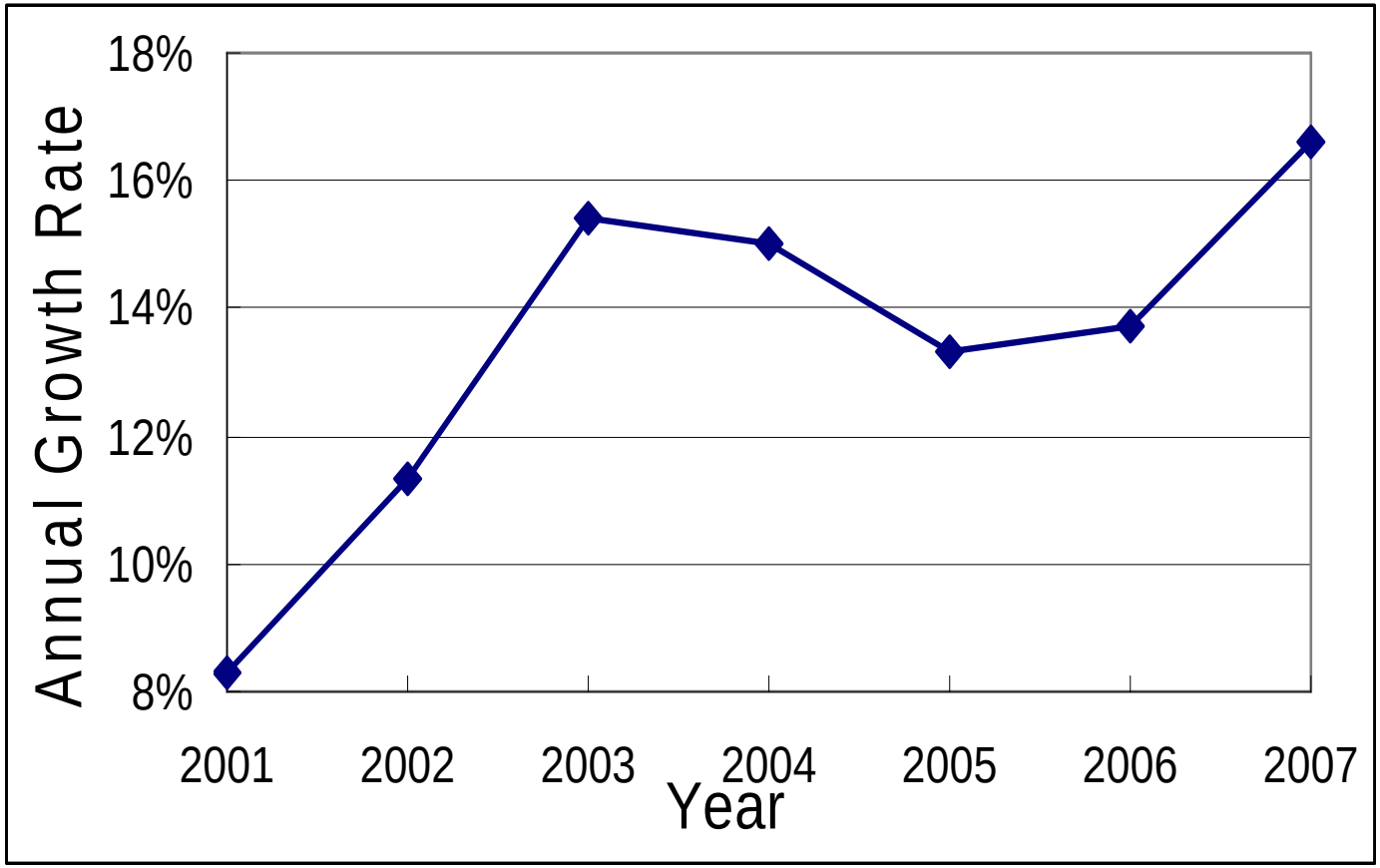

Figure 3 Generation Capacity Growth Rate (%)

Introduction

- The performance characteristics of NHR

  The nuclear heating reactor (NHR) is designed with a number of advanced and innovative features, including:

  - integrated arrangement
  - natural circulation
  - self-pressured performance
  - hydraulic control rod drive and a passive safety system

Introduction

- So, the NHR is one of the most suitable energy producing this process steam which can be used

  * in process heat of industry and

  * in seawater desalination.

Input parameters

- Design parameters

Thermal-hydraulic parameters:	
Thermal power output / MW_{th}	200
Operation pressure of core loop /MPa	4
Coolant flow rate of core loop /kg/s	1334.7
Temp. of core inlet/outlet /℃	228/250
Temp. of middle loop inlet/outlet /℃	210/230
Pressure of middle loop /MPa	4.5
Temp. of steam supply loop outlet /℃	197
Pressure of steam supply loop /MPa	1.5
Structural parameters of the reactor loop:	
Inner-diameter of pressure shell /m	4.5
Height of pressure shell /m	13
Shape of fuel assemblies	12×12
Number of fuel assemblies / sets	120
Number of control rod / sets	32

Input parameters

- Investment costs

The overnight cost /RMB Yuan million	615.67 (USD76.96)
The total capital investment /RMB Yuan million	898.35 (USD112.29)
The specific investment cost /RMB Yuan	4491.74 (USD561.45)

Input parameters

- Main economic parameters

Currency reference year /RMB	2005
Average burn up (equilibrium enrichment is 3% U235) / GW·d/tU	30
The depreciation of fixed asset /Year	30
The economic life /Year	30
Annual average loan interest rate /%	6.50
Annual price inflatable escalation rate /%	4.00
Annual average labor cost /Yuan/person	60,000
Water and electric price /Yuan/GJ	5.14
Value added tax /%	17
Enterprise income tax /%	33
Total operating availability /%	85

Economic analysis

- Cost component of PSNR200 at first year of operation with full load:

Cost items	PSNR200(RMB thousand Yuan)
Nuclear fuel cycle cost	27.92
Materials cost	3.32
Purchased water and electrical cost	26.97
Labor/ manager salaries	7.5
O&M cost	19.77
Depreciation of fixed asset	38.63
Payment interest cost	46.71
Annual total cost	170.82
Unit production cost (Yuan/t of steam)	90.68
Average Unit production cost (Yuan/t of steam) in economic life	64.23

Economic analysis

- Annual cost of PSNR200 during the calculation life:

Time /a	1	2	3	4	5	6	7 ~10	11~25	26~30
Annual total cost /RMB Yuan million	170.82	163.73	156.25	148.36	140.46	132.16	124.11	119.62	85.48
Unit cost /RMB Yuan/t	90.68	86.91	82.94	78.75	74.56	70.16	65.88	63.5	45.37
Average unit cost /RMB Yuan/t	64.23	64.23	64.23	64.23	64.23	64.23	64.23	64.23	64.23

Economic analysis

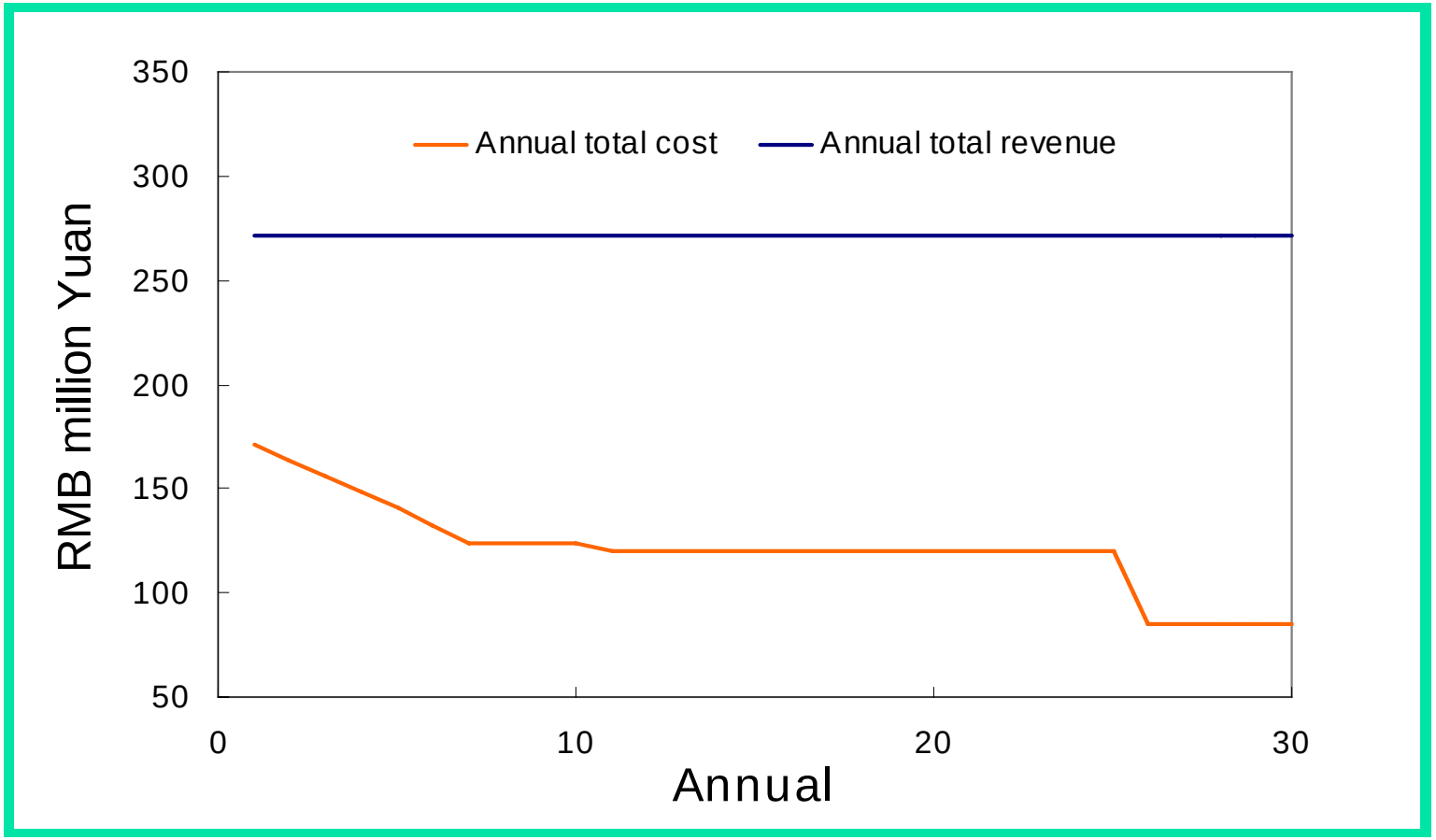

Figure 4 The revenue and cost of PSNR200

Economic analysis

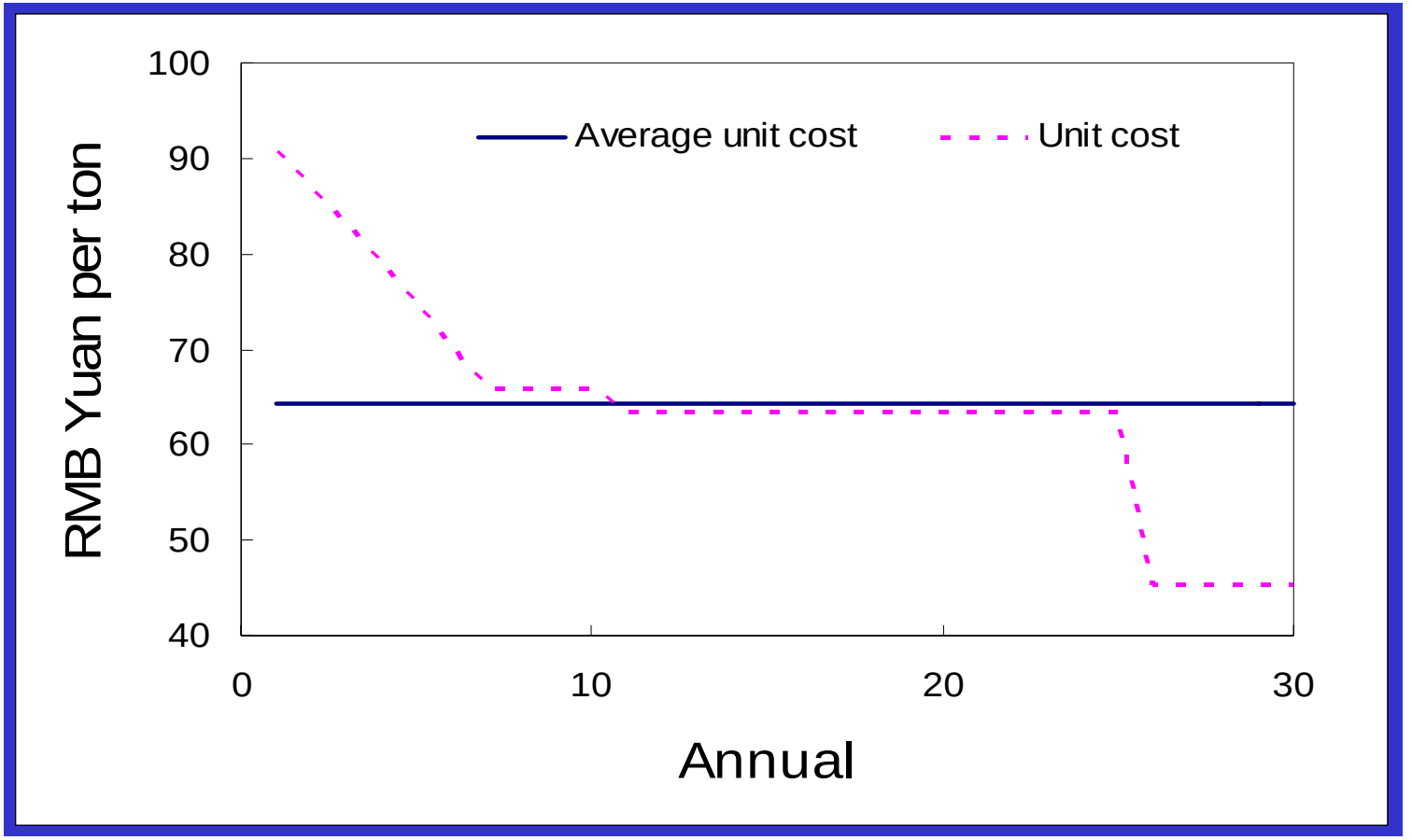

Figure 5 The unit cost of PSNR200

Economic analysis

- Results of calculation economic data of PSNR200

Option	PSNR200(million RMB Yuan)
Total capital investment costs	898.35
Nuclear power plant	808.35
Heating steam pipe net	90
Total annual revenue	271.27
Average unit cost in economic life time, RMB/t	64.23
Annual total profit of initial operation	70.44
Annual total profit of after payback	97.49
Capital recovery time (include lead time)/ years	8.34
Payback time (include lead time)/ years	9.98
Internal rate of return/ %	13.18
Net present worth (discount rate: 10%)	357.14

Economic calculation under the CDM

- Greenhouse gas reducing emissions calculations
  - The nuclear power plant (NPP) option is a virtually non-CO2 emitting energy, which avoids the emissions of about total weight of carbon (*TC*) each year compared to a coal-fired plant of the same electrical output is given by the following formula,

$$T_A = \frac{P_{we}}{R_e} \times 3600 \times 24 \times 365 \times O_A,$$

$$T_{ce} = \frac{T_A}{R_{ce}} \div R_B,$$

$$T_C = T_{ce} \times R_C$$

Economic calculation under the CDM

T_A – is total annual thermal quantity for a nuclear power plant, GJ

P_{we} – is reference power plant unit net electrical output, MW_{el}

R_e – is reference net thermal efficiency, %

O_A – is Operating availability

T_{ce} – is total annual coal-fired weight, ton of coal

R_B – is average coal-fired boiler efficiency, 70%

R_{ce} – is average heat value of reference coal equivalent per kilogram, 29680 kJ/kg [5]

R_C – is exchange rate of coal equivalent and carbon equivalent, 0.714 [6]

Economic calculation under the CDM

- The results of greenhouse gas reducing emissions in PSNR200 per year

184,243 tones of carbon→675,559 tones of CO2

during their 30 years economic life time.

Economic calculation under the CDM

- Carbon taxes and economic indexes sensitivities of PSNR200

Carbon Taxes, $/ton of CO_2	**0**	15	25	35	45	55
Annual increased extensional profit /million RMB Yuan	**0**	81.07	135.11	189.16	243.2	297.25
Payback time (include lead time)/ years	**9.98**	7.88	7.14	6.64	6.29	6.02
Internal rate of return/ %	**13.18**	17.99	20.86	23.53	26.03	28.38
Annual net present worth (discount rate: 10%) /million RMB Yuan	**357.14**	845.29	1170.71	1496.14	1821.57	2147

Conclusion

- The calculation results indicated **a significant economics** in process steam application in oil and chemical industry from the PSNR200.

- The economics of the PSNR200 is **significantly improved** while account on the environment benefits using the clean development mechanism (CDM)
  - The total annual revenue is from RMB Yuan 271.27 million to RMB Yuan 406.27 million,
  - Internal rate of return is from 13.18 to 20.86%,
  - Maximum net present worth values (discount rate: 10%) is from RMB Yuan 357.14 million to RMB Yuan 1170.04 million.

Thank you !