Supercritical and Ultra-Supercritical Power Plants –

SEA's Vision or Reality?

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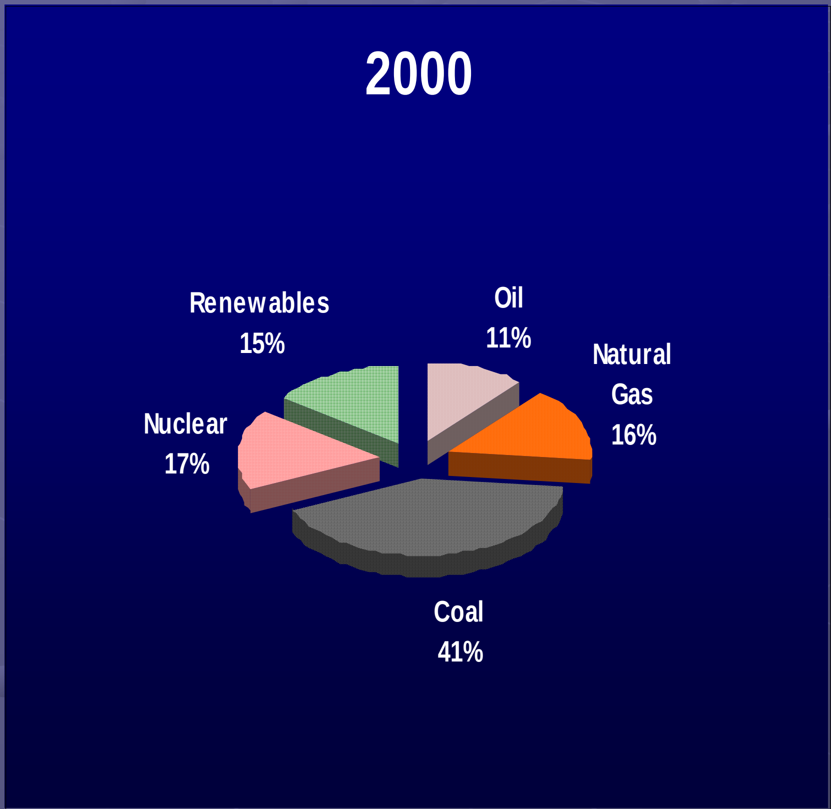
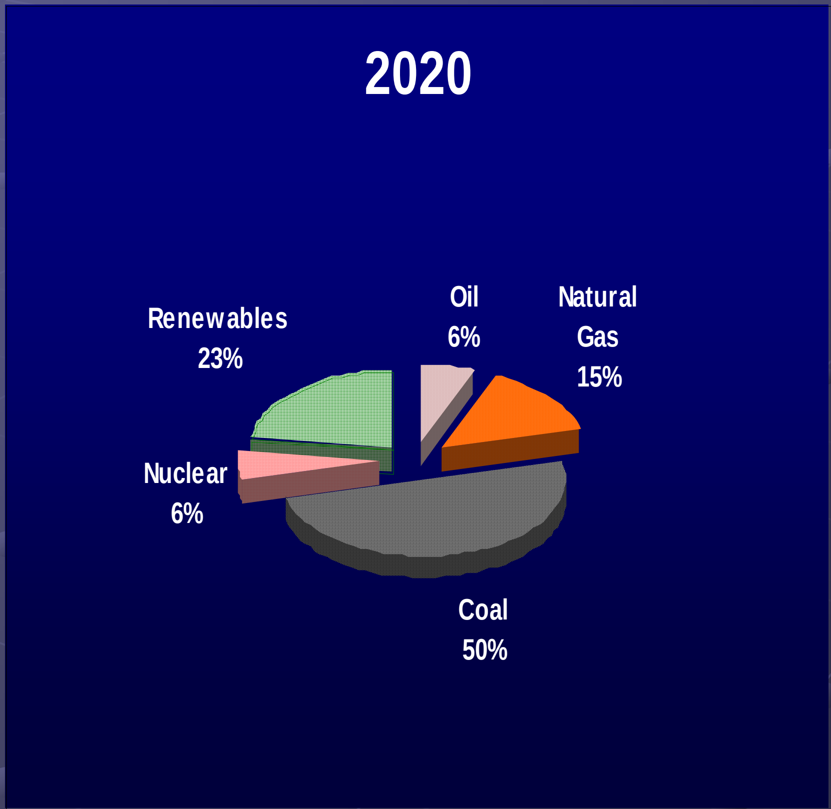
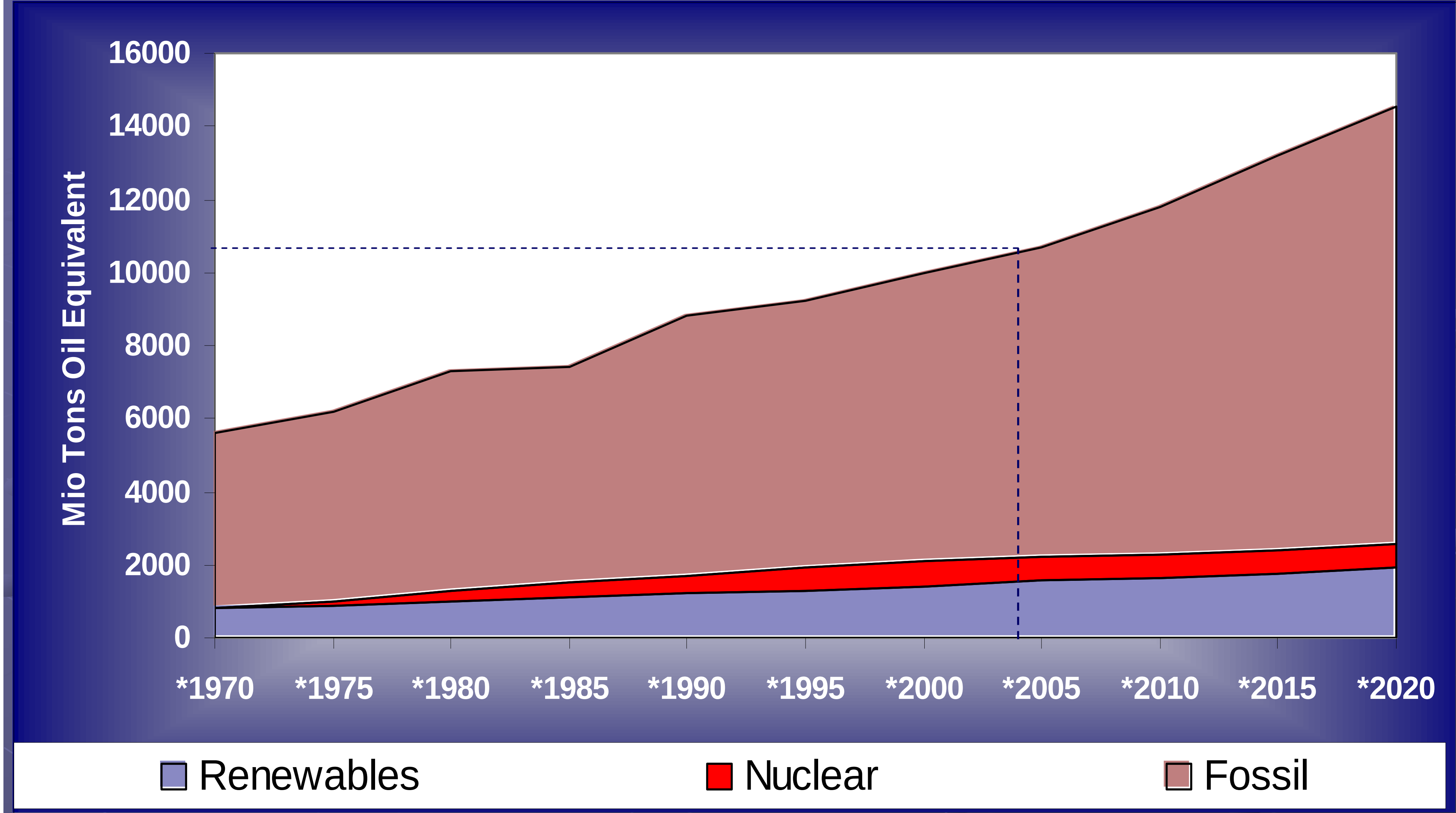
Powergen Asia 2004 **Bangkok**

Fuel Share of World Electricity Generation

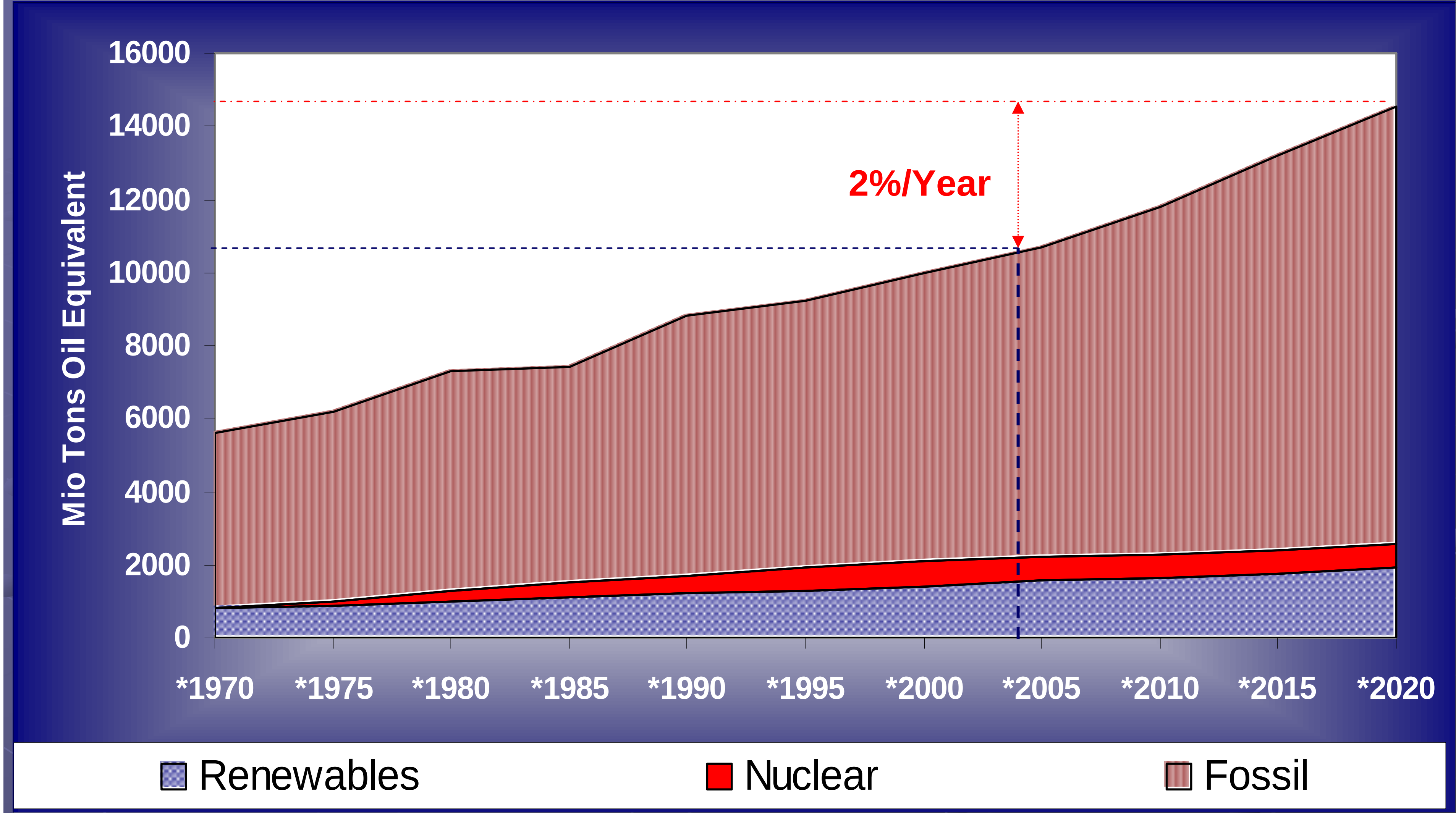




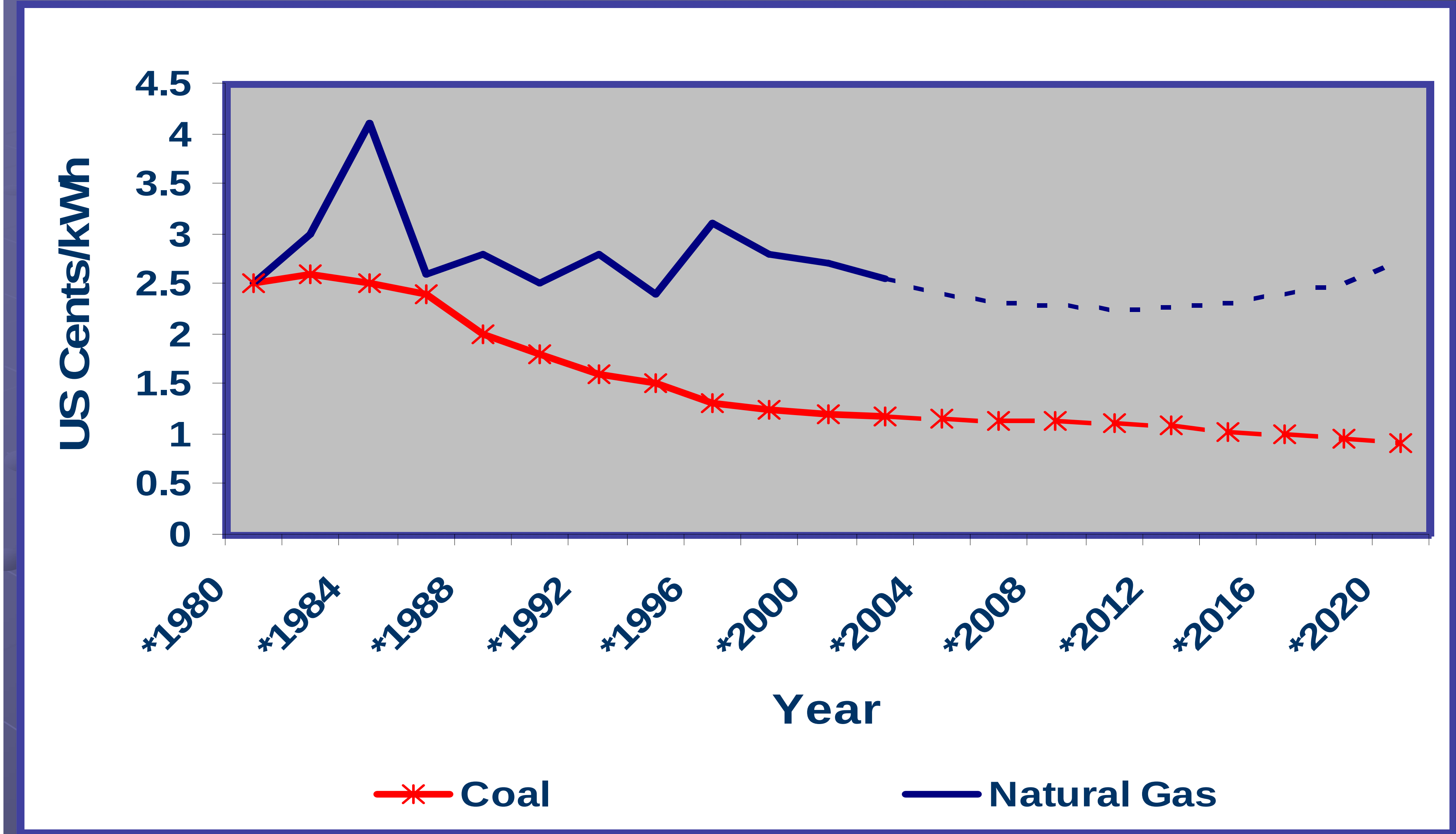
World Energy Supply by Fuel 1970-2020



World Energy Supply by Fuel 1970-2020



Fuel Cost for Coal and NG based Power Plants



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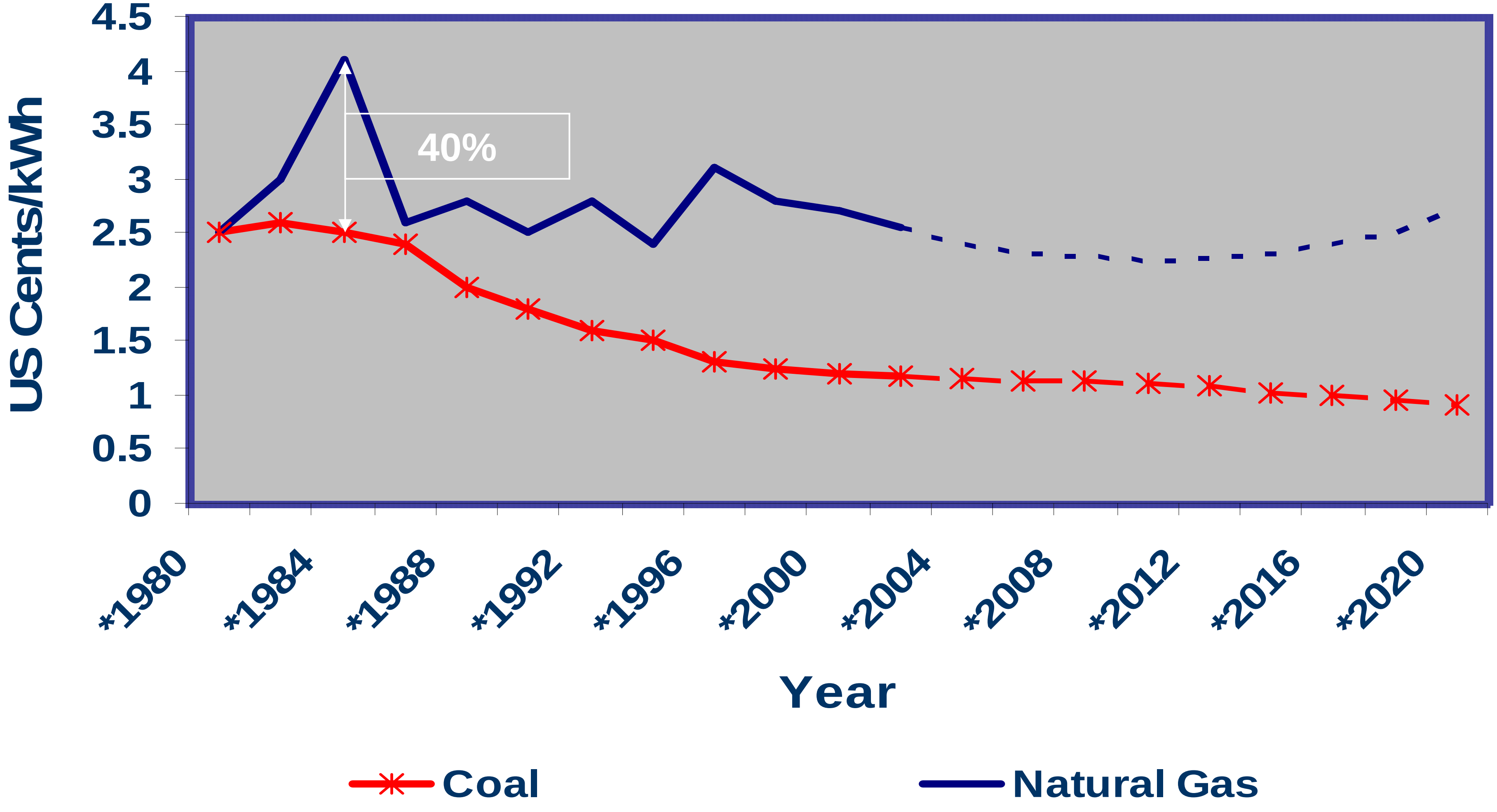

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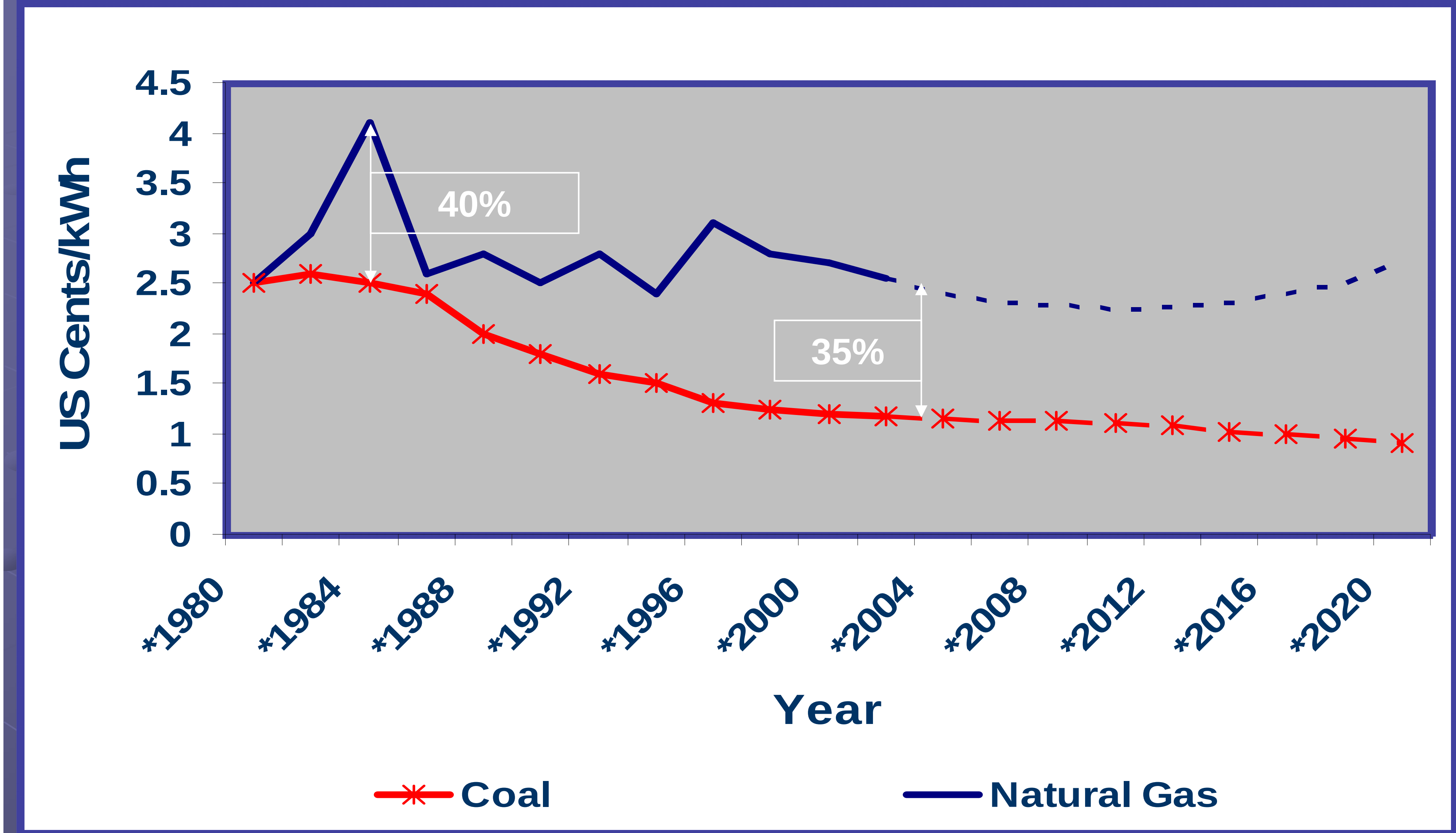
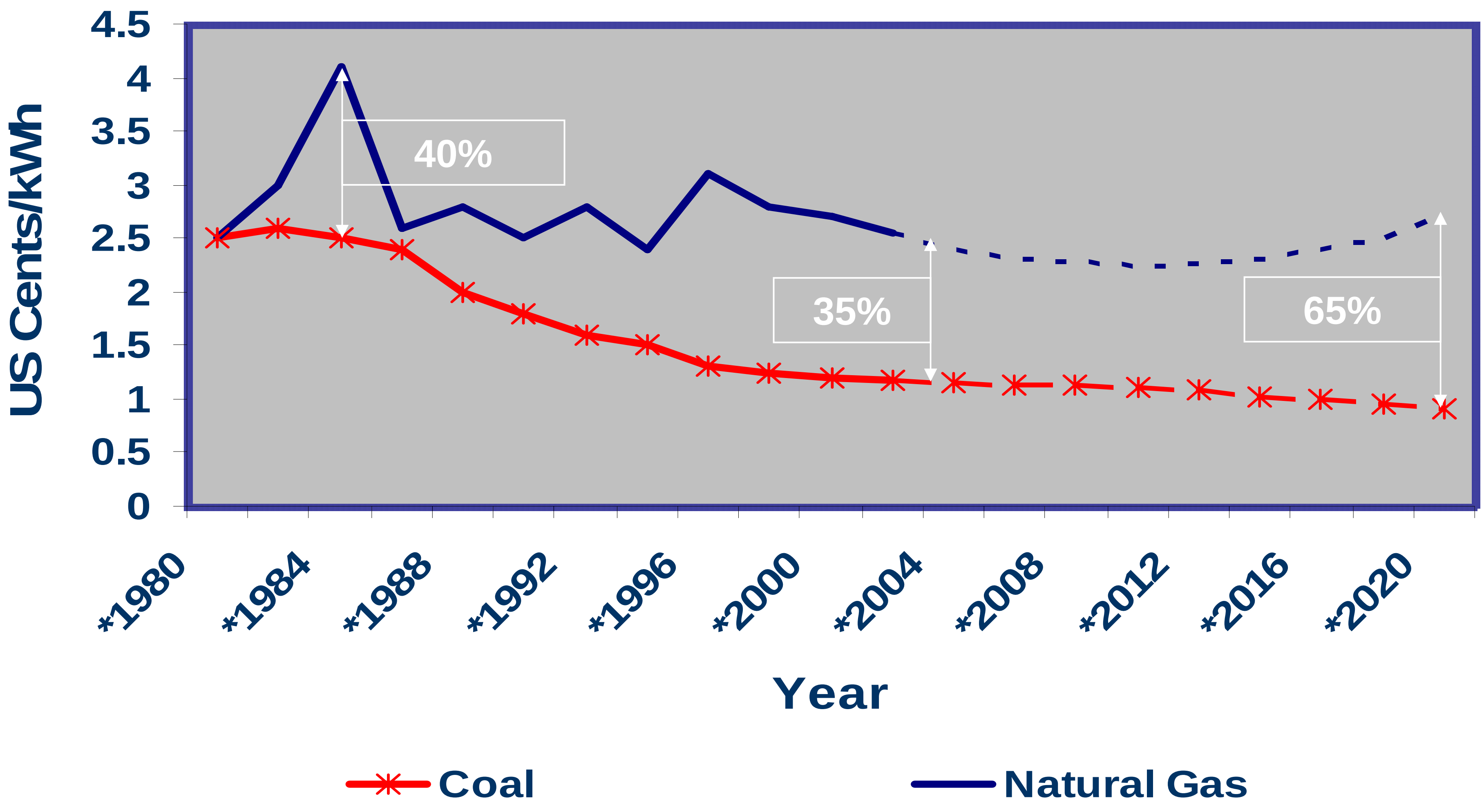
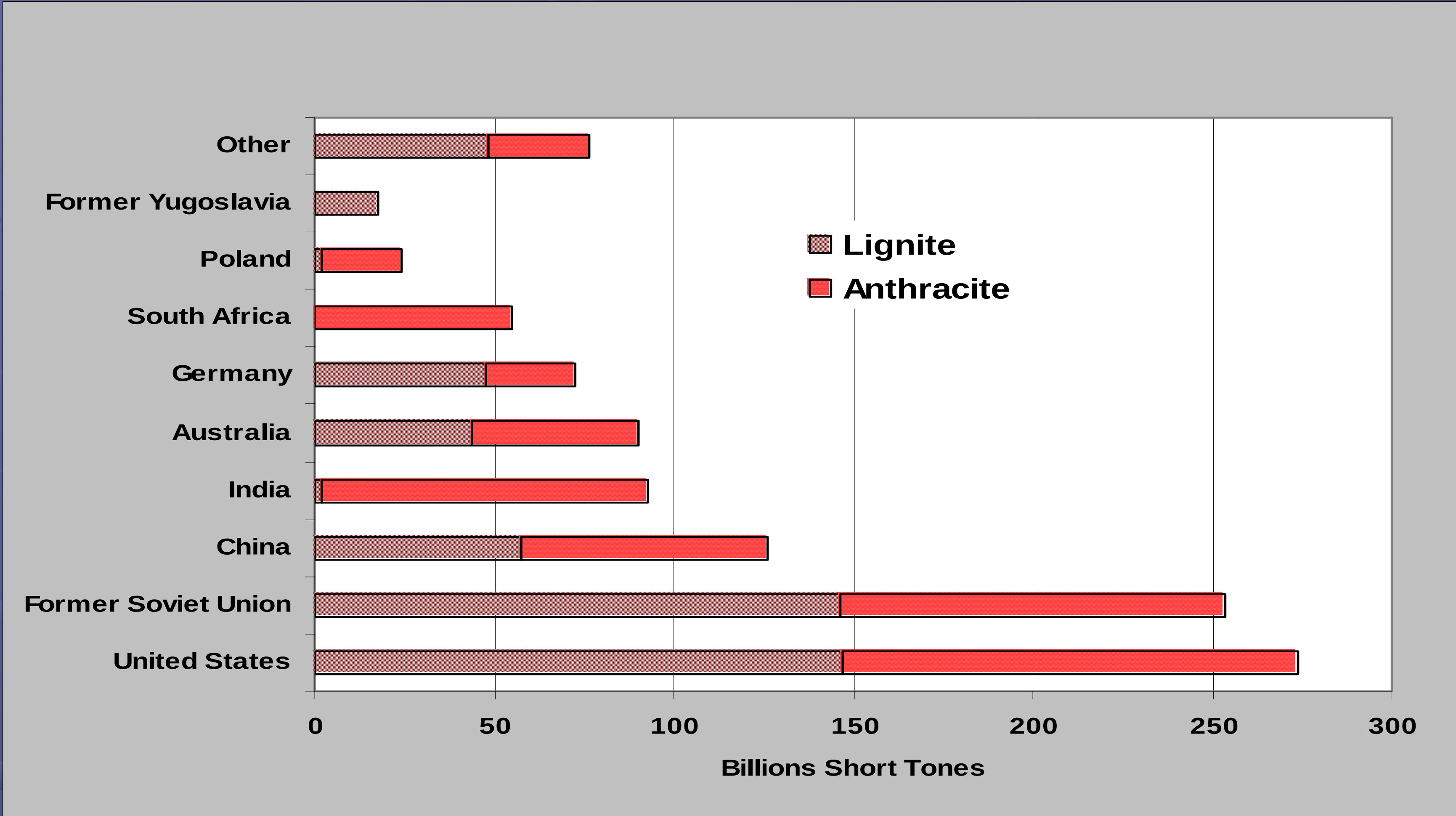


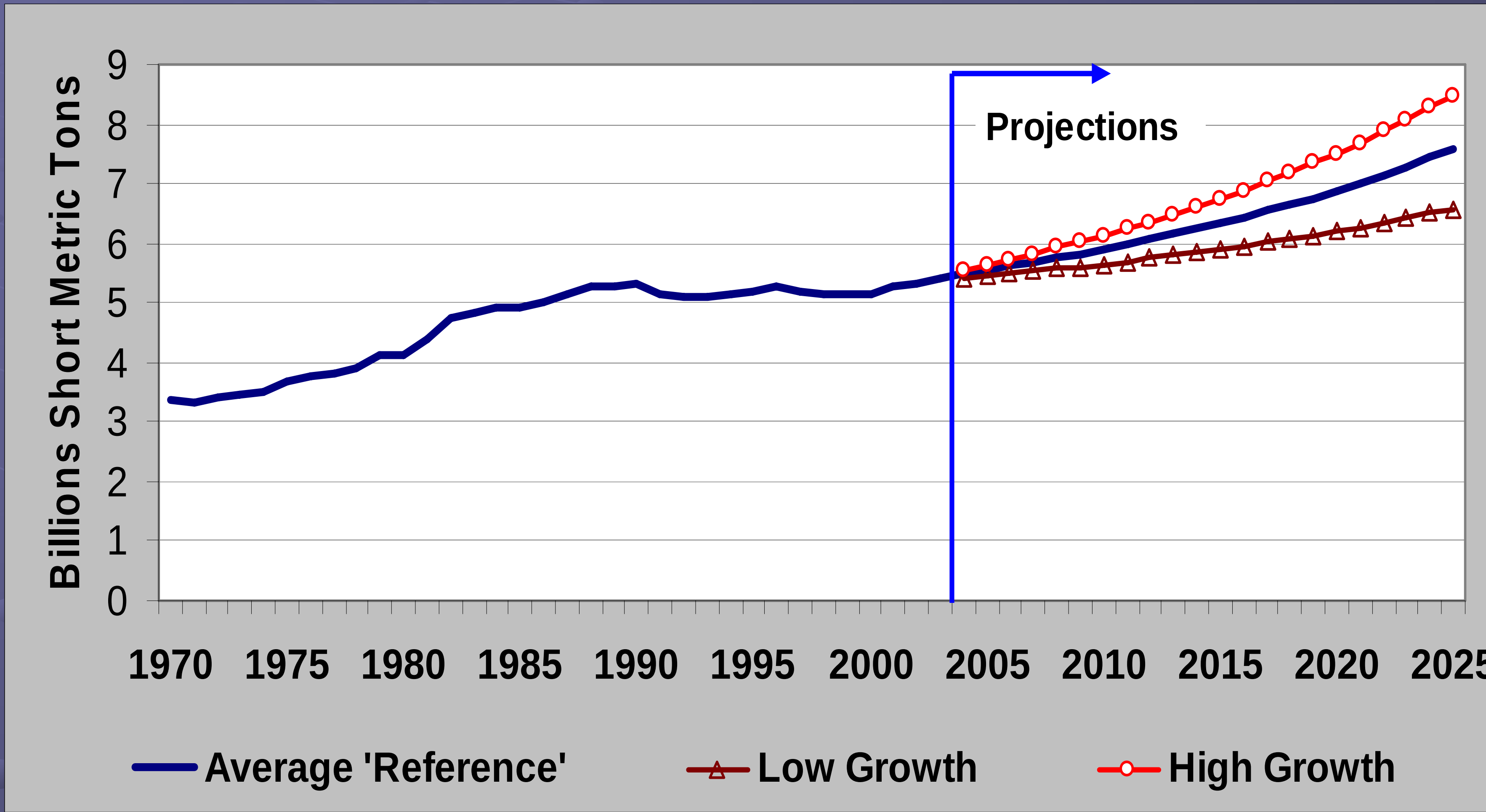
Fuel Cost for Coal and NG based Power Plants



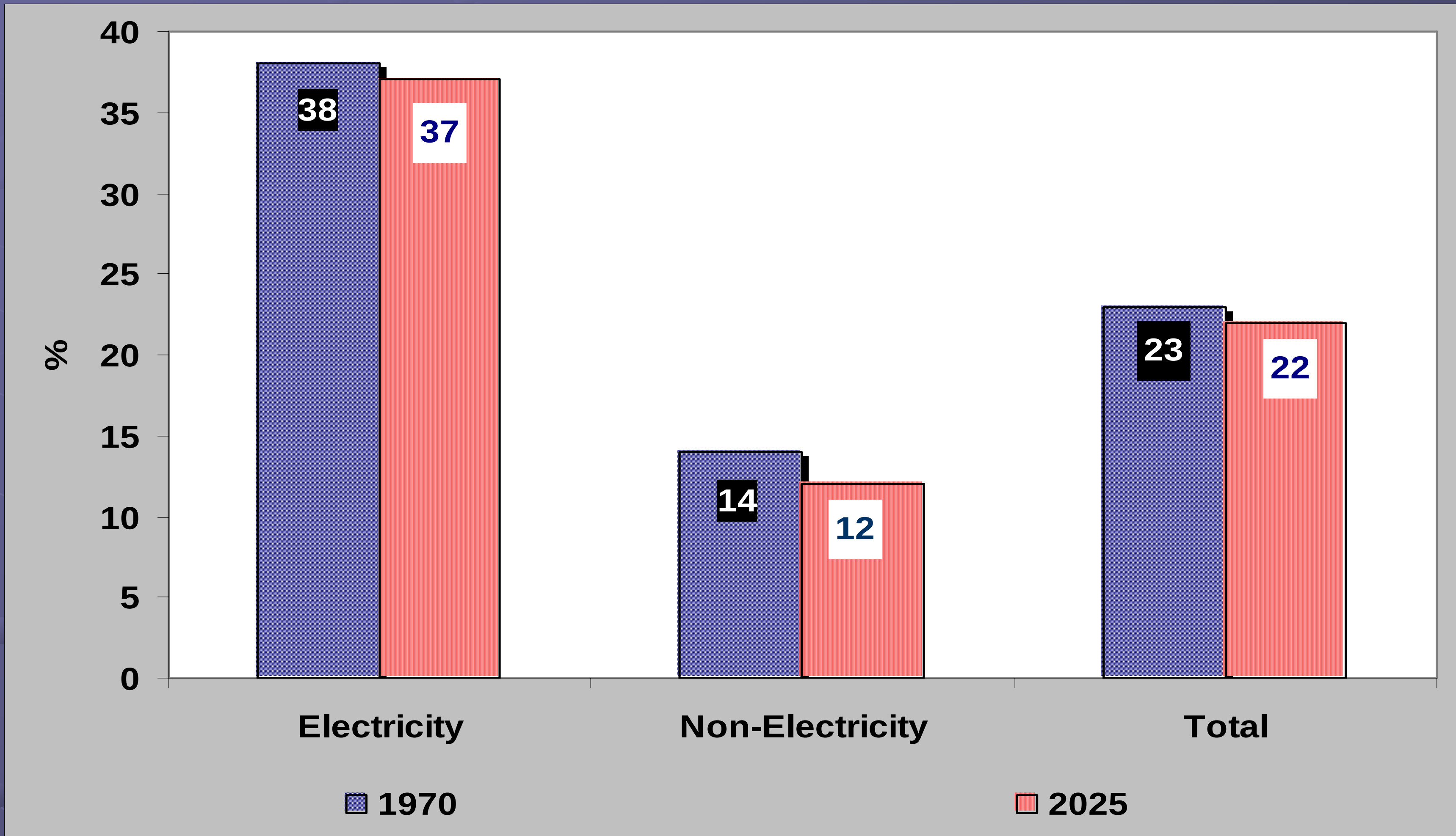
World Recoverable Coal Reserves

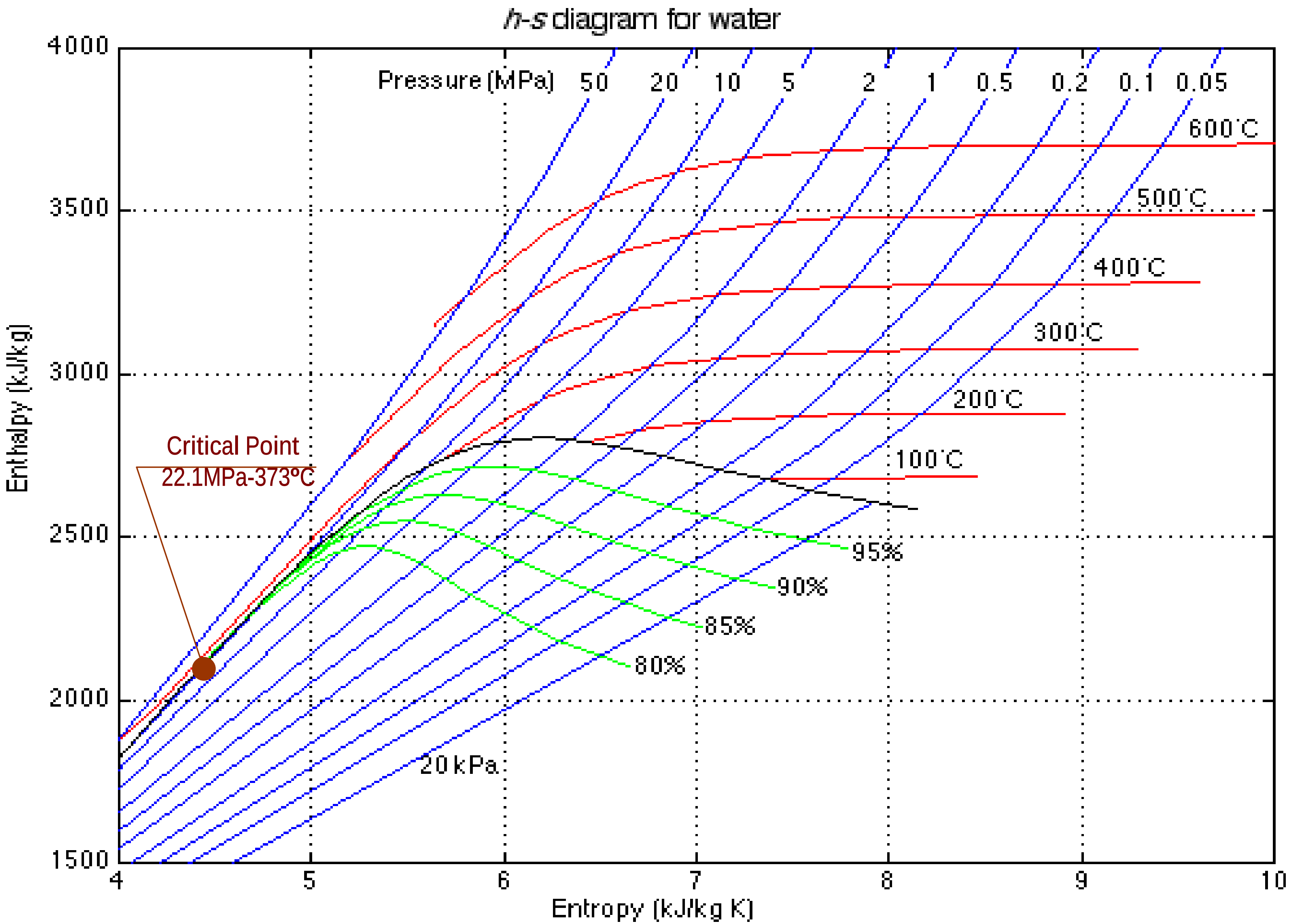


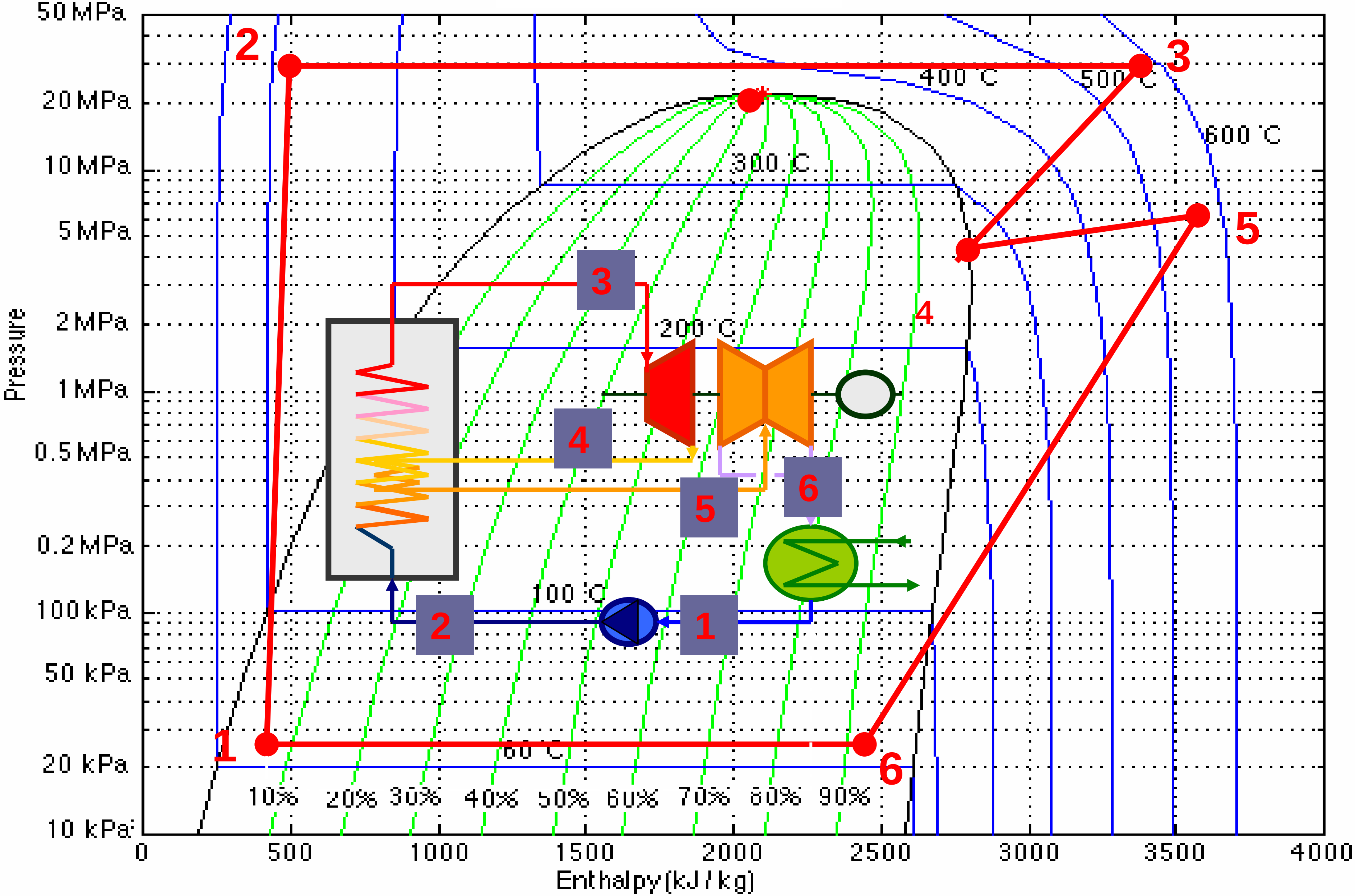
World Coal Consumption



Coal Share of World Energy




h-s diagram for water
Pressure (MPa)
50
20
10
5
2
1
0.5
0.2
0.1
0.05
600°C
500°C
400°C
300°C
200°C
100°C
Critical Point
22.1MPa-373°C
95%
90%
85%
80%
20 kPa
Enthalpy (kJ/kg)
Entropy (kJ/kg K)
4000
3500
3000
2500
2000
1500
4
5
6
7
8
9
10



50 MPa
20 MPa
10 MPa
5 MPa
2 MPa
1 MPa
0.5 MPa
0.2 MPa
100 kPa
50 kPa
20 kPa
10 kPa
Pressure
0
500
1000
1500
2000
2500
3000
3500
4000
Enthalpy (kJ / kg)
400 °C
500 °C
600 °C
300 °C
200 °C
100 °C
60 °C
10%
20%
30%
40%
50%
60%
70%
80%
90%
1
2
3
4
5
6

Conventional vs. SC & USC

Conventional, SC and USC technology is commercially available in wide range of size.

Conventional vs. SC & USC

SC & USC technology offers higher efficiency and consequently lower specific flue gas throughput resulting in much cleaner electricity generation.

Conventional vs. SC & USC

Conventional technology provides greater coal flexibility

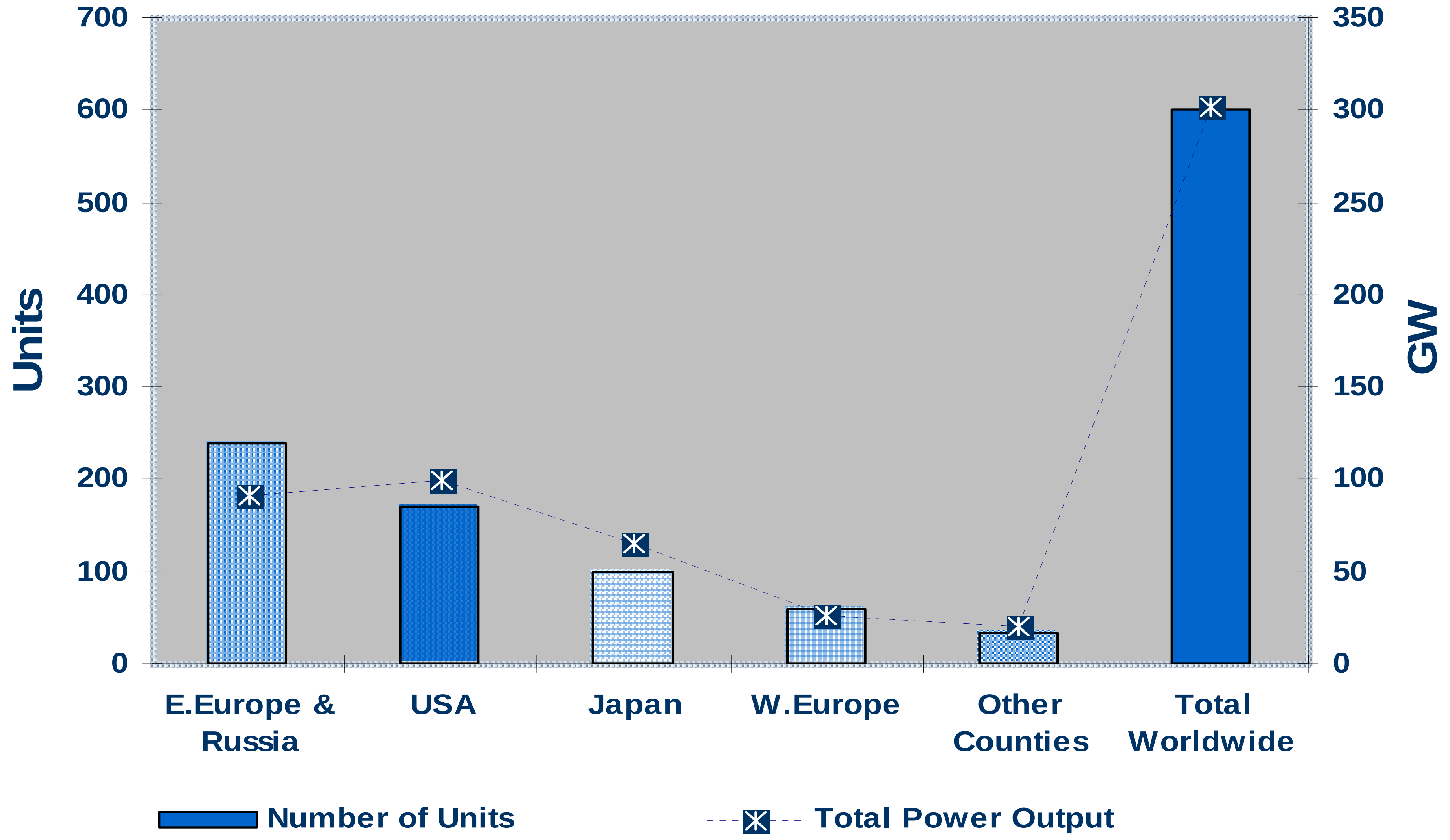
Conventional vs. SC & USC

Higher temperatures encountered in SC & USC units' makes corrosion more critical, thus coals with slugging or corrosion potential are less suitable for SC & USC plants.

Conventional vs. SC & USC

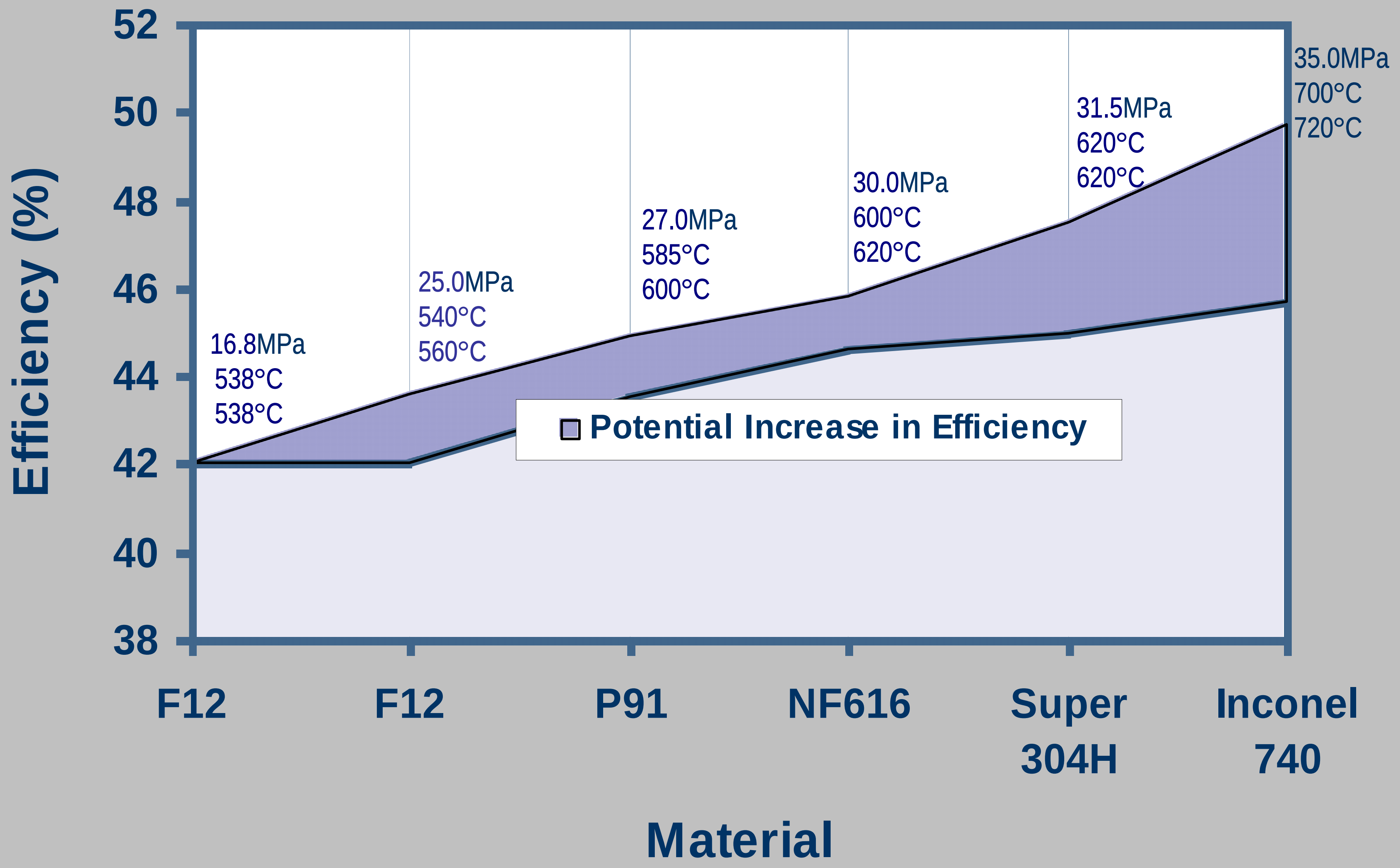
State-of-the-art SC power plants have an efficiency of about 46% and satisfy current emission standards worldwide.

Capacity of SC & USC Power Plants Worldwide



Comparison SC - USC vs. Conventional

Plant Type	Price US$/ kW	Steam Pres. MPa	Steam Temp. °C	Auxiliary Cons. %	Eff. %	CO_2 g/kWh	SO_2 g/kWh)
Conventional	850	165	538 / 538	4-6	< 40.0	≈ 855	≈ 2.4
580°C - SC	1050	290	580 / 580 / 580	5-7	> 42.0	≈ 780	≈ 2.2
700°C - USC	1100	365	700 / 700 / 700	6-8	> 48.0	≈ 710	≈ 2.0


Efficiency (%)
52
50
48
46
44
42
40
38
16.8MPa
538°C
538°C
25.0MPa
540°C
560°C
27.0MPa
585°C
600°C
30.0MPa
600°C
620°C
31.5MPa
620°C
620°C
35.0MPa
700°C
720°C
Potential Increase in Efficiency
F12
F12
P91
NF616
Super 304H
Inconel 740
Material

Steam Pressure - Temperature & Material Development

Live steam		When	What
Pressure MPa	Temperature °C		
<25.0	<520	Since early 60's	X20
<30.0	<593	Since late 80's	P91 9%Cr
<33.0	<620	Start 2000	P92 NF616
35.0-47.0	700-720	Start 2010	Super Alloys

Materials for SC-ST Applications

Steam temperature	>600°C	538°C
Rotor	New 12 Cr forging	Cr-Mo-V forging
Inner HP casing	No 1 Cr-Mo-V-B cast steel	1 ¼ Cr – ½ Mo cast steel
Inner IP casing	12 Cr cast steel	1 ¼ Cr – ½ Mo cast steel
Outer casing	2 ¼ Cr – 1Mo cast steel	1 ¼ Cr – ½ Mo cast steel
Rotating blade	Refractory alloy (R-26)	12 Cr forging
Main steam stop valve	9 Cr - 1 Mo forging	2 ¼ Cr – 1Mo forging
Main steam governing valve	9 Cr – 1 Mo forging	2 ¼ Cr – 1Mo forging

Selected SC & USC Power Plants

No	Power Plant Name	Country	Output (MW)	Live Steam (MPa / °C / °C)	Efficiency (%)	Fuel	Commercial Operation
❶	Matsuura	Japan	1000	25.5 / 598 / 596		PC	1997
❷	Haramashi	Japan	1000	25.9 / 604 / 602		PC	1998
❸	Tachibana-Wan-2	Japan	1050	26.4 / 605 / 613	47.0	PC	2001
❹	Isogo 1 & 2	Japan	2 x 500	24.5 / 600 / 600	46.0	PC	2001
❺	Hitachinaka	Japan	1000	24.5 / 600 / 600		PC	2003
❻	Torrevaldaliga	Italy	6 x 660	25.0 / 600 / 610	45.0	PC	2006
❼	Yuhuan	PR China	2x1000	25.0 / 600 / 600		PC	2008
❽	Niederaussem	Germany	1000	27.5 / 580 / 600	45.2	L	2002
❾	Nordjyllaend 3	Denmark	410	29.0 / 582 / 580	47.0	PC	1998
❿	Misumi 1	Japan	600	25.0 / 605 / 600	46.0	PC	2001
①	Tomato Atsuma 4	Japan	700	25.0 / 600 / 600		PC	2002
②	Skaerbaek 3	Denmark	410	29.0 / 582 / 580	49.0	NG	1997
③	Nanaoota 2	Japan	700	25.5 / 597 / 595		PC	1998
④	Tsuruga 2	Japan	700	25.5 / 597 / 595		PC	2000
⑤	Avedore 2	Denmark	450	30.0 / 580 / 600	49.7/48.2/ 45.0	NG/PC/BS	2001

USC Power Plant Avedore - Denmark

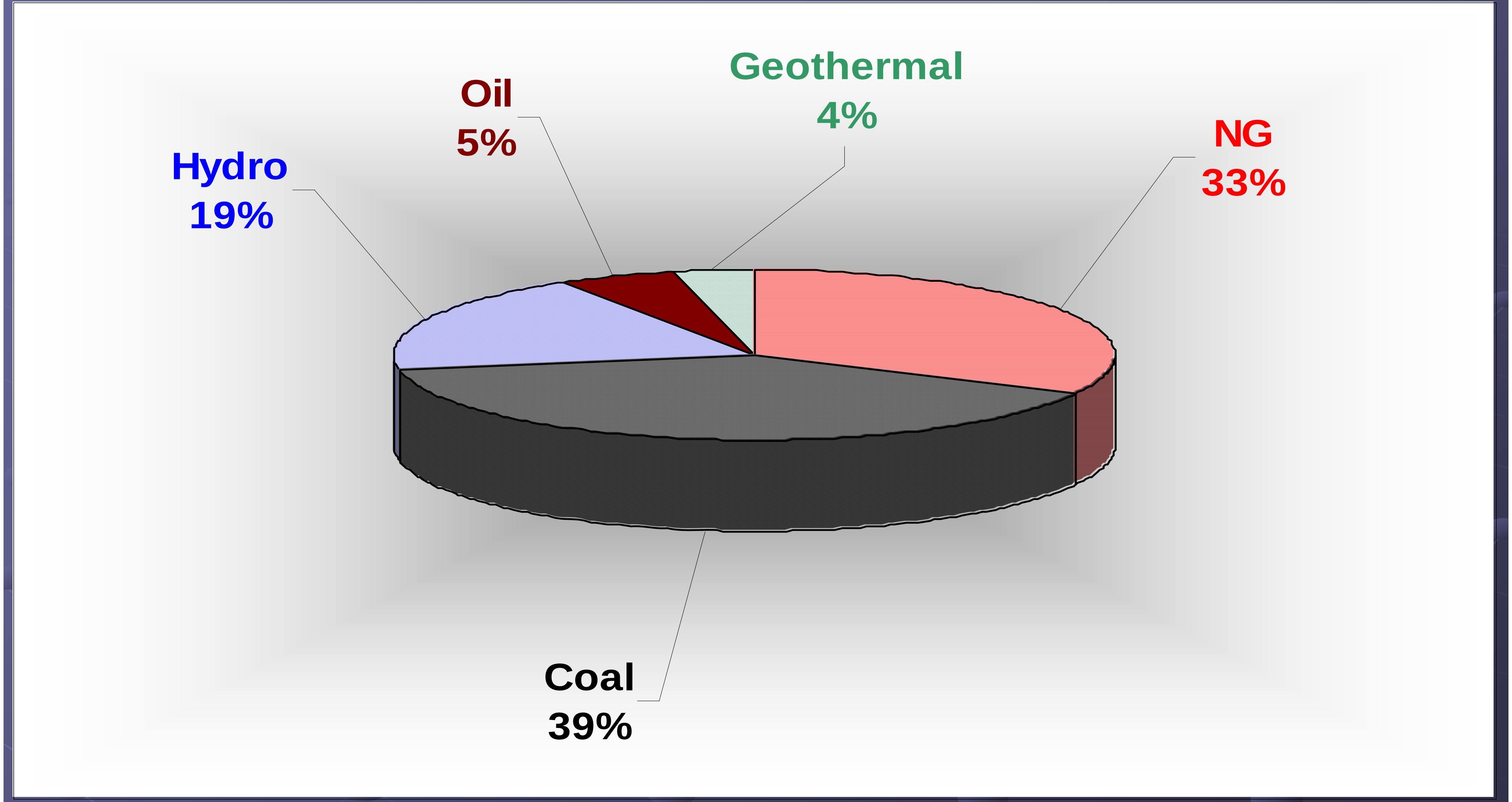
SC Power Plant Misumi - Japan

Niederaussem

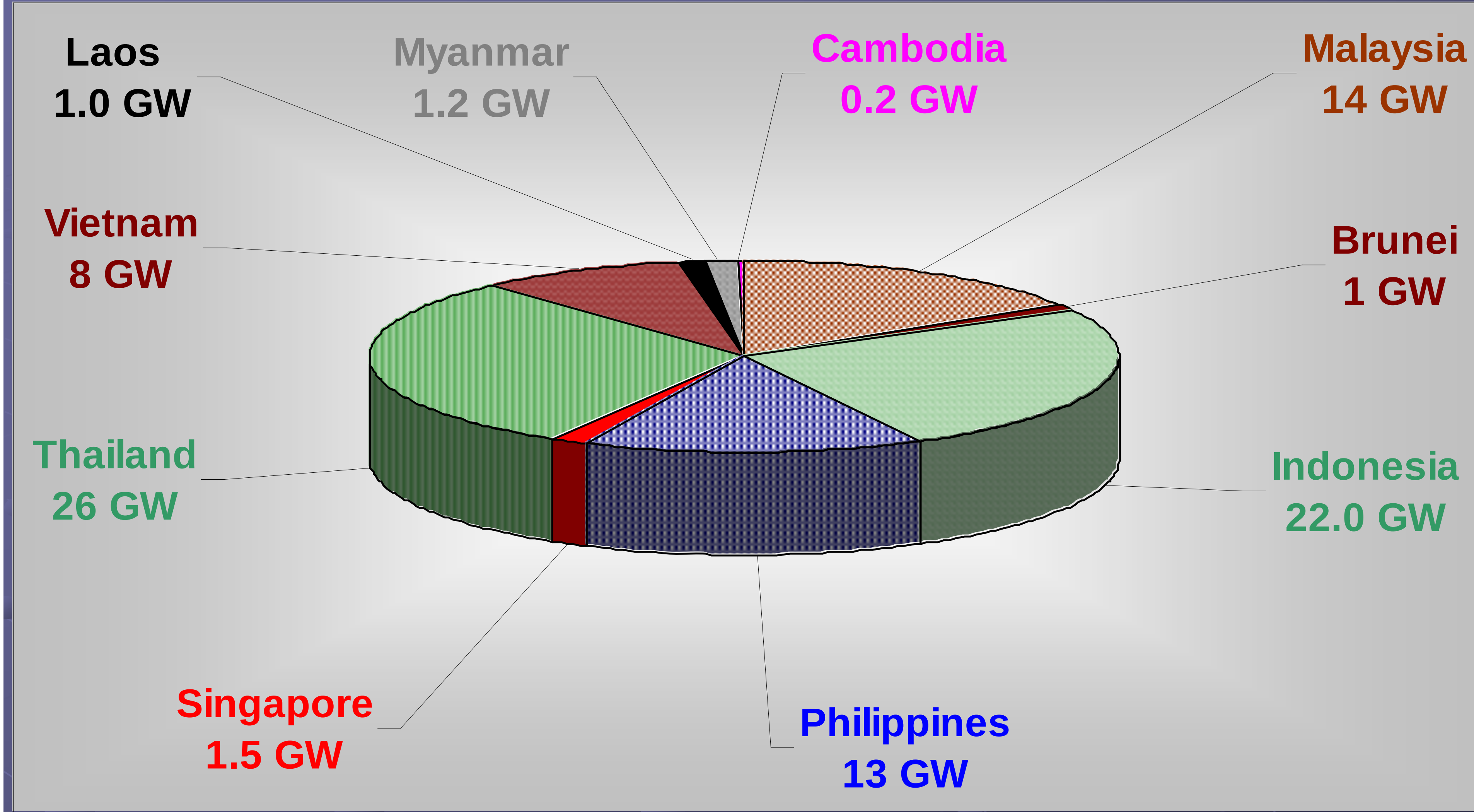
Tachibana-Wan Power Station

Isogo Power Station

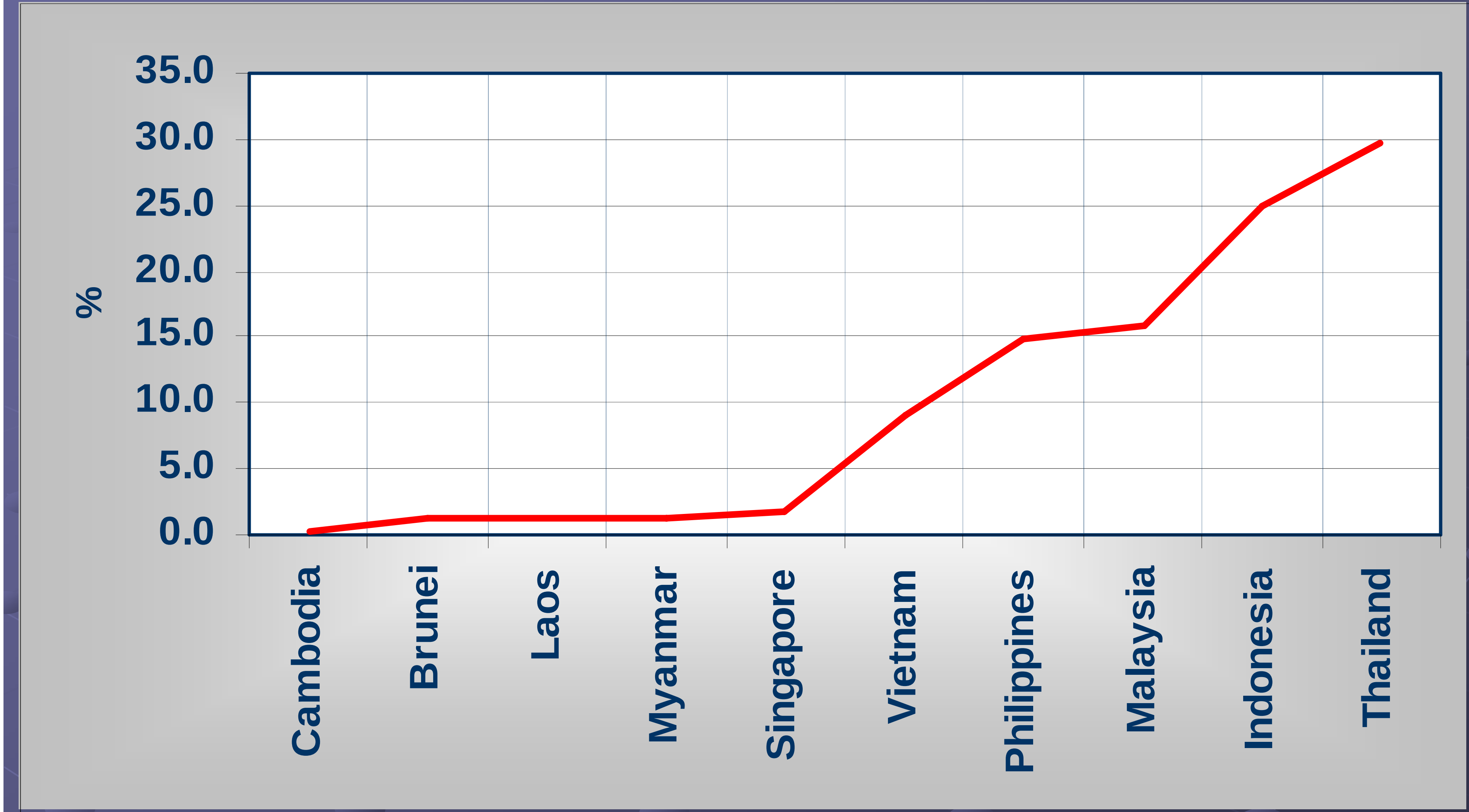
SEA Power Generation Fuel Split 2004



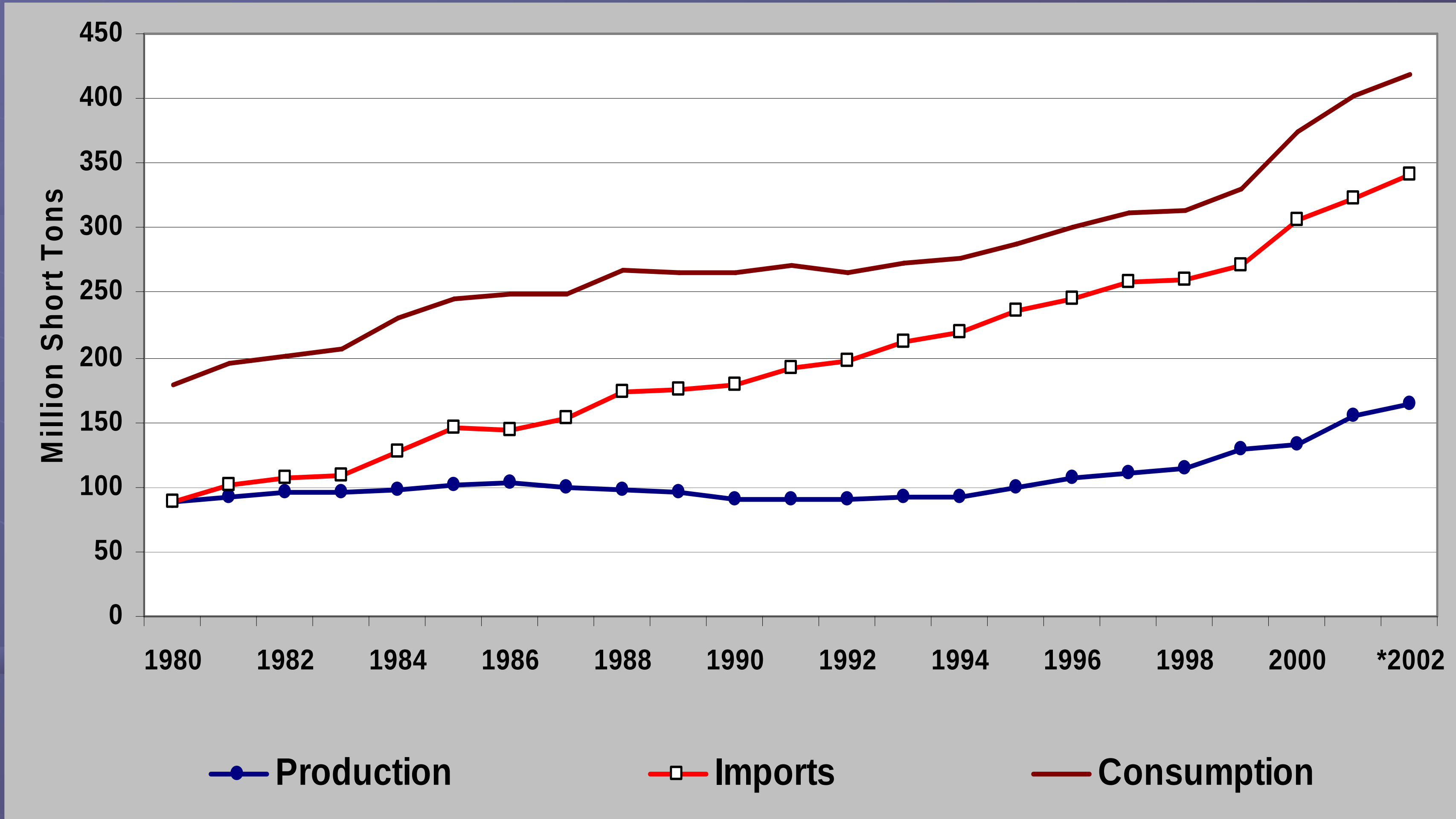
SEA Power Generation Capacity 2004



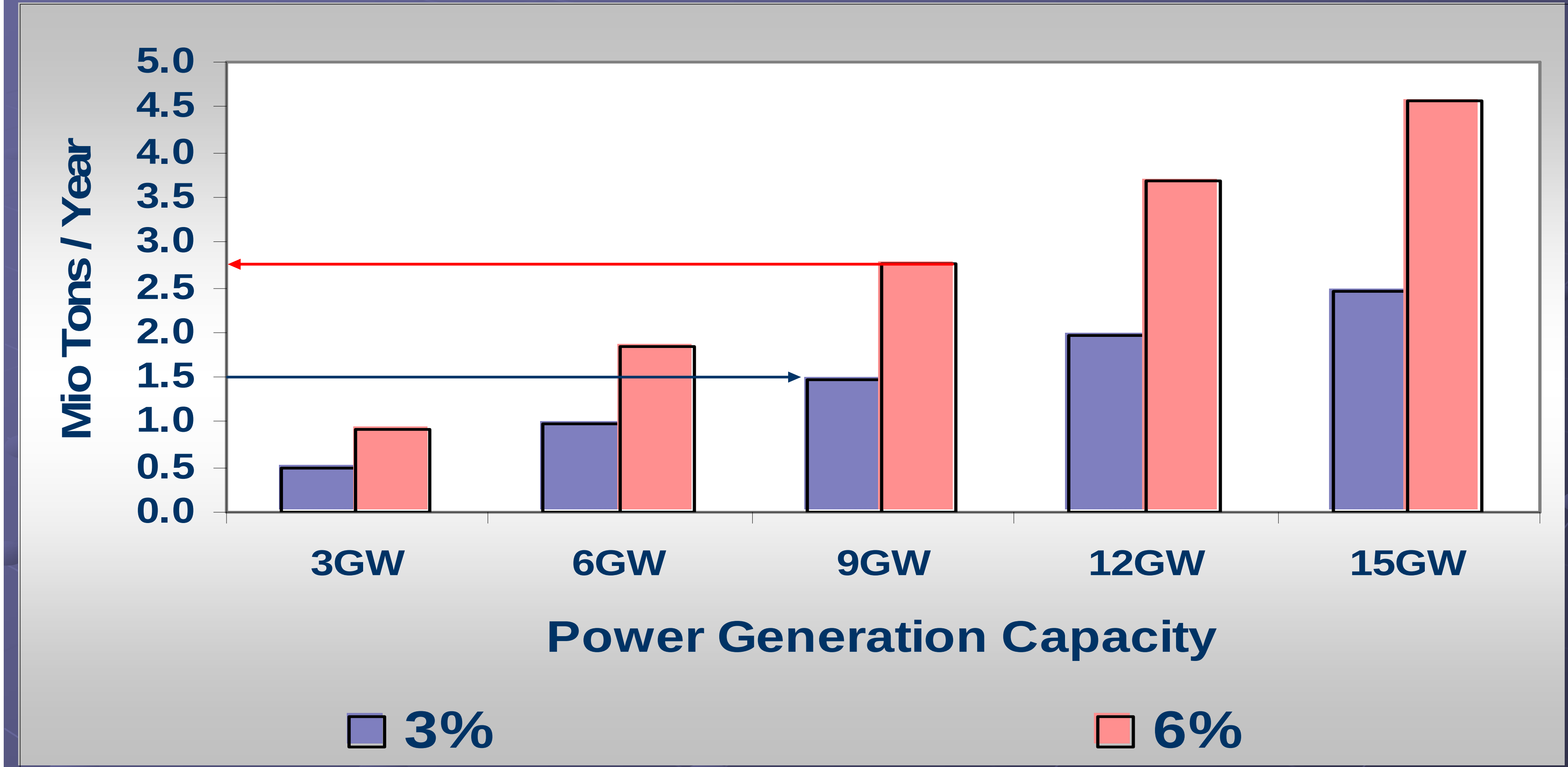
SEA Power Generation Capacity 2004



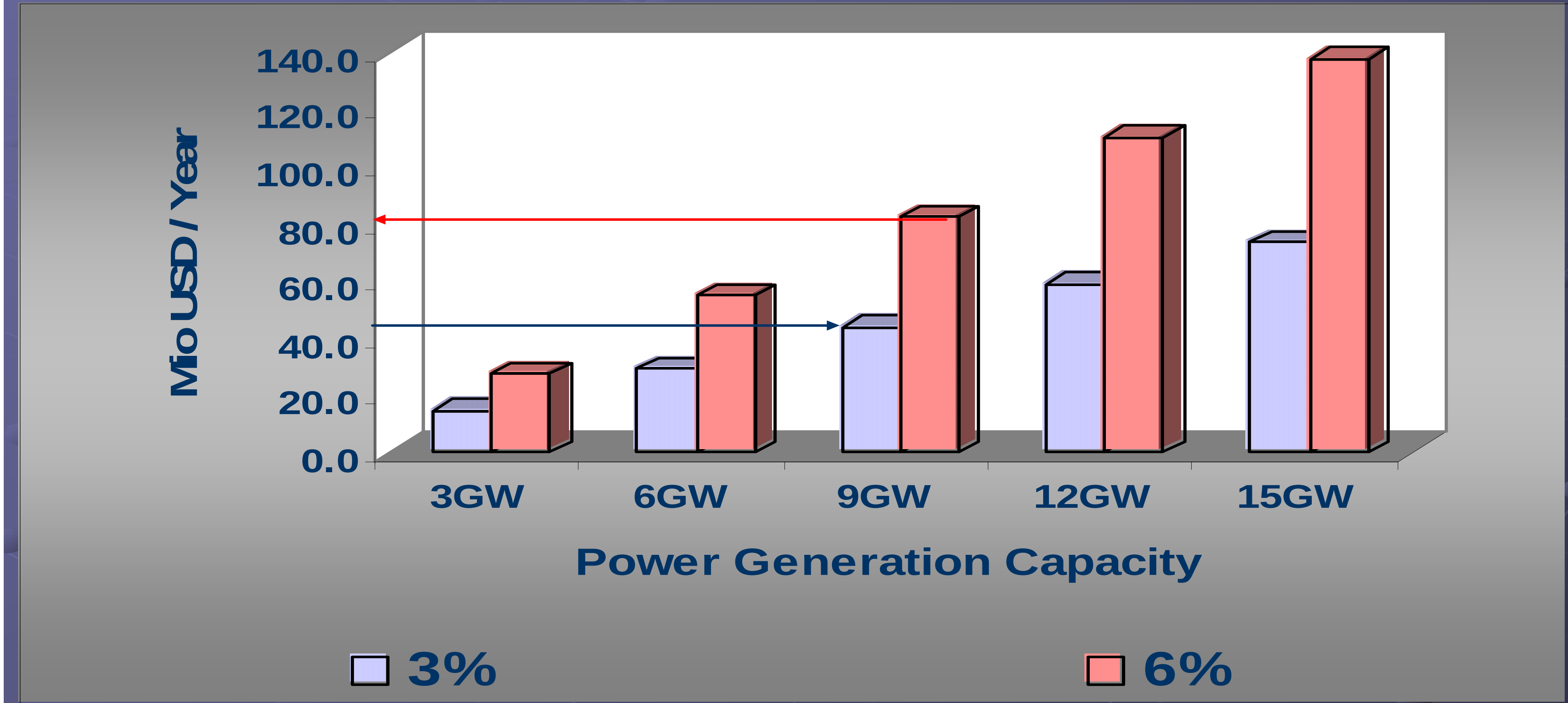
Hard Coal Management in Asia



Coal Savings

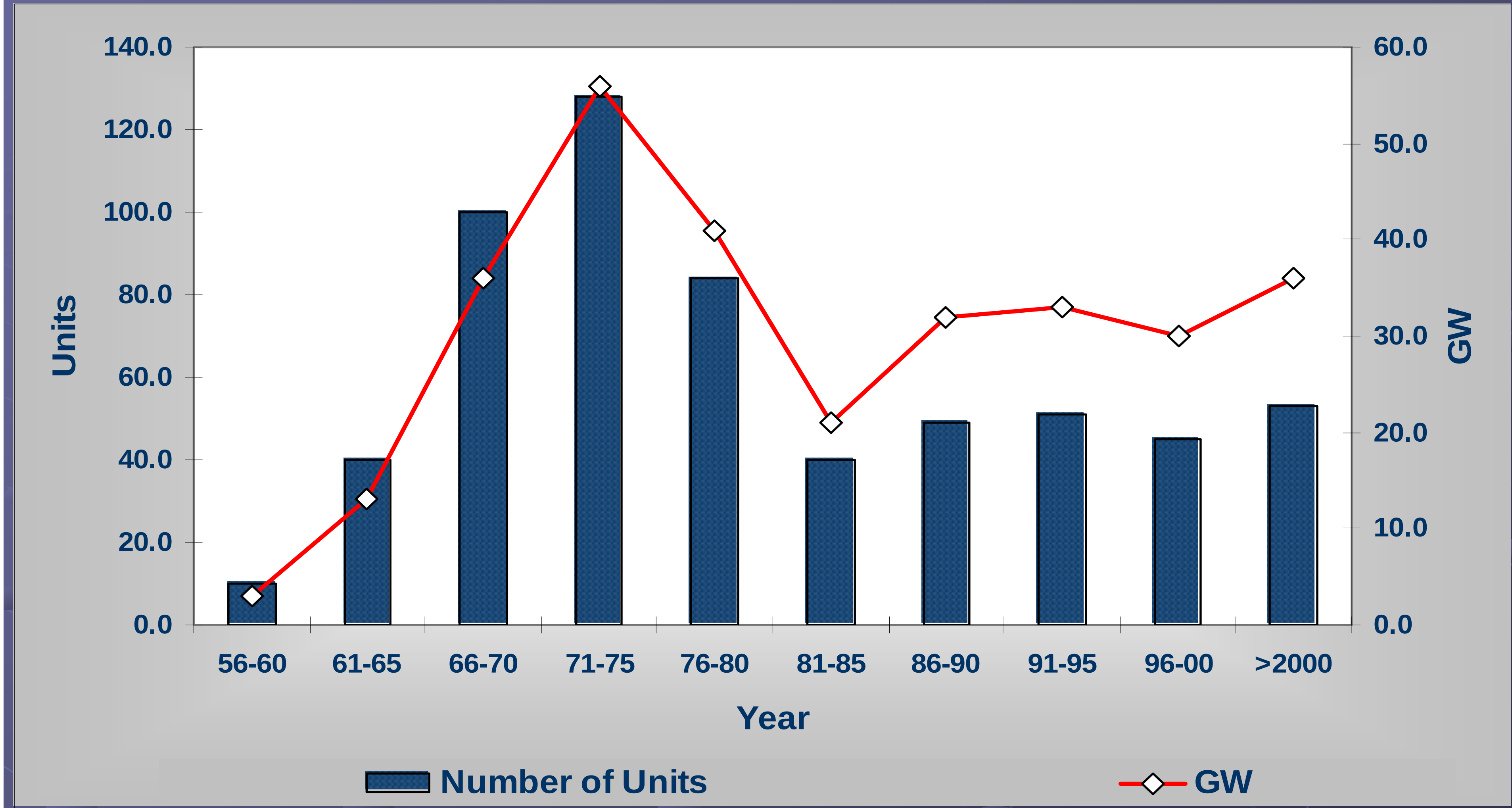


Operational Costs savings

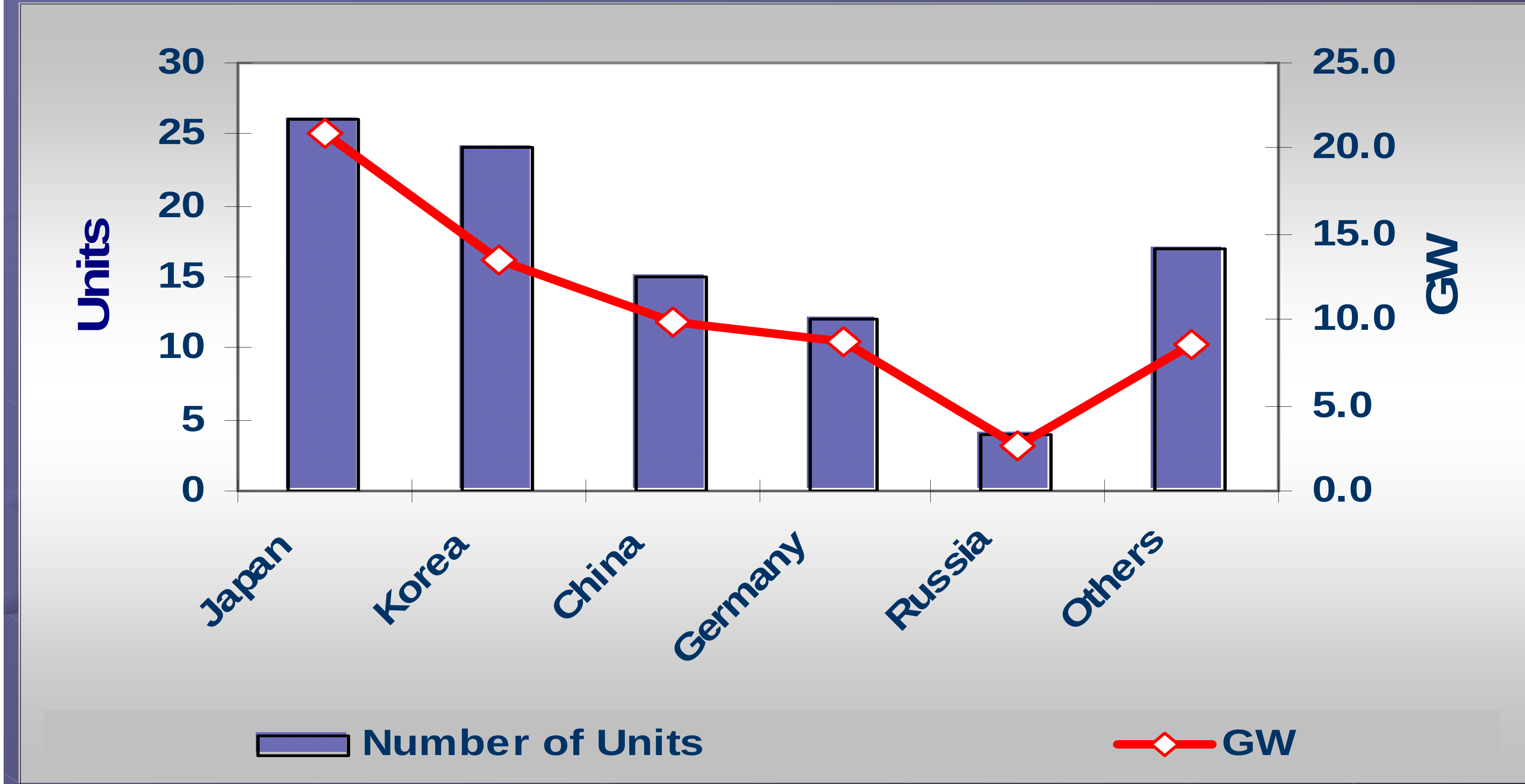


30 USD/Ton

SC & USC Power Generation Capacity 1956-2004



SC & USC Power Generation Capacity 1995-2004



Conclusions

- Advanced SC & USC technology has substantial potential to improve the efficiency of PC power plant and to reduce the harmful impacts on the environment.
- Many Asian countries have already large capacity for SC & USC components manufacturing.
- SC power plants have already attained similar or even higher availability as conventional power plants.
- Cost patterns indicate a rapid decline in the average cost of power generation from SC & USC power plants.
- Higher construction costs are well balanced by lower fuel costs.
- SC & USC technology offers better operational dynamics at all loads and higher thermal efficiency at low loads.

Constraints

- SC & USC technology has to become economic against the alternative technologies such as conventional and NG-fired CCGT power plants.
- Ni base super-alloys are needed for higher temperatures.
- Higher strength materials are needed for upper water walls of boilers.
- Better understanding of maintenance needs of the USC boiler & ST and related auxiliary systems is essential for long-term, reliable operation.

Coal based SC power generation technology is matured and advanced technique that can be favorably compared with well proven conventional power generation technology.

USC takes all advantages of well proven SC technology and is continuously build-up on this strong SC foundation.

In the medium to long term, as NG and fuel oil become a more scarce fuel and prices increase, and in conjunction with further economic improvements in clean coal technologies, SC & USC technology can expect to receive a renaissance as a feasible option for new large scale coal fueled power generation plants.

There is no solution capable meeting of our all future energy requirements.

Instead the answer will come from a family of diverse New Technologies which will have an impact on everything — from environmental quality to costs that consumers will ultimately have to pay.

Thank You.