Power Plant Economics

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Overview

- Economic Terms
- Economic Methodologies
- Cost Models
- Pitfalls
- Cost Studies
- Results
- Some words about CO2
- Conclusions

Economic Terms

- Return on Sales = Net after tax/Sales revenue
- Asset turnover = Sales revenue/Assets
- Leverage = Assets/Equity
- PE Ratio = Stock Market Price (per share)/Net after tax (per share)
- Market/Book Ratio = Stock Market Price (per share)/Equity (per share)
- Return on Assets = Net/Assets
- Return on Equity = Net/Equity
- Discount Rate = Time value of Money
- Net Present Value = Present Value of Future Returns @ Discount Rate
- Internal Rate of Return = Discount Rate which yields an NPV of zero

Why do we care?

- ROS x Turnover x Leverage x PE = Market/Book
  - Listed firms want to increase stock price (shareholder value)
- The Discount Rate considers risk as well interest rates and inflation
  - The discount rate is often a project hurdle rate
- Many firms use IRR for project evaluation
- Return on Equity is a key consideration for any investment

Economic Methodologies

- A Power Plant is a long lived asset that is capital intensive.
- It also takes a long time to acquire the asset.
  - Construction times range from 2 years for a combined cycle plant to 3 – 4 years for a coal plant to 10 years for a nuclear plant.
- A key issue is treating the time value of money.
- Depreciation is a key consideration.
- Different entities treat these considerations differently.

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Plant Cost

- Plant Cost is exceptionally site specific.
  - Labor costs
  - Shipping and material costs
  - Environmental costs
  - Site preparation costs
  - Site impacts on performance
  - Fuel costs
  - Cooling water type and availability
  - Connection costs
- Today, we really don't know what the final cost of a plant will be.
  - Raw material escalation
  - Shipping costs
  - Labor costs

Plant Cost Terminology

- There are numerous ways to talk about plant cost.
  - Engineered, Procured, and Constructed (EPC cost)
    - Most commonly used today
    - Fits best with Merchant Plant model
    - Does not included Owner's Costs
      - Land, A/E costs, Owner's Labor, Interconnection, Site Permits, PR, etc.
    - Can often be obtained as a fixed price contract for proven technology
  - Equipment Cost
    - Generally the cost to fabricate, deliver, and construct the plant equipment
  - Overnight Cost
    - Either the equipment cost or the EPC cost with the NPV of interest during construction. This was used in the 70s and 80s to compare coal plants with nuclear plants due to the difference in construction times.
  - Total Installed Cost (TIC)
    - The total cost of the equipment and engineering including interest during construction in present day dollars. This is the cost that a utility would record on its books without the cost of land and other home office costs.
  - Total Plant Cost (TPC) – includes all costs

Economic Methodologies

- Simple payback
  - The number of years it takes to pay back the original investment
- Return on Equity
  - For regulated utilities, the ROE is set by the regulatory body. The equity is determined by the total plant cost being allowed in the rate base. The equity portion is determined by the leverage of the company. The ROE is applied to the equity and added to the cost in determining the cost of electricity and thus the rate to be charged to the customer.
- Capital Charge Rate
  - This is the rate to be charged on the capital cost of the plant in order to convert capital costs (ie investment) into operating costs (or annual costs). This rate can be estimated in a number of ways. This rate generally includes most of our ignorance about the future (ie interest rates, ROE, inflation, taxes, etc.)
- Discounted Cash Flow Analysis
  - This method is preferred by economists and developers. A spread sheet is set up to estimate the cash flows over the life of the project. An IRR can be calculated if an electricity price is known (or estimated).

Economic Methodologies

- All of these methods can be made equivalent to one another for any given set of assumptions.
  - A simple payback time can be selected to give the same cost of electricity (COE) as the other methods.
  - A return on equity can be selected to give the same COE.
  - A capital charge rate can be selected to give the same COE.
  - The Discounted Cash Flow method is considered the most accurate. However, there are still a considerable number of assumptions that go into such a model such as the discount rate, inflation rate, tax rate, interest rates, fuel prices, capacity factors, etc. that the accuracy is typically less in reality.
- The Independent Power Producer pioneered the use of the DCF model for smaller power projects.
  - In this model, the developer attempted to fix as many costs as possible by obtaining fixed price contracts for all of the major cost contributors. These included the EPC price, the fuel contract, the Operations & Maintenance Contract (O&M), and the Power Purchase Agreement.

Cost Models

- Capital Charge Rate Model
  - The goal is to select a capital charge rate that typically covers most of the future unknowns. This rate is applied to the EPC cost in order to provide an annual cost that will provide the desired return on equity.
  - In its simplest form, one can use the following:
    - Interest rate on debt - 8 - 10% for utility debt
    - ROE - 10 – 12 % for most utilities
    - Inflation rate - 3 – 4%
    - Depreciation - 2 – 4%
    - Taxes and Insurance - 3 – 5%
    - Risk - ? (typically 3% for mature technologies, higher for others)
  - Another approach would be to run a number of DCF cases with different assumptions and then assess a capital charge rate that is consistent.
  - A reasonable number for a regulated utility is 20% (one significant figure)

Discounted Cash Flow Model

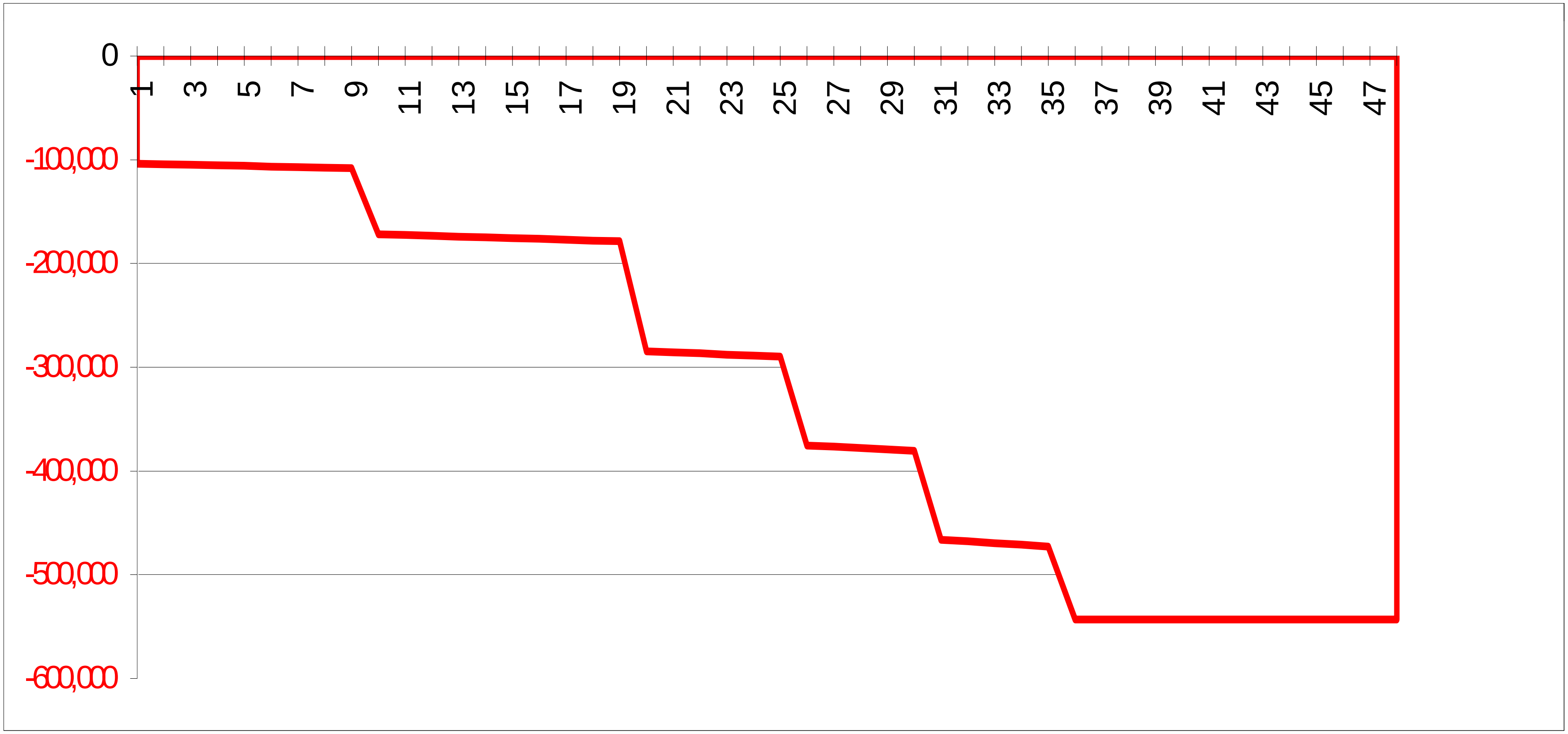
- The goal is to estimate the cash flows of the project over the life of the plant. A significant number of variables are involved and must be estimated or assumed in order to make the spread sheet work.
  - Input variables include net output, capacity factor, availability, net plant heat rate (HHV), degradation, EPC price, construction period, insurance, initial spares/consumables, fixed O&M, variable O&M, fuel price, fuel heating value (HHV), financial closing date, reference date, depreciation, analysis horizon, owner's contingency, development costs, permitting costs, advisory/legal fees, start up fuel, fuel storage, inflation rates, interest rates, debt level, taxes, construction cash flow, discount rate, and ROE.
  - A detailed cash flow analysis is set up for each year of the project. For shorter term projects, these estimated cash flows are more realistic. For longer term projects, the accuracy is debatable.
  - Since the cash generation may be variable, it is often desirable to perform some kind of levelizing function to generate an average that is understandable. There are risks associated with this step.
  - The most common application is to assume a market price for electricity and then try to maximize the IRR for the project.

Discounted Cash Flow Model

- The model assumes that we know a lot about the project and the number of variables. What if we don't know very much about the future project? For example, what if we don't know where the plant will be located? What if we don't know which technology we will use for the plant? What if we want to compare technologies on a consistent basis?
- One approach is to run the DCF model "backwards". In this approach, we stipulate a required return and calculate an average cost of electricity needed to generate that return. We still need to make a lot of assumptions, but at least we can be consistent.
- One advantage of having such spread sheet programs is that a wide range of scenarios and assumptions can be tested. This approach gives us a little more insight into the decision making process and helps us understand why some entities might chose one technology over another.

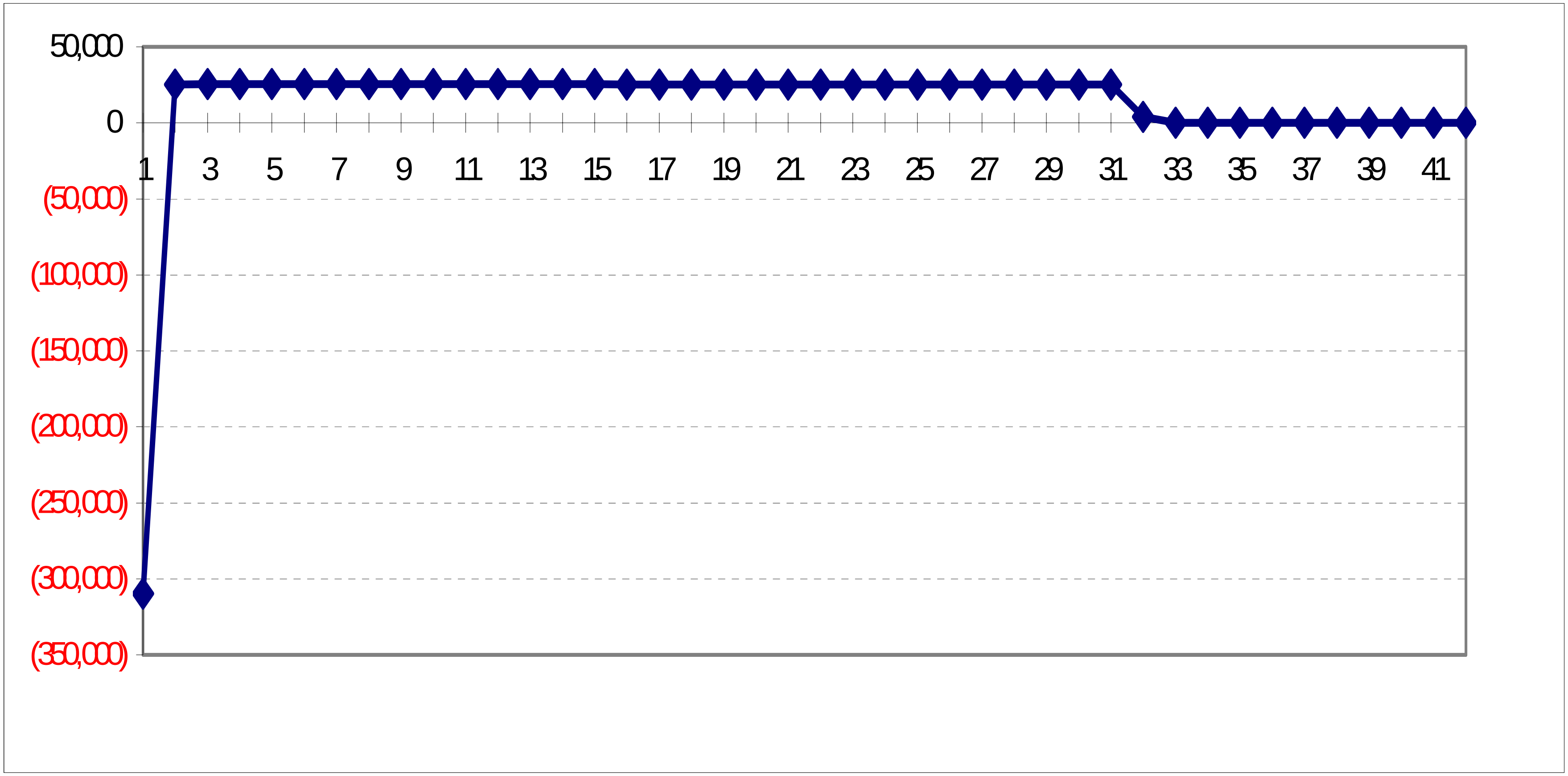
Typical Construction Period w/Cash Drawdown

1. Cumulative Drawdown



Typical Levelized Cash Flow

4. Ending Equity Cashflow



Pitfalls

- The biggest pitfall is thinking that these numbers are “real”. They are only indicative. Just because a computer can calculate numbers to the penny does not mean that the numbers are accurate. There is a lot of uncertainty due to the number of assumptions that have to be made.
- It is important to understand what the goal and/or objective of the analysis is. In the following study, the goal was to compare technologies that might be used in the future. This goal is different from looking at a near term project where the site, technology, fuel, customer, and vendors have already been selected.
- There is no substitute for sound management judgement.
- The analysis itself does not identify the risks. The analyzer must consider the risks and ask the appropriate “what if” questions. In the following study, over 3,000 spread sheet runs were made in order to analyze the comparisons effectively.
- Avoid the “Swiss Watch” mentality.

Technology Position and Experience

	Experience Base	Major Competitors	Technology Maturity
Sub-Critical PC	1,200 GW	Alstom,MHI, B&W, FW and Several Others	Mature
Super-Critical PC	265 GW	Alstom,MHI, B&W	Proven
PFBC	0.5 GW		Demo
IGCC	1 GW	GE, Shell, Conoco Phillips	Demo
CFB	20 GW	Alstom, FW	Proven
NGCC	200 GW GT 100 GW ST	GE, Siemens, Alstom	Mature

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Baseline Economic Inputs – 1997 400 MW Class

	Subcritical	Supercritical	P800 PFBC	IGCC
Size (MW)	400	400	400	400
Capital Cost ($/ kW)	1,000	1,050	1,100	1,380
Heat Rate (Btu/ kWh)	9,374	8,385	8,405	8,700
Availability (%)	80	80	80	80
Cycle Time (months)	36	36	48	48
Fixed O&M ($/ kW)	31.14	32.11	33.69	39.08
Variable O&M (mills/ kWh)	0.77	0.69	1.01	0.42
Source:	Market	Market	ABB	GE

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Baseline Economic Inputs – 1997 100 MW Class

	CFB	P200 PFBC	NGCC
Size (MW)	100	100	270
Capital Cost ($/ kW)	1,000	1,200	500
Heat Rate (Btu/ kWh)	10,035	8,815	6,640
Availability (%)	80	80	80
Cycle Time (months)	30	32	24
Fixed O&M ($/ kW)	44.13	55. 41	16.92
Variable O&M (mills/ kWh)	1.18	1.06	0.01
Source:	Market	ABB	PGT

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Baseline Economic Inputs - 2005 400 MW Class

	Subcritical	Supercritical	P800 PFBC	IGCC
Size (MW)	400	400	400	400
Capital Cost ($/ kW)	750	750	750	1,100
Heat Rate (Btu/ kWh)	8,750	8,125	8,030	7,800
Availability (%)	80	80	80	80
Cycle Time (months)	24	24	30	36
Fixed O&M ($/ kW)	26.33	26.33	26.95	33.69
Variable O&M (mills/ kWh)	0.81	0.75	1.05	0.37
Source:	BA Plan	BA Plan	SECAR	GE

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Baseline Economic Inputs – 2005 100 MW Class

	CFB	P200 PFBC	NGCC
Size (MW)	100	100	270
Capital Cost ($/ kW)	725	850	325
Heat Rate (Btu/ kWh)	9,350	8,530	6195
Availability (%)	80	80	80
Cycle Time (months)	18	22	18
Fixed O&M ($/ kW)	38.84	48.67	16.44
Variable O&M (mills/ kWh)	1.15	1.12	0.01
Source:	BA Plan	SECAR	PGT

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Financing Scenario Summary

Loan structure	Municipal	Utility	IPP 1	IPP 2	Industrial
Horizon (years)	40	30	15	15	10
Interest rate (%)	5.75	7.75	8.75	8.75	8.25
Loan term (years)	40	30	9	9	10
Depreciation (years)	40	30	15	15	10
Equity (%)	0	50	30	50	75
Debt (%)	100	50	70	50	25
ROE (%)	n/a	10	20	20	23
Taxes (%)	0	20	30	30	30

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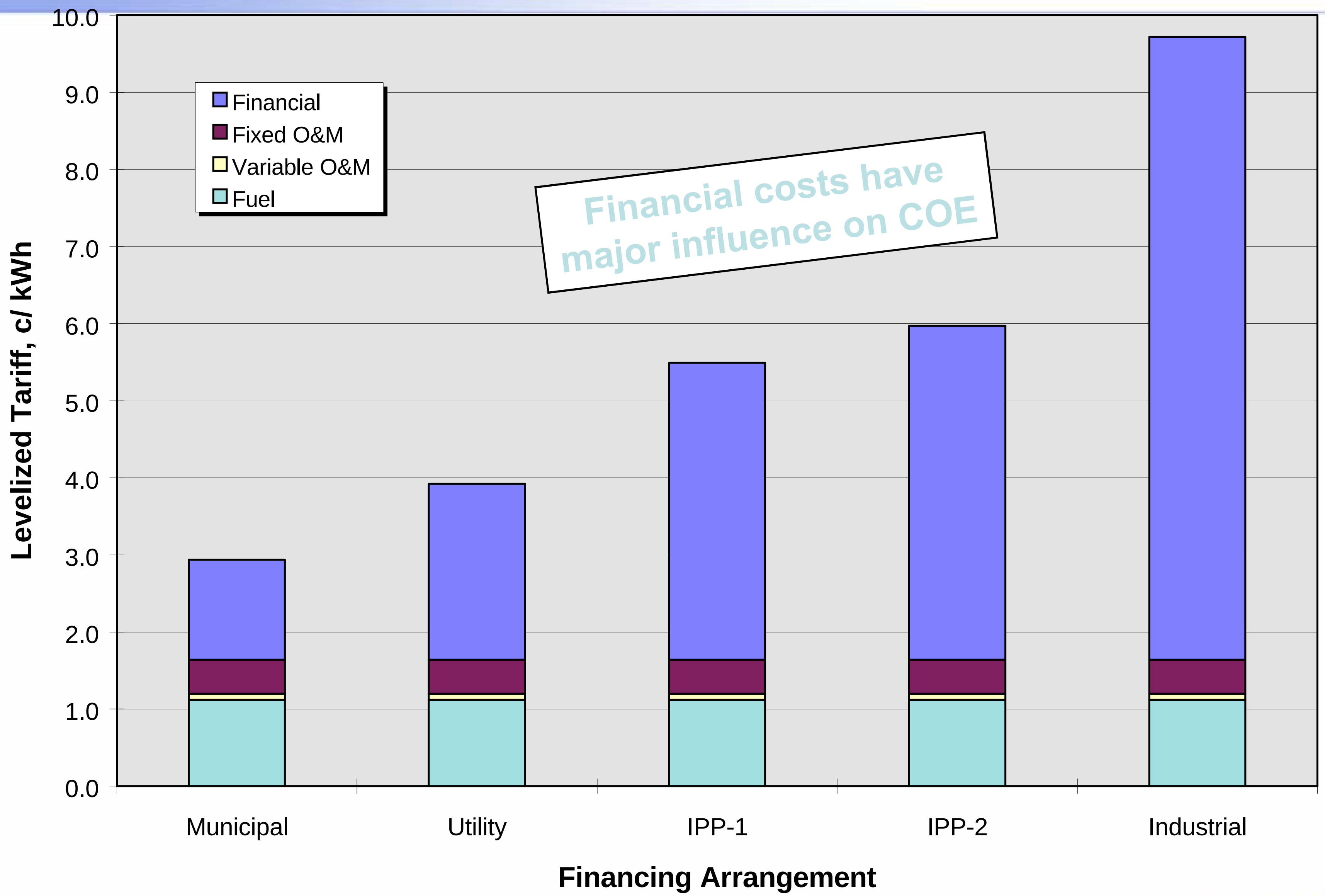
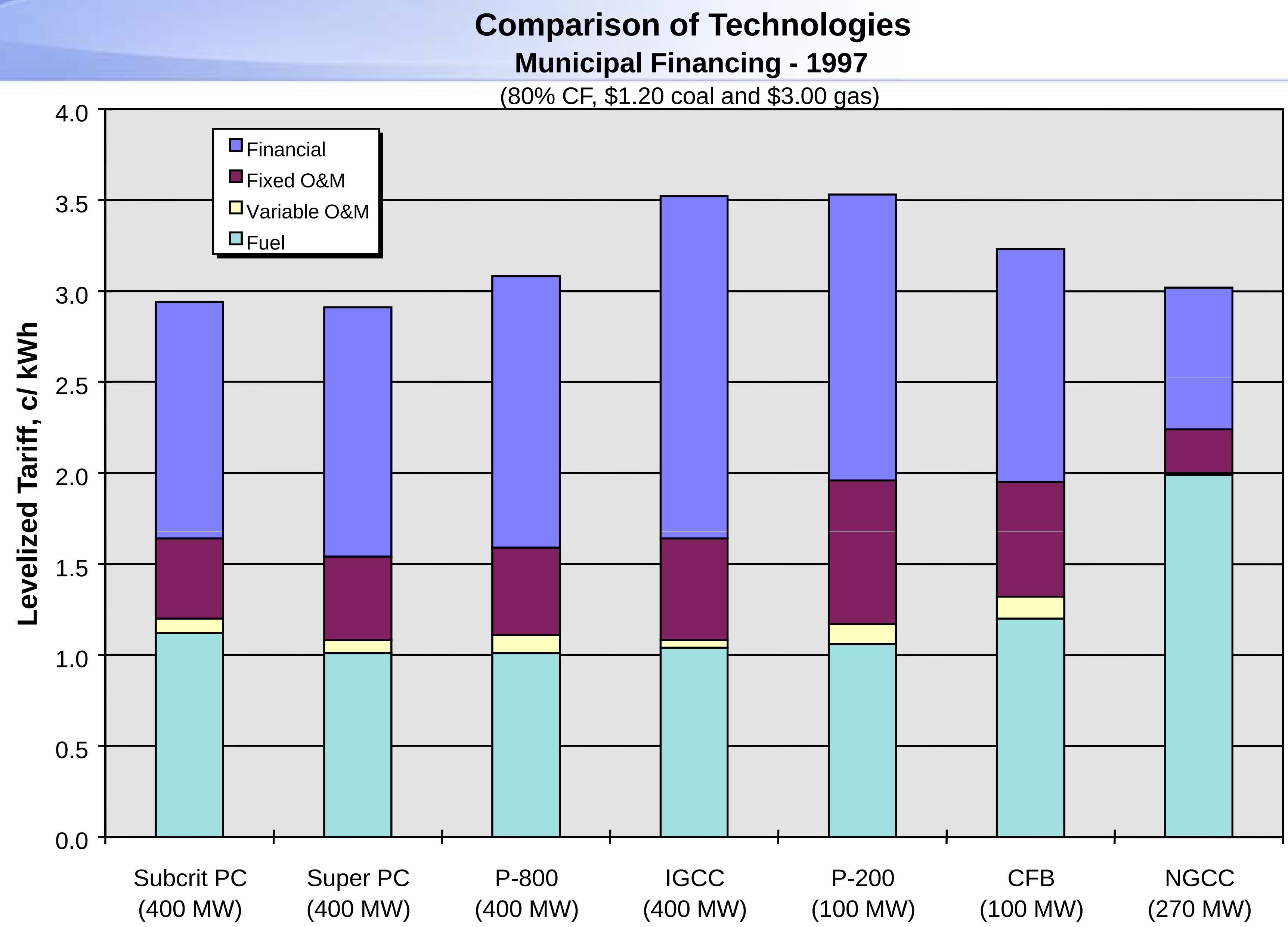
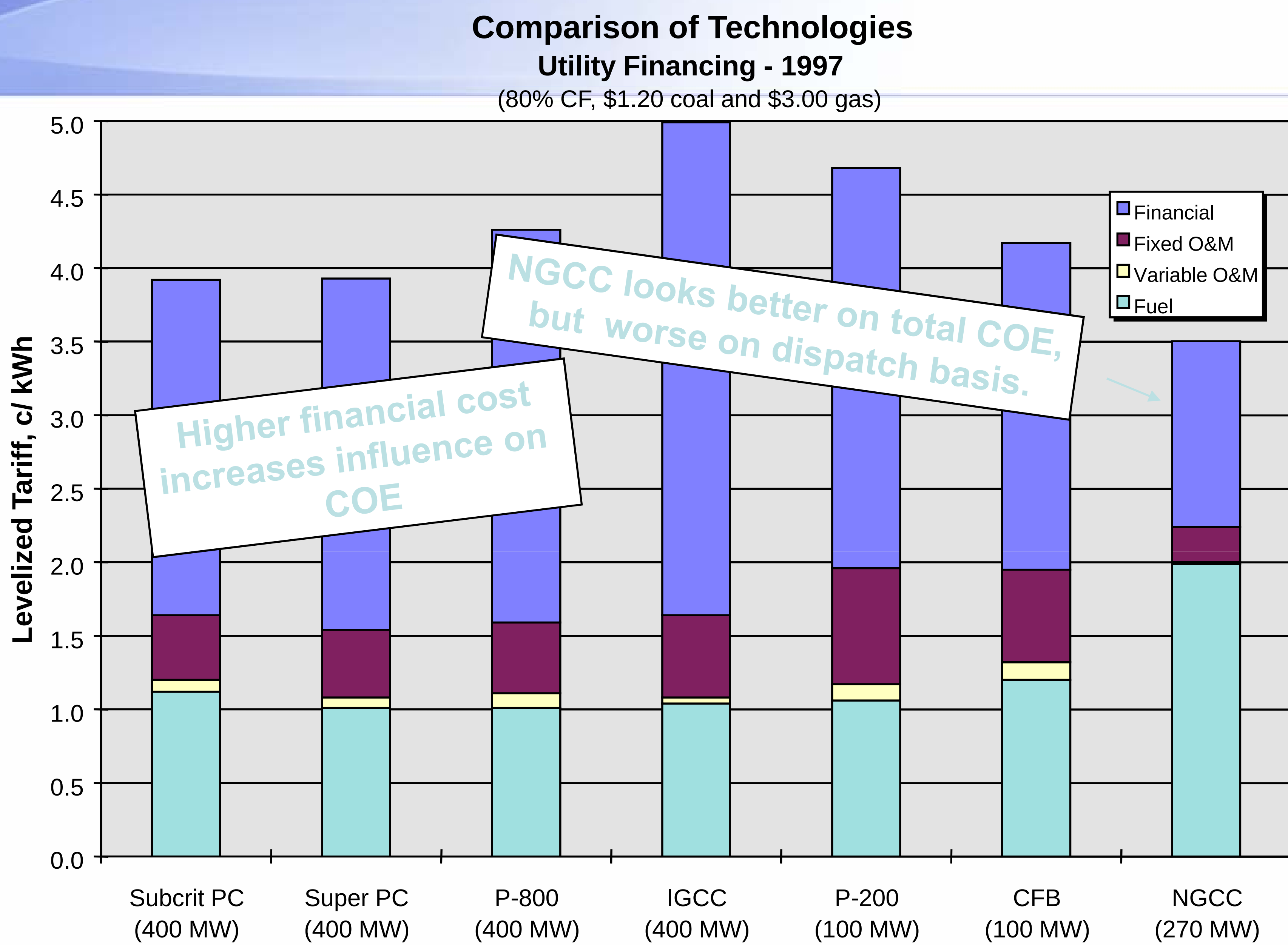
Comparison of Financing Scenarios

400 MW Subcritical PC Fired Plant





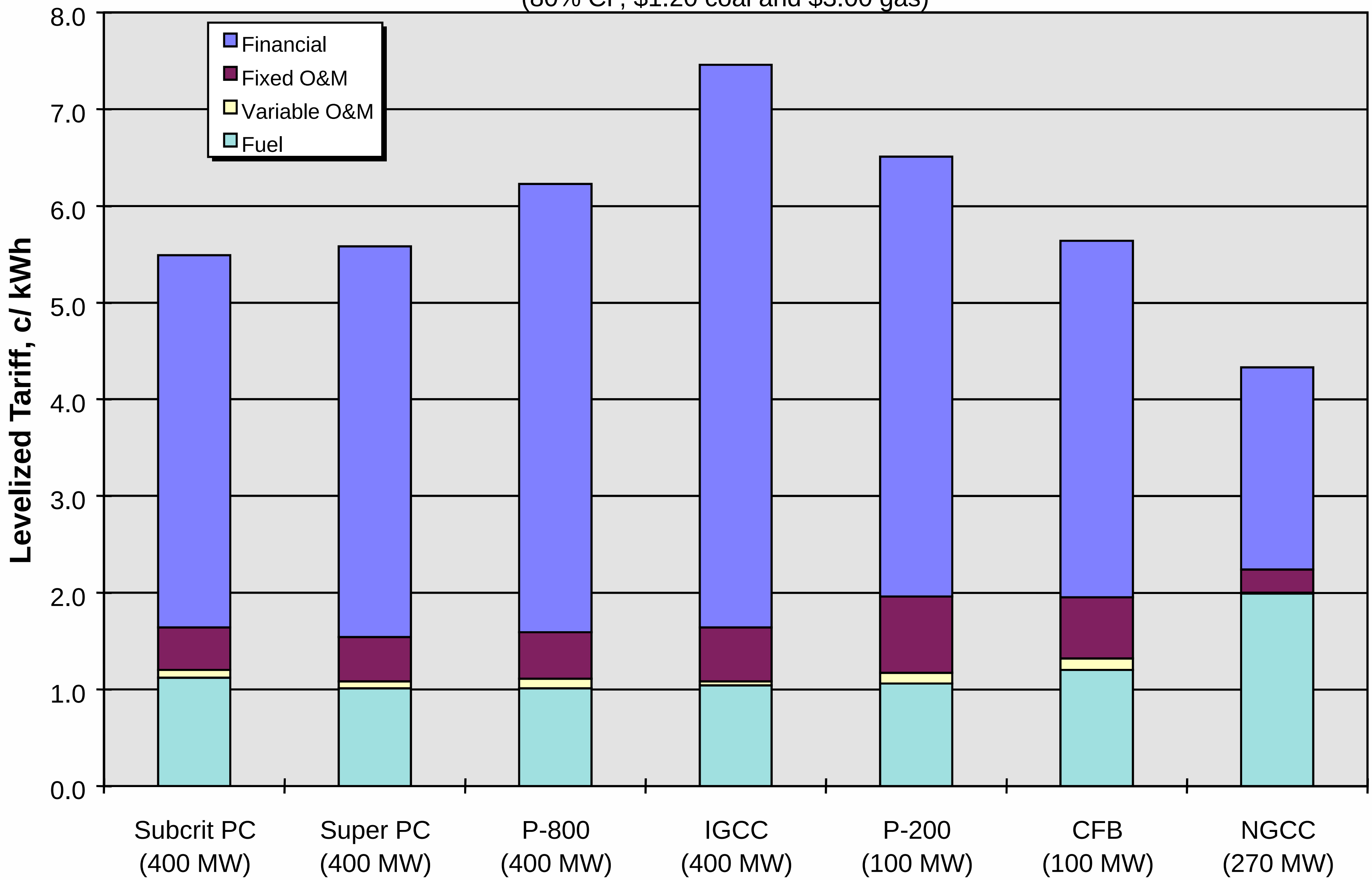
Comparison of Technologies
Municipal Financing - 1997
(80% CF, $1.20 coal and $3.00 gas)
Levelized Tariff, c/ kWh
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Financial
Fixed O&M
Variable O&M
Fuel
Subcrit PC (400 MW)
Super PC (400 MW)
P-800 (400 MW)
IGCC (400 MW)
P-200 (100 MW)
CFB (100 MW)
NGCC (270 MW)


Comparison of Technologies
Utility Financing - 1997
(80% CF, $1.20 coal and $3.00 gas)
Levelized Tariff, c/ kWh
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Financial
Fixed O&M
Variable O&M
Fuel
NGCC looks better on total COE, but worse on dispatch basis.
Higher financial cost increases influence on COE
Subcrit PC (400 MW)
Super PC (400 MW)
P-800 (400 MW)
IGCC (400 MW)
P-200 (100 MW)
CFB (100 MW)
NGCC (270 MW)

Comparison of Technologies

IPP(1) Financing - 1997

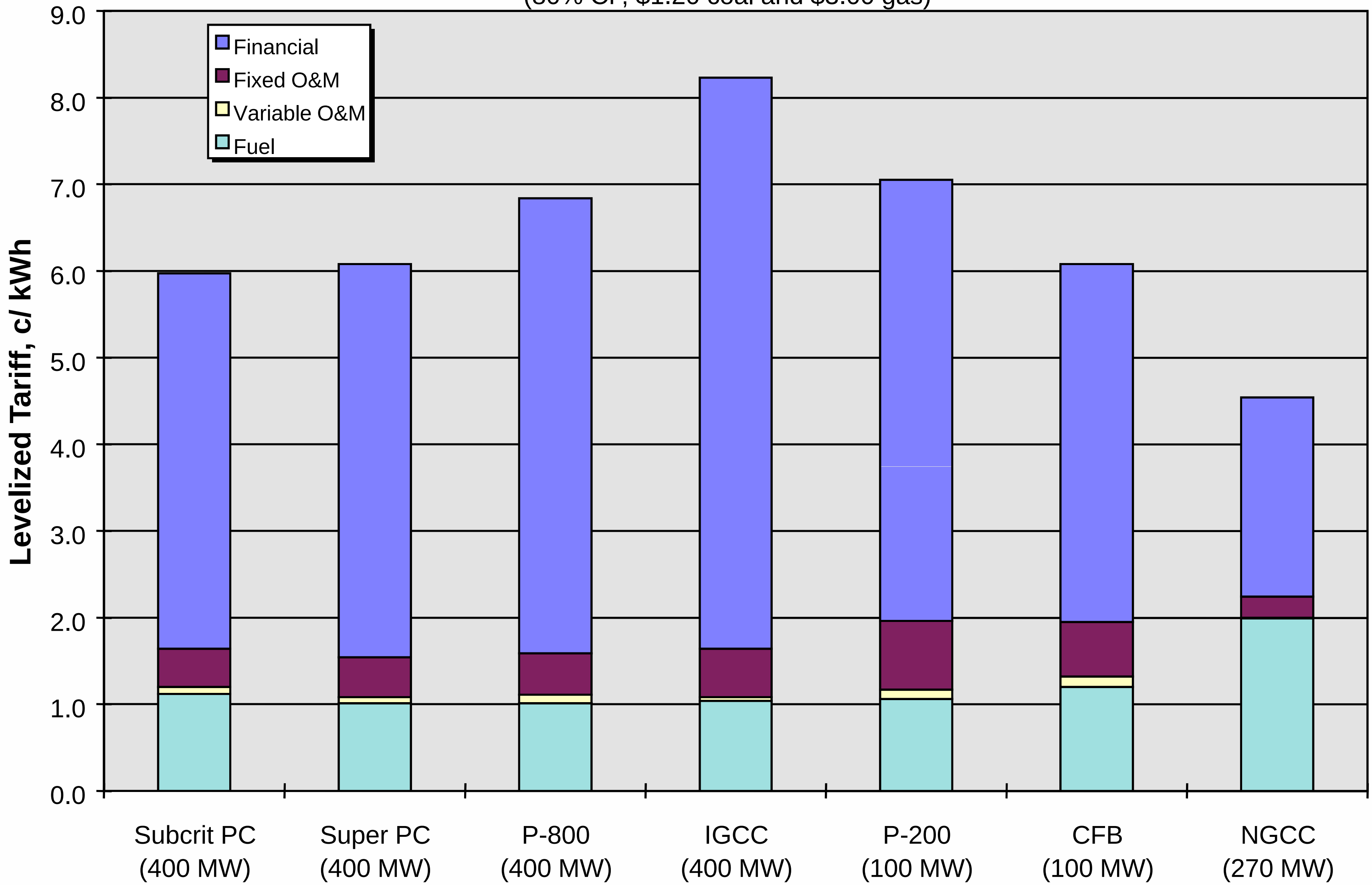
(80% CF, $1.20 coal and $3.00 gas)



Comparison of Technologies

IPP(2) Financing - 1997

(80% CF, $1.20 coal and $3.00 gas)



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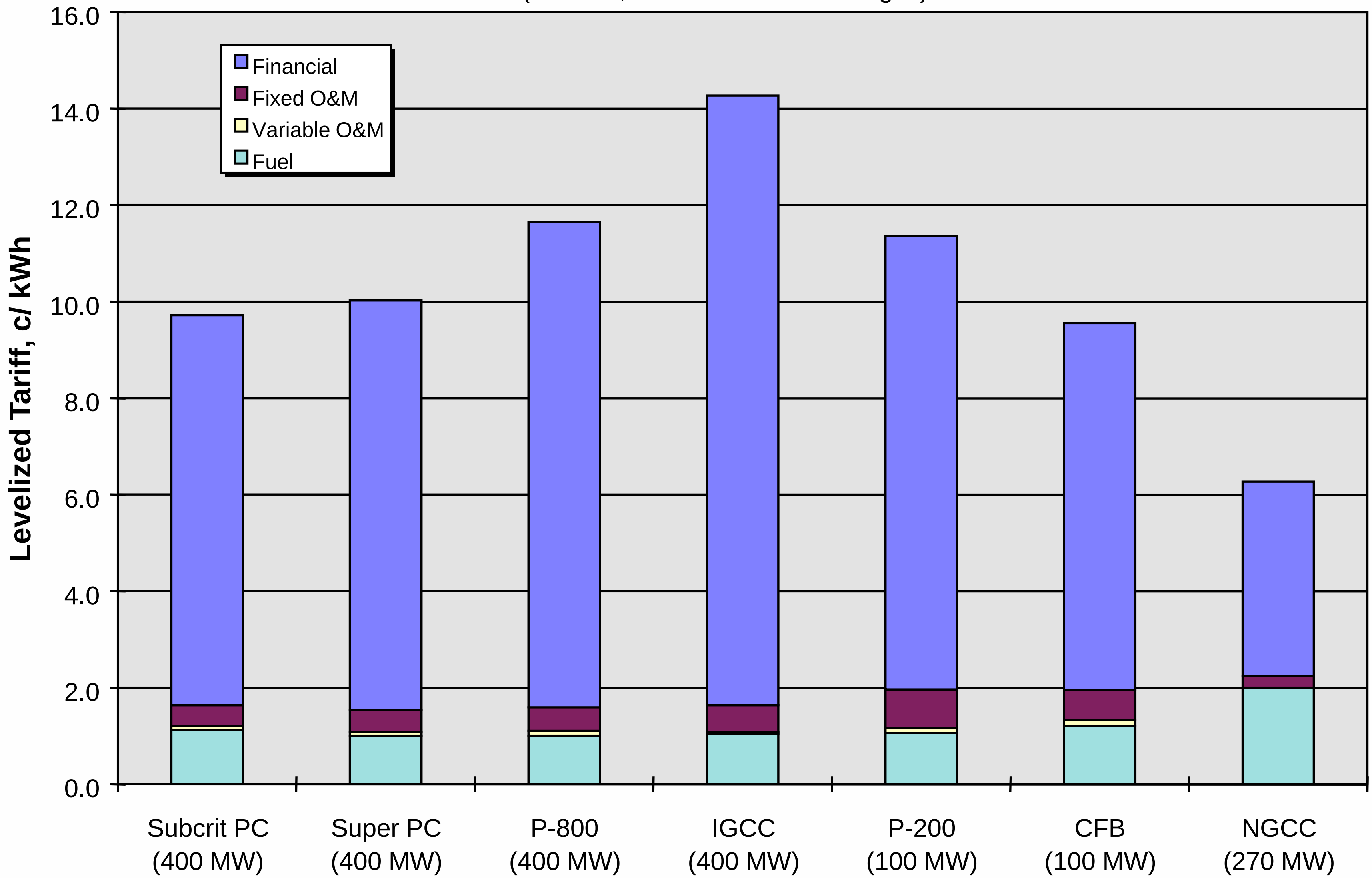
Comparison of Technologies

Industrial Financing - 1997

(80% CF, $1.20 coal and $3.00 gas)



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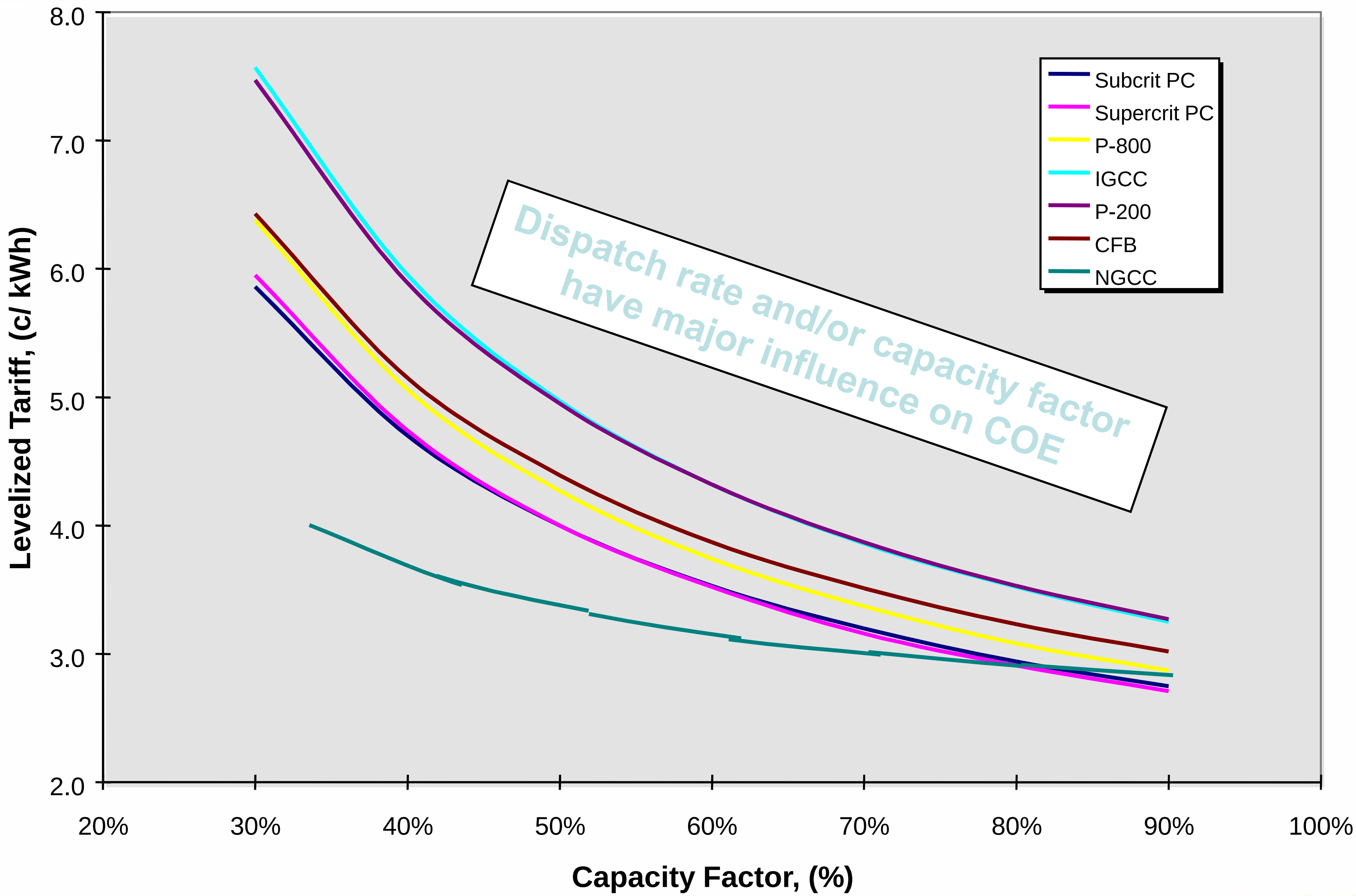
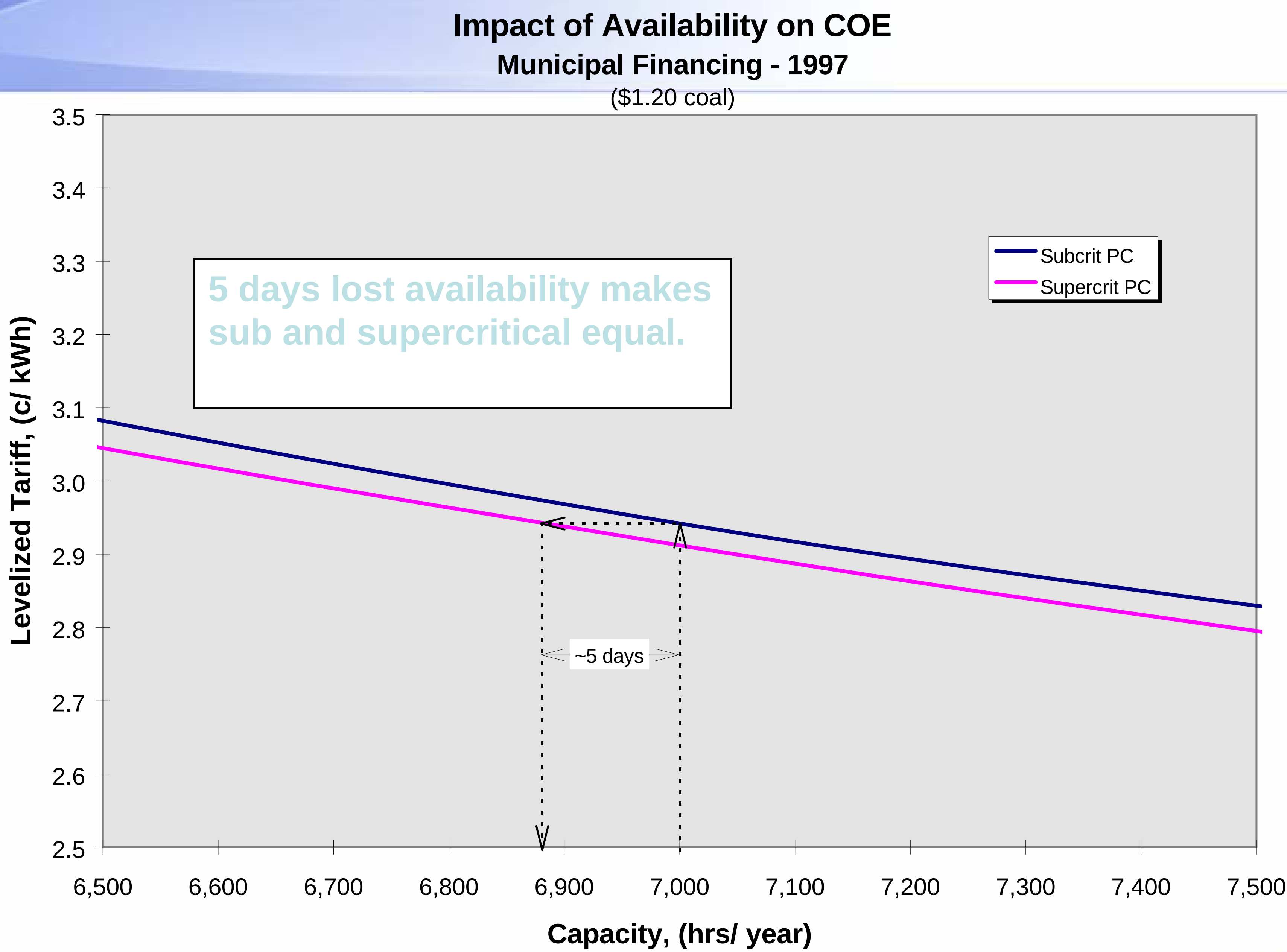
Capacity Factor Effect on COE

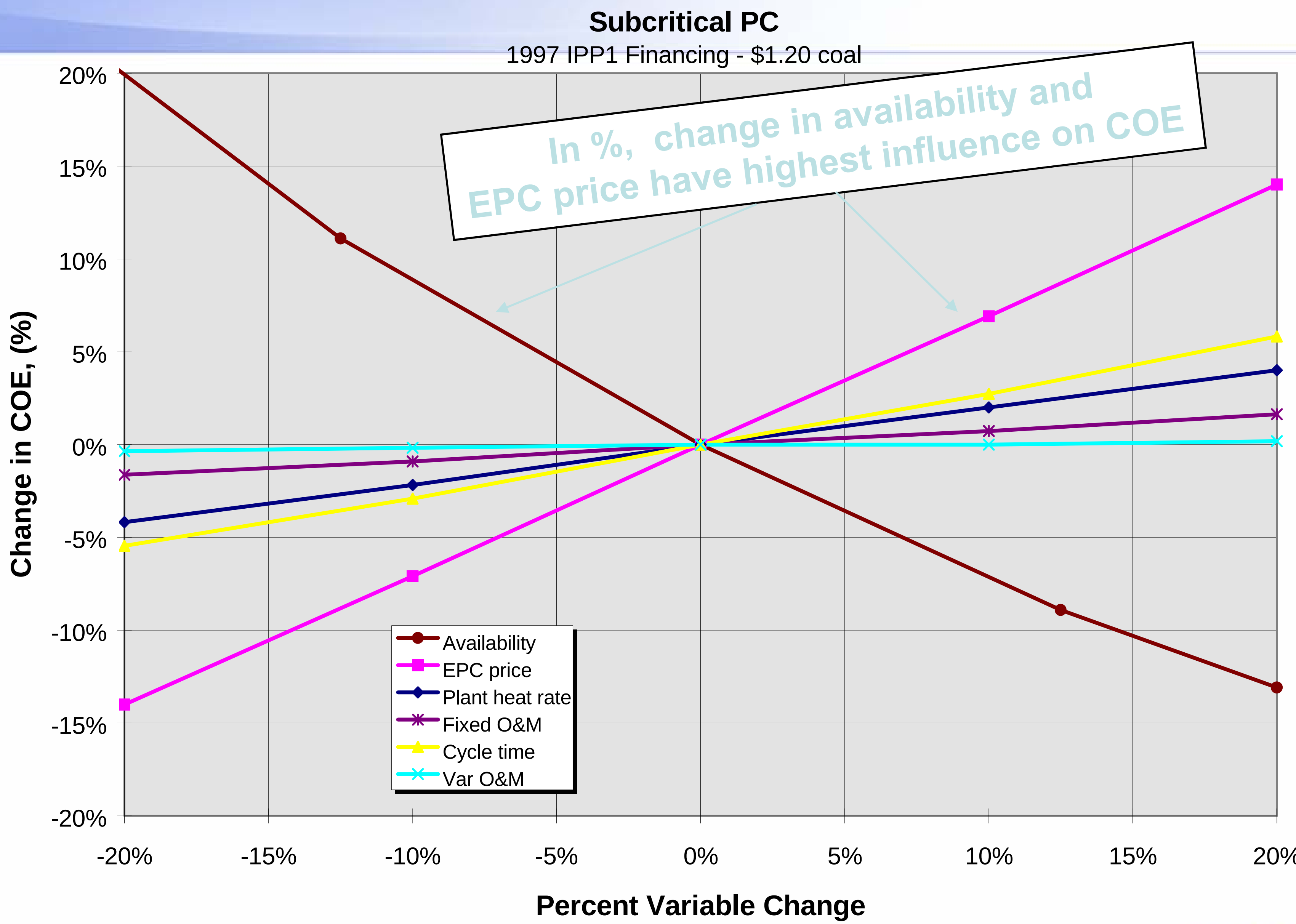
Municipal Financing - 1997

($1.20 coal and $3.00 gas)




Impact of Availability on COE
Municipal Financing - 1997
($1.20 coal)
5 days lost availability makes sub and supercritical equal.
Subcrit PC
Supercrit PC
~5 days
Levelized Tariff, (c/ kWh)
3.5
3.4
3.3
3.2
3.1
3.0
2.9
2.8
2.7
2.6
2.5
6,500
6,600
6,700
6,800
6,900
7,000
7,100
7,200
7,300
7,400
7,500
Capacity, (hrs/ year)

Sensitivity Analysis



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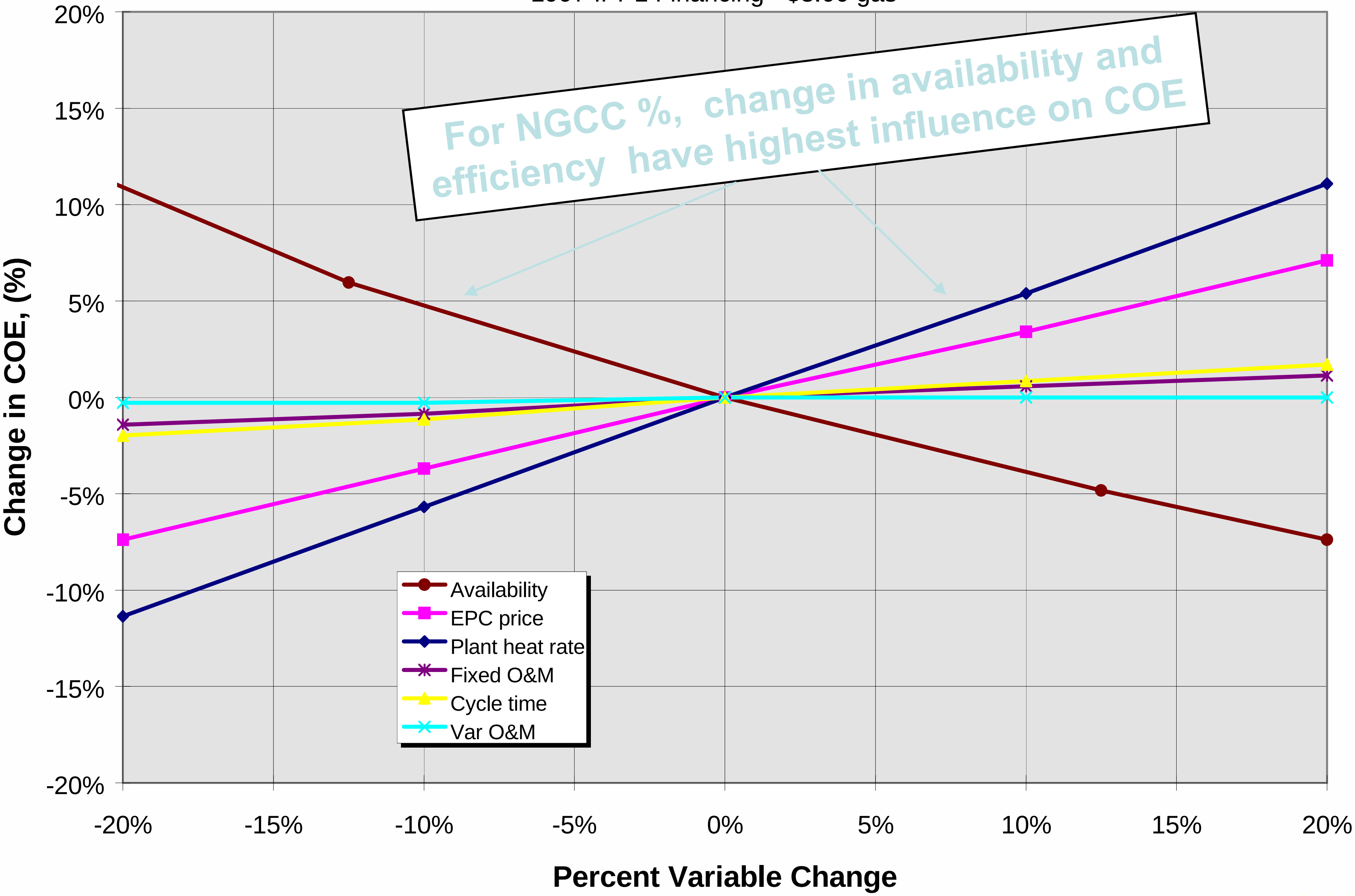
Sensitivity Analysis

NGCC

1997 IPP1 Financing - $3.00 gas



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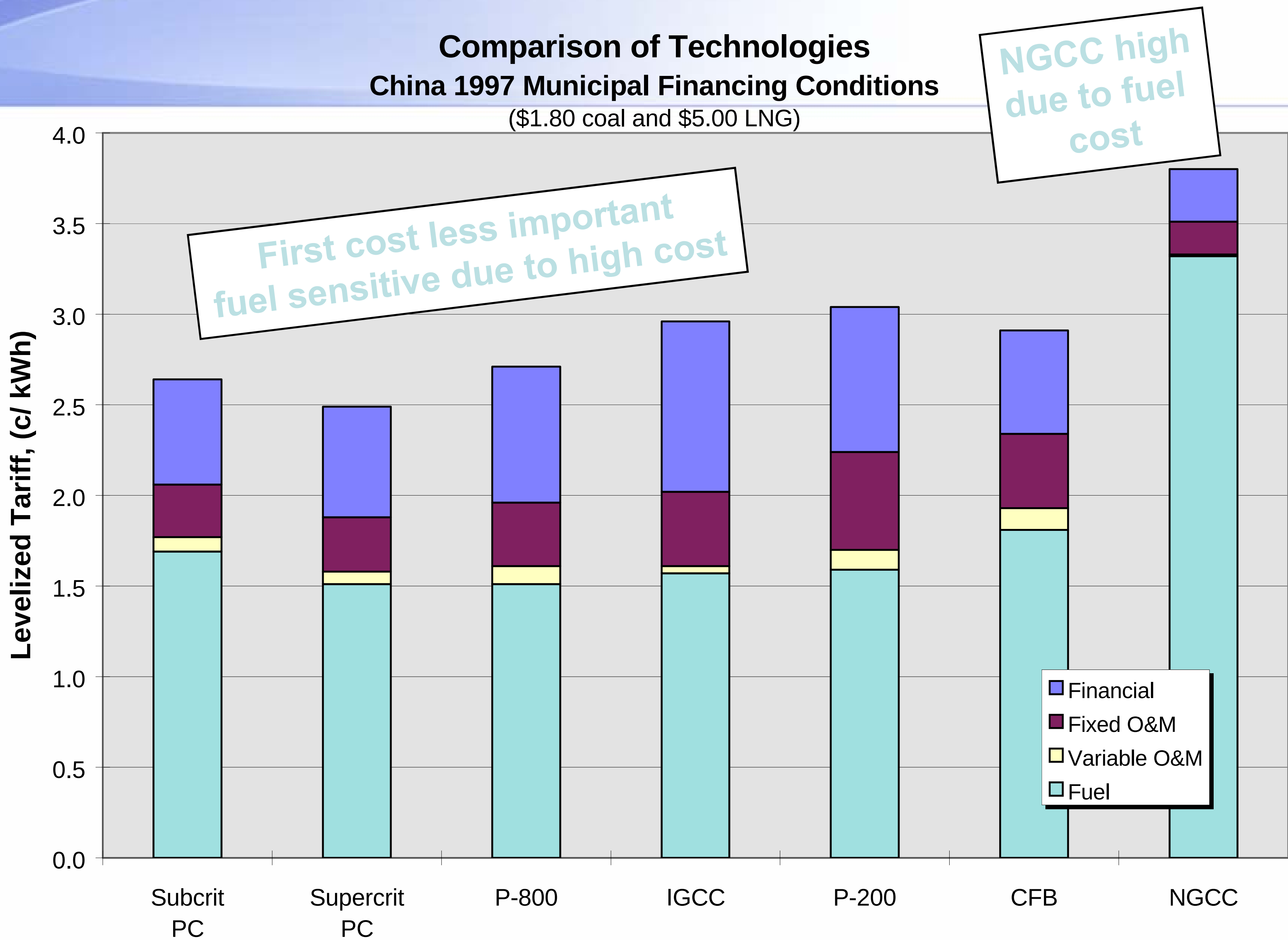
Comparison of Technologies

China 1997 Municipal Financing Conditions

($1.80 coal and $5.00 LNG)



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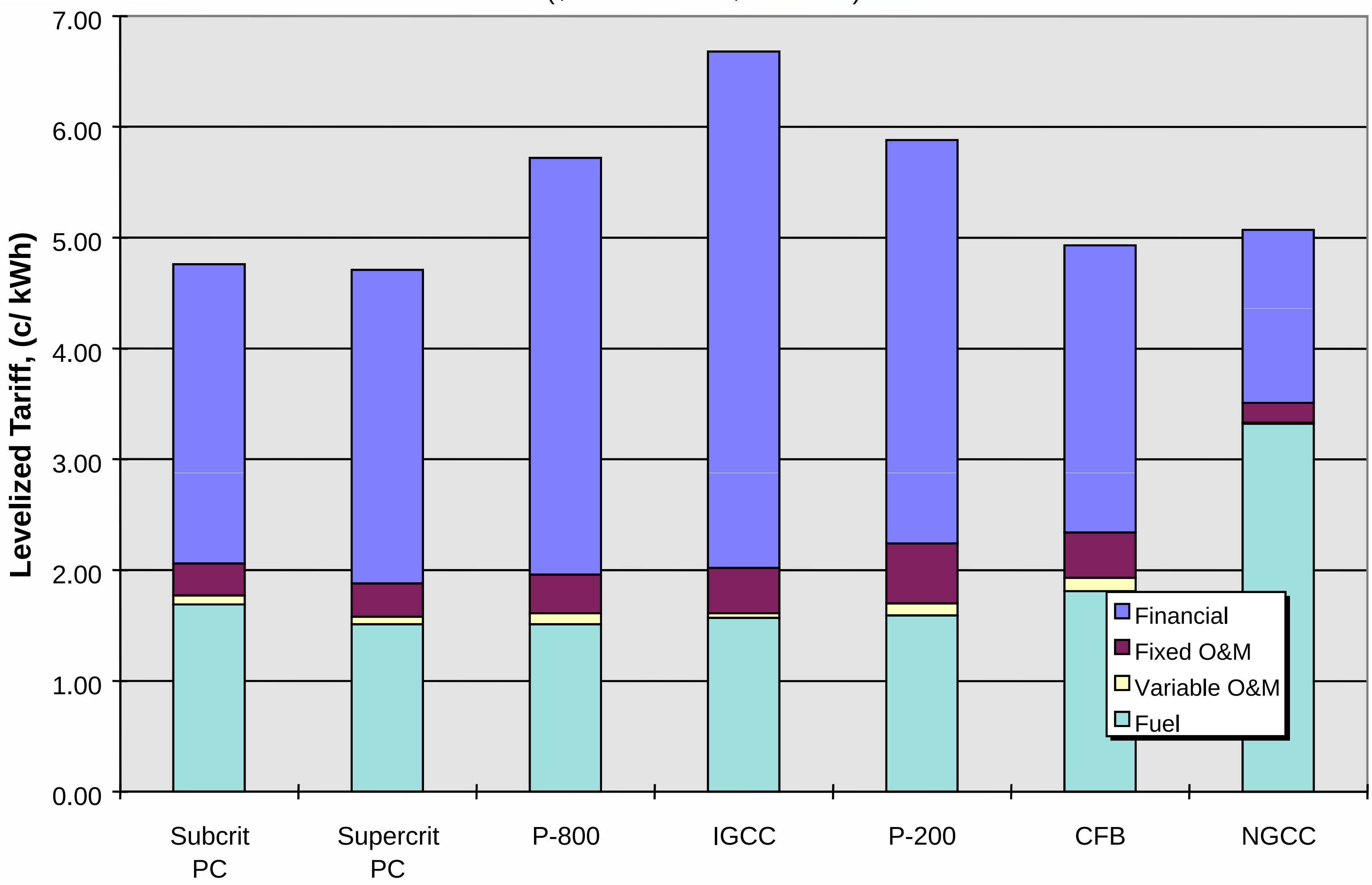
Comparison of Technologies

China 1997 IPP Financing Conditions

($1.80 coal and $5.00 LNG)



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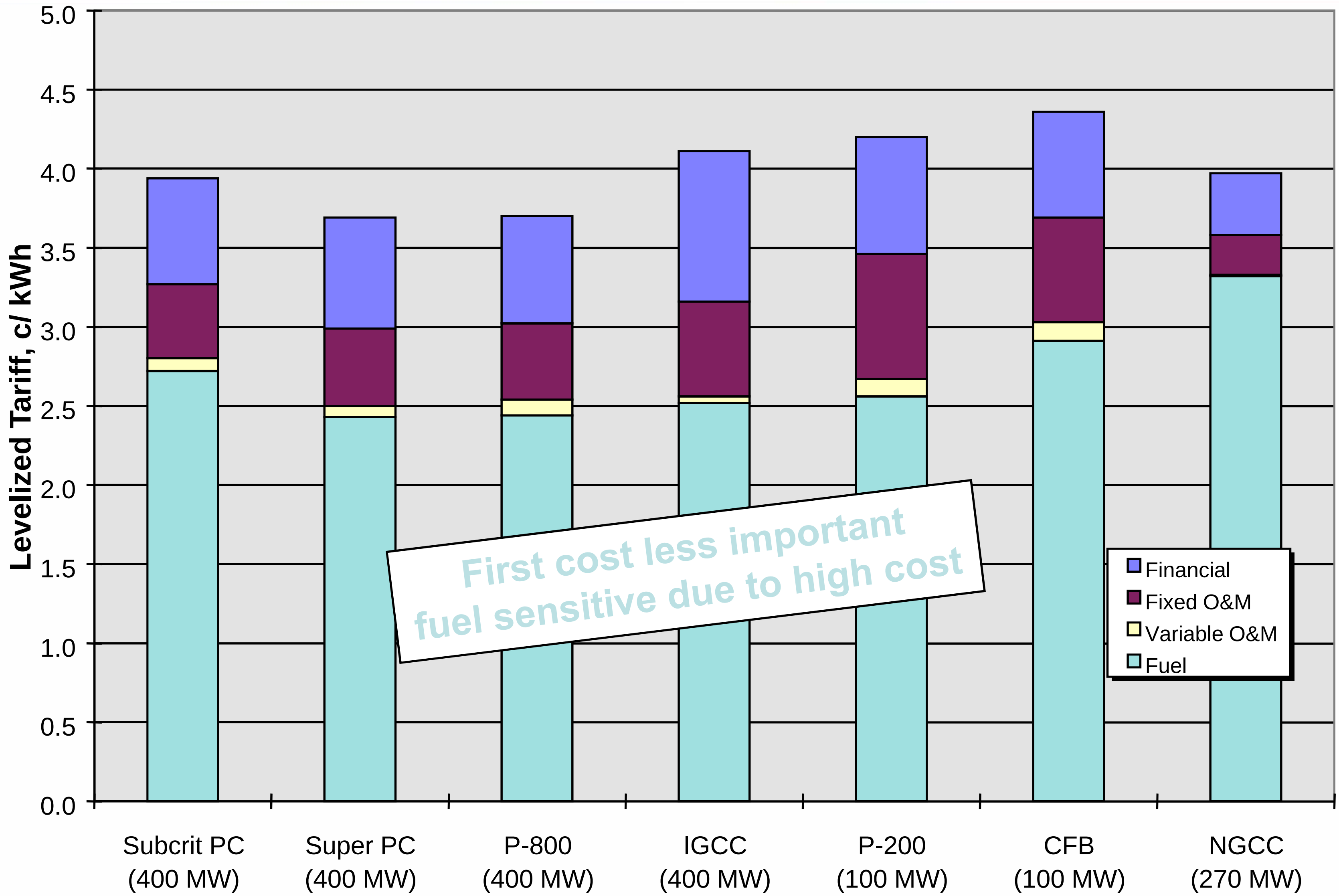
Comparison of Technologies
Japan Market Conditions - 1997
($2.90 coal and $5.00 LNG)



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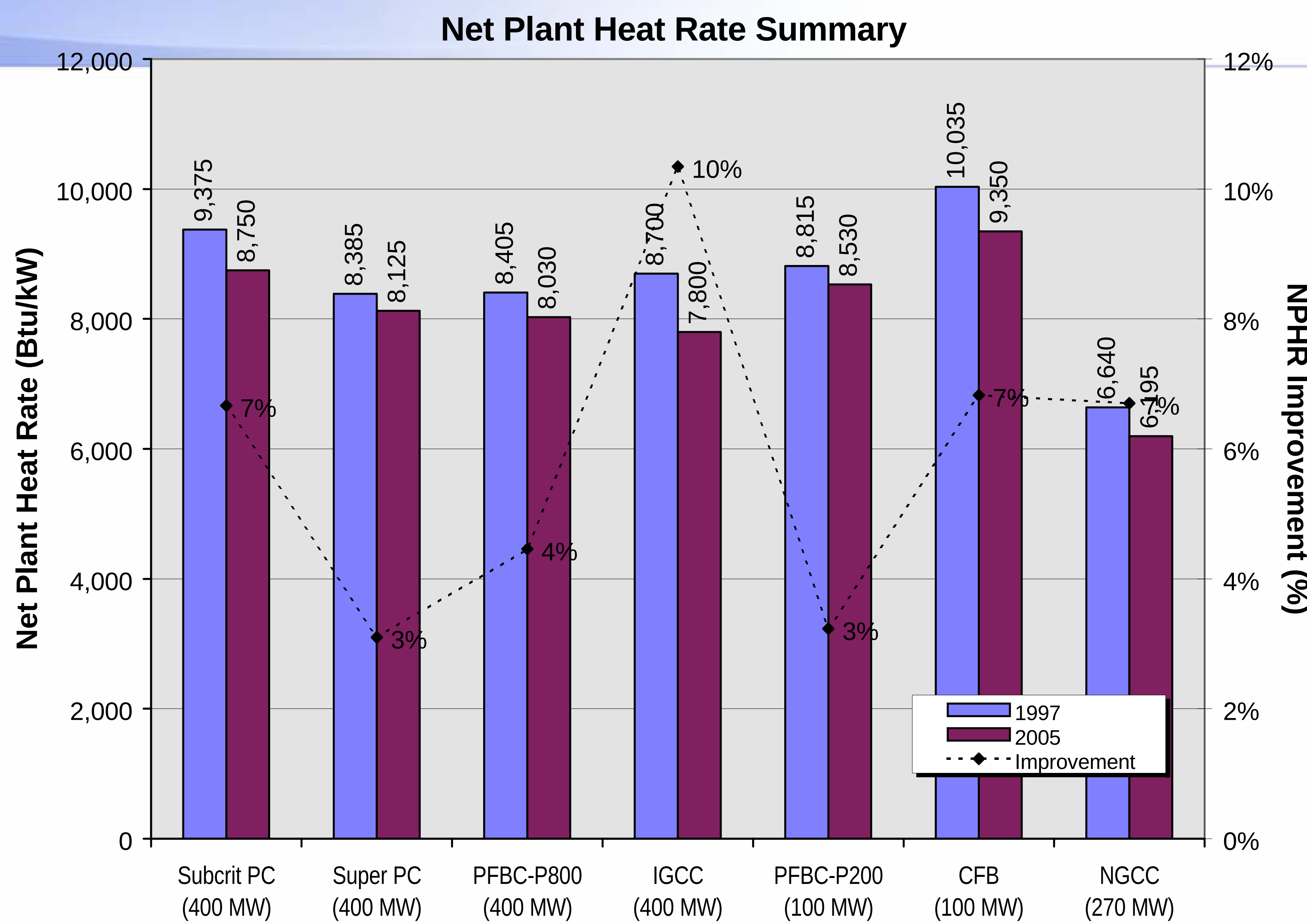
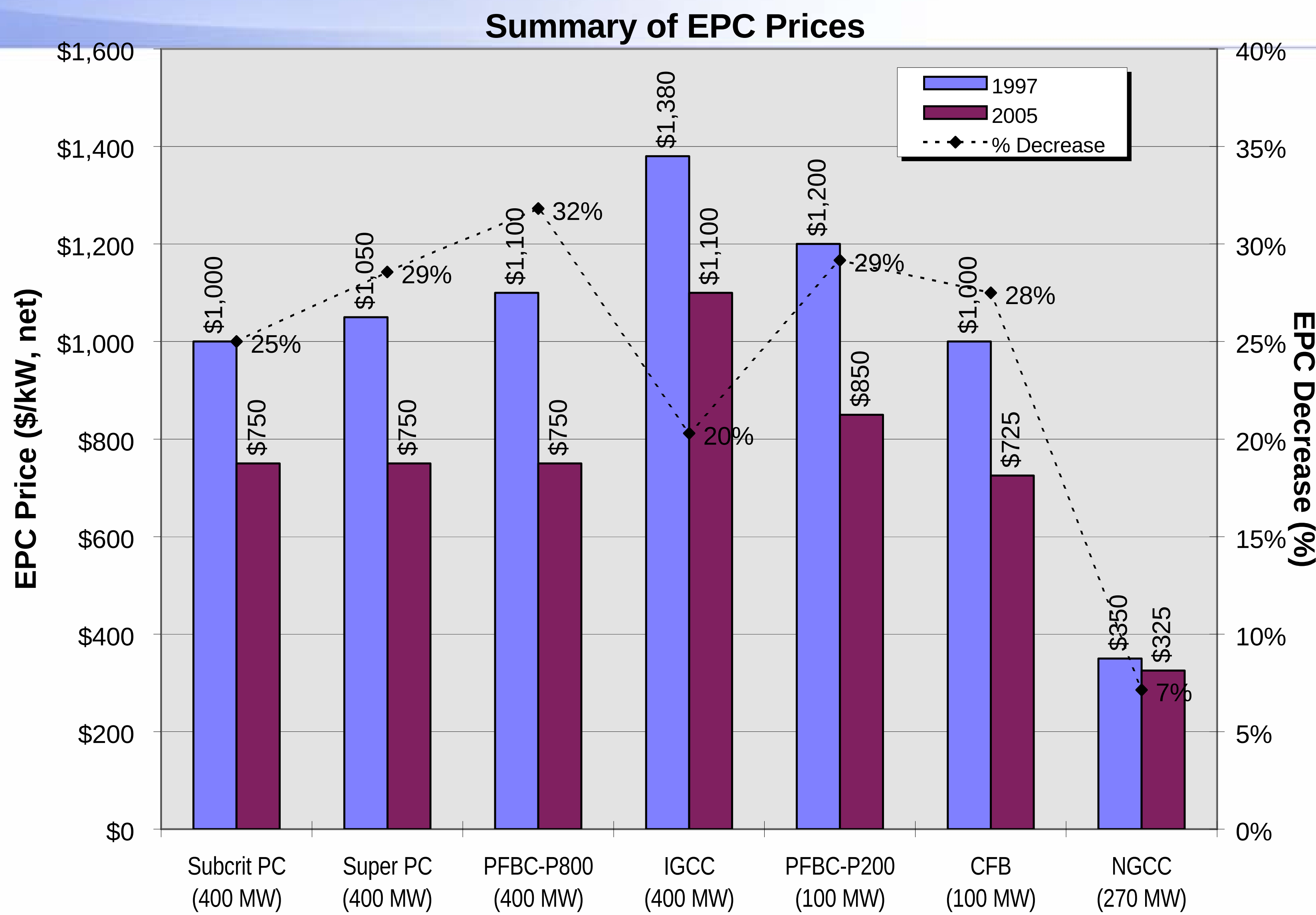

Net Plant Heat Rate Summary
Net Plant Heat Rate (Btu/kW)
NPHR Improvement (%)
12,000
10,000
8,000
6,000
4,000
2,000
0
12%
10%
8%
6%
4%
2%
0%
9,375
8,750
8,385
8,125
8,405
8,030
8,700
7,800
8,815
8,530
10,035
9,350
6,640
6,195
7%
3%
4%
10%
3%
7%
7%
Subcrit PC (400 MW)
Super PC (400 MW)
PFBC-P800 (400 MW)
IGCC (400 MW)
PFBC-P200 (100 MW)
CFB (100 MW)
NGCC (270 MW)
1997
2005
Improvement


Summary of EPC Prices
EPC Price ($/kW, net)
EPC Decrease (%)
1997
2005
% Decrease
$1,600
$1,400
$1,200
$1,000
$800
$600
$400
$200
$0
40%
35%
30%
25%
20%
15%
10%
5%
0%
$1,000
$750
25%
$1,050
$750
29%
$1,100
$750
32%
$1,380
$1,100
20%
$1,200
$850
29%
$1,000
$725
28%
$350
$325
7%
Subcrit PC (400 MW)
Super PC (400 MW)
PFBC-P800 (400 MW)
IGCC (400 MW)
PFBC-P200 (100 MW)
CFB (100 MW)
NGCC (270 MW)

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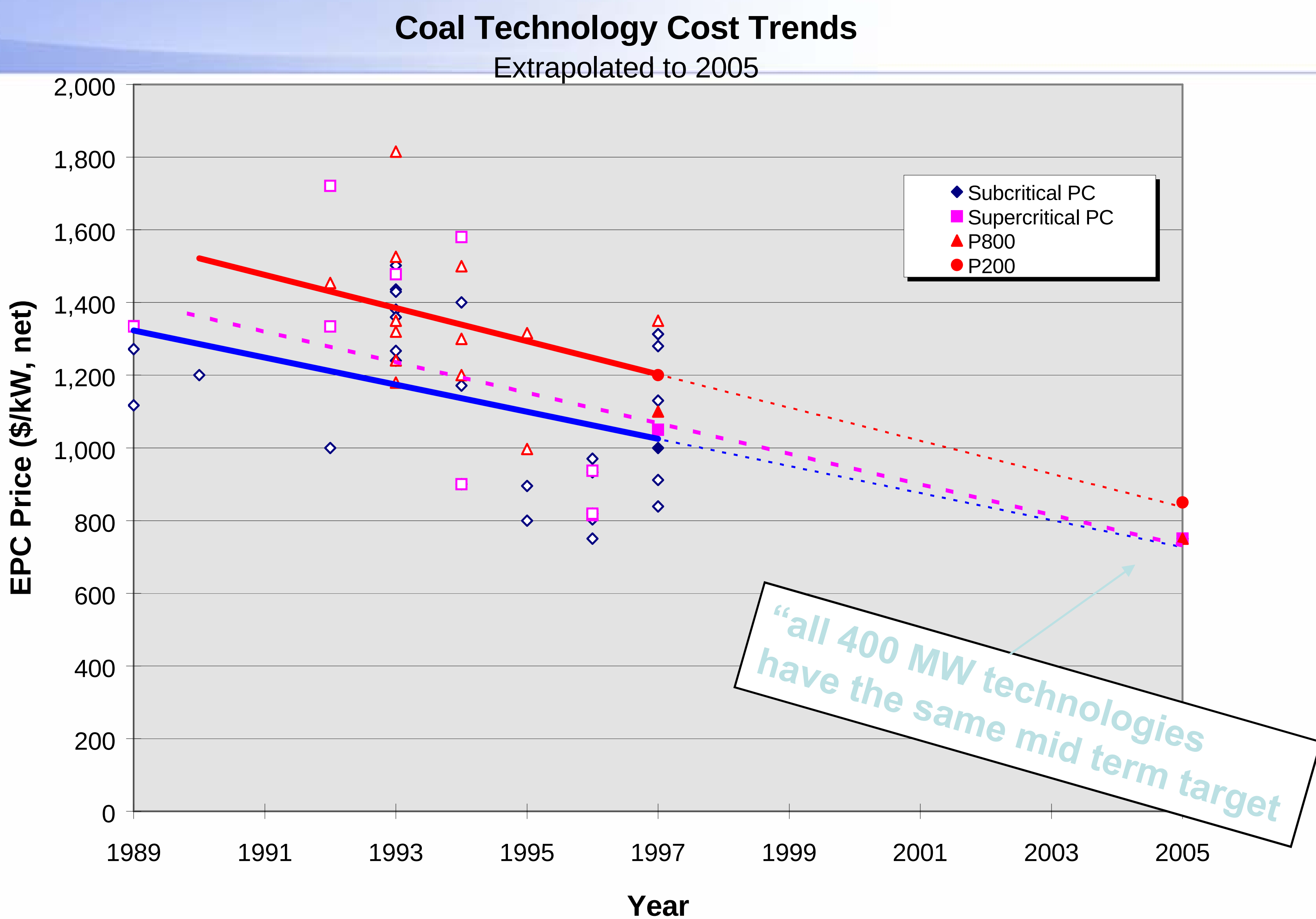
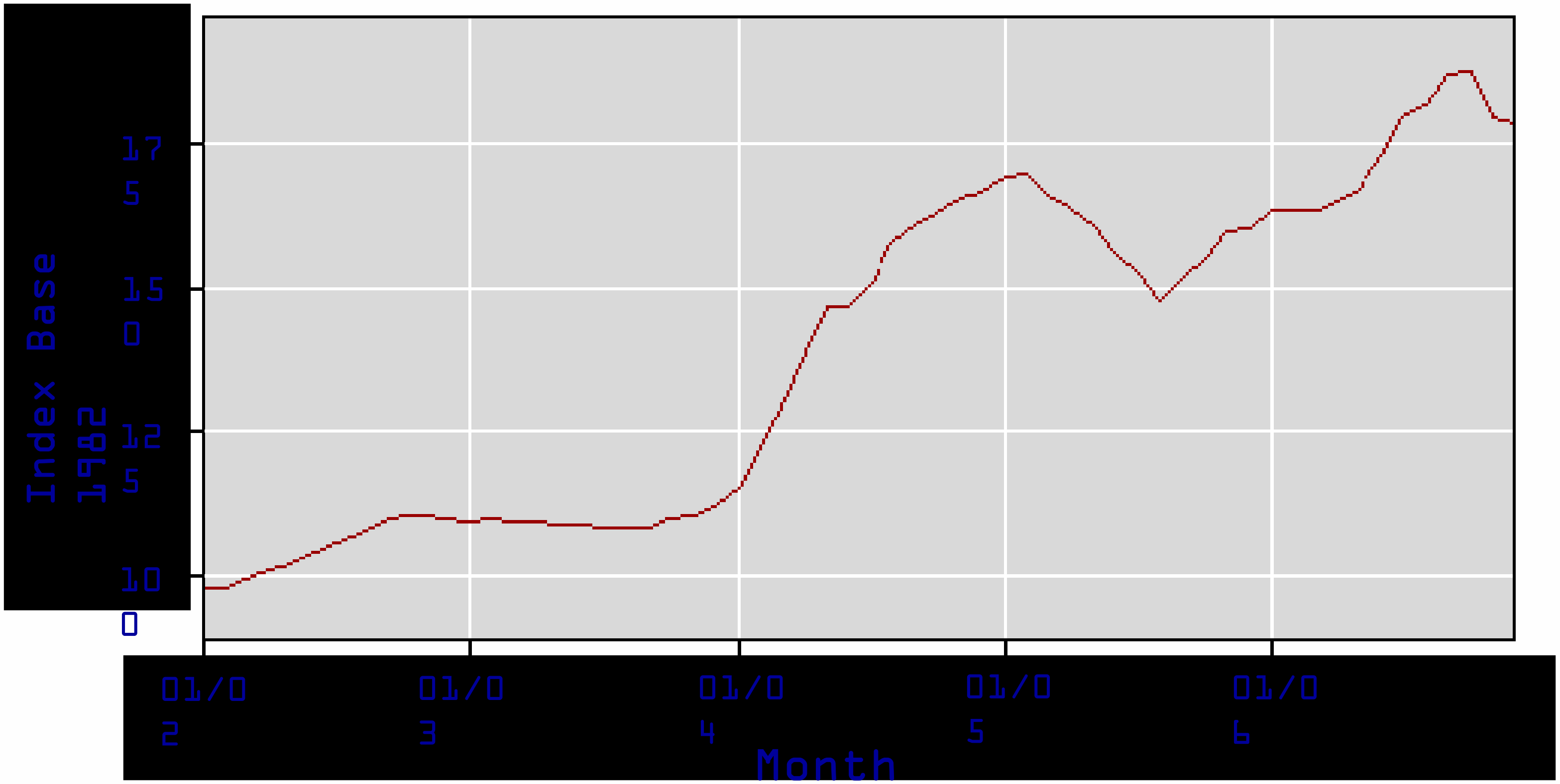

Coal Technology Cost Trends
Extrapolated to 2005
EPC Price ($/kW, net)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1989
1991
1993
1995
1997
1999
2001
2003
2005
Year
Subcritical PC
Supercritical PC
P800
P200
"all 400 MW technologies
have the same mid term target

Market Trends

Carbon Steel Price Trends



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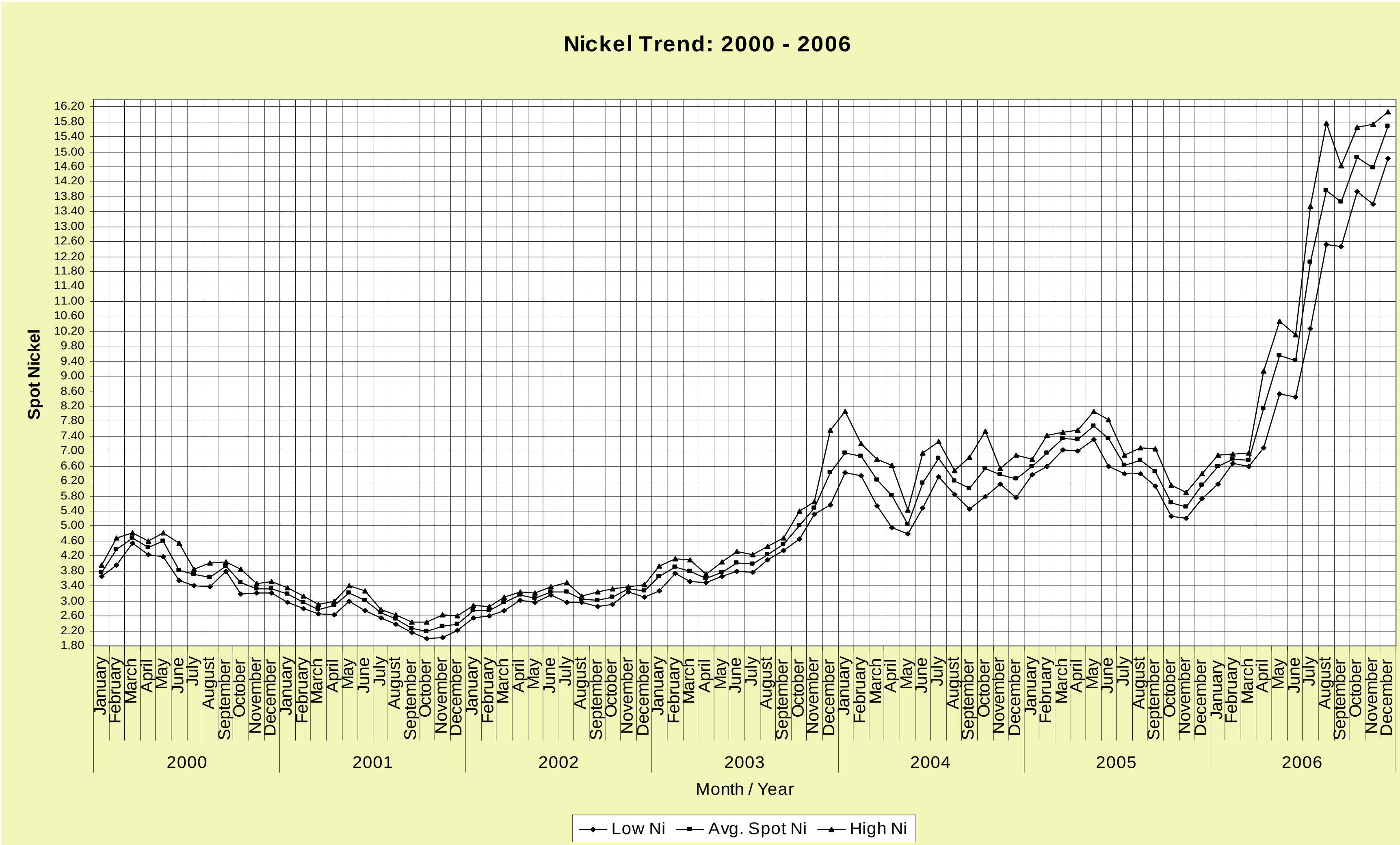
Market Trends



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Today's Costs (Estimated)

- Today's debate centers around conventional pulverized coal plants (PC) and integrated gasification combined cycle plants (IGCC).
- As we have seen, the current level of development for IGCC makes it uncompetitive with PC, which explains why very few have been built.
- The claim for the future is that the cost of capture of CO2 to mitigate greenhouse gas concentrations in the atmosphere will be more expensive for PC than for IGCC. Further, as IGCC develops, its costs will come down (learning curve).
- As we are in a state of flux with regard to present day costs for plants, the best we can assume (to one significant figure) is that costs have escalated from their 1997 level to about double. That is, a PC plant is now about $2000/Kw and an IGCC is about $3000/Kw (EPC). Recall that the forecast in 1997 was for PC to be $750/Kw and the IGCC to be $1100/Kw. Unfortunately, that is one of the dangers of forecasting.

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Today's Costs (Estimated)

- Fuel costs have also escalated. Recent data for fuel costs delivered to new plants is about $1.75/MMBTU for coal and $7.50/MMBTU for gas.
- We can input these new costs into the spread sheet model and get an estimate for the COE for a utility trying to make a decision today.
  - Under these conditions, with no CO2 capture, the COE for the PC plant would be 6.55 cents/Kwhr and the IGCC plant would be 9.41 cents/Kwhr.
  - The natural gas plant would again look competitive at 6.6 cents/Kwhr with an 80% capacity factor. However, at a more typical 40% capacity factor, the COE is 8.30 cents/Kwhr.
  - As a result, we see a lot of utilities considering supercritical pulverized coal plants.
- What about the argument for CO2 capture?
  - This is a subject of intense debate/argument. IGCC costs are expected to increase by 15 - 20% for CO2 capture. The range for PC is considerable. Old technology could increase by as much as 50%. Current technology ranges from 20 – 30%. New technology is estimated between 10 – 15%. Who's right?

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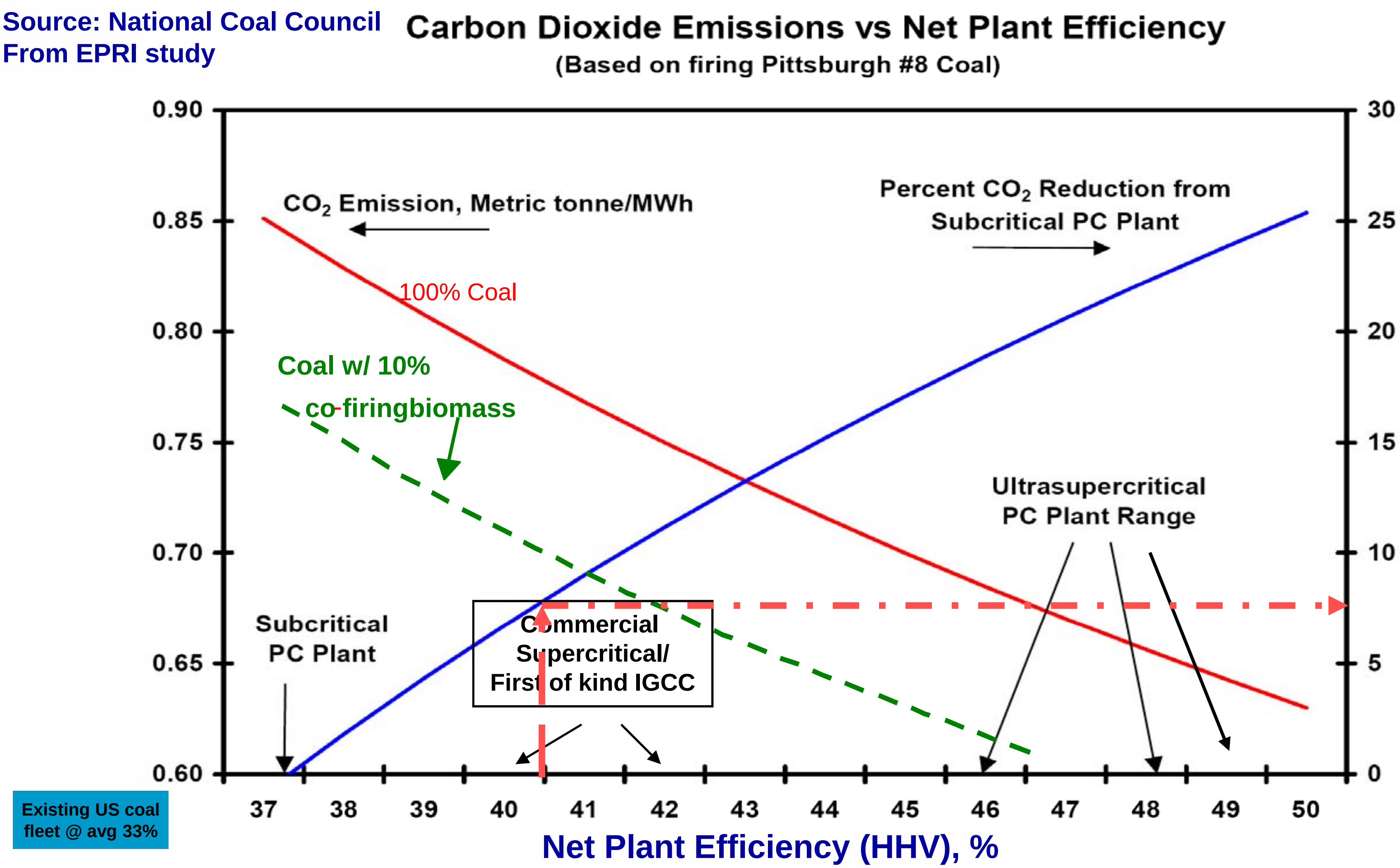
Efficiency –
Critical to emissions strategy

Source: National Coal Council
From EPRI study



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CO_2 Mitigation Options – for Coal Based Power

✓ Increase efficiency

Maximize MWs per lb of carbon processed

✓ Fuel switch with biomass

Partial replacement of fossil fuels = proportional reduction in CO_2

✓ Then, and only then ….Capture remaining CO_2 for EOR/Sequestration

= Logical path to lowest cost of carbon reduction

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