Cooling System Retrofit Costs

EPA Workshop on
Cooling Water Intake Technologies
Arlington, Virginia

May 6, 2003

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Once-Through to Cooling Towers

- **How much do retrofits cost?**
  - What has to be done?
  - What cost information is available?
  - How do they compare?
  - How site-specific are the costs?
  - What are costs beyond capital costs?
  - What are some of the other issues?

Starting with the Conclusions

COSTS ARE VERY SITE-SPECIFIC

General correlations don’t work

Cost vary widely—x2 to x10

Operating/penalty costs can be important

Cooling towers have environmental effects too

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What has to be done?

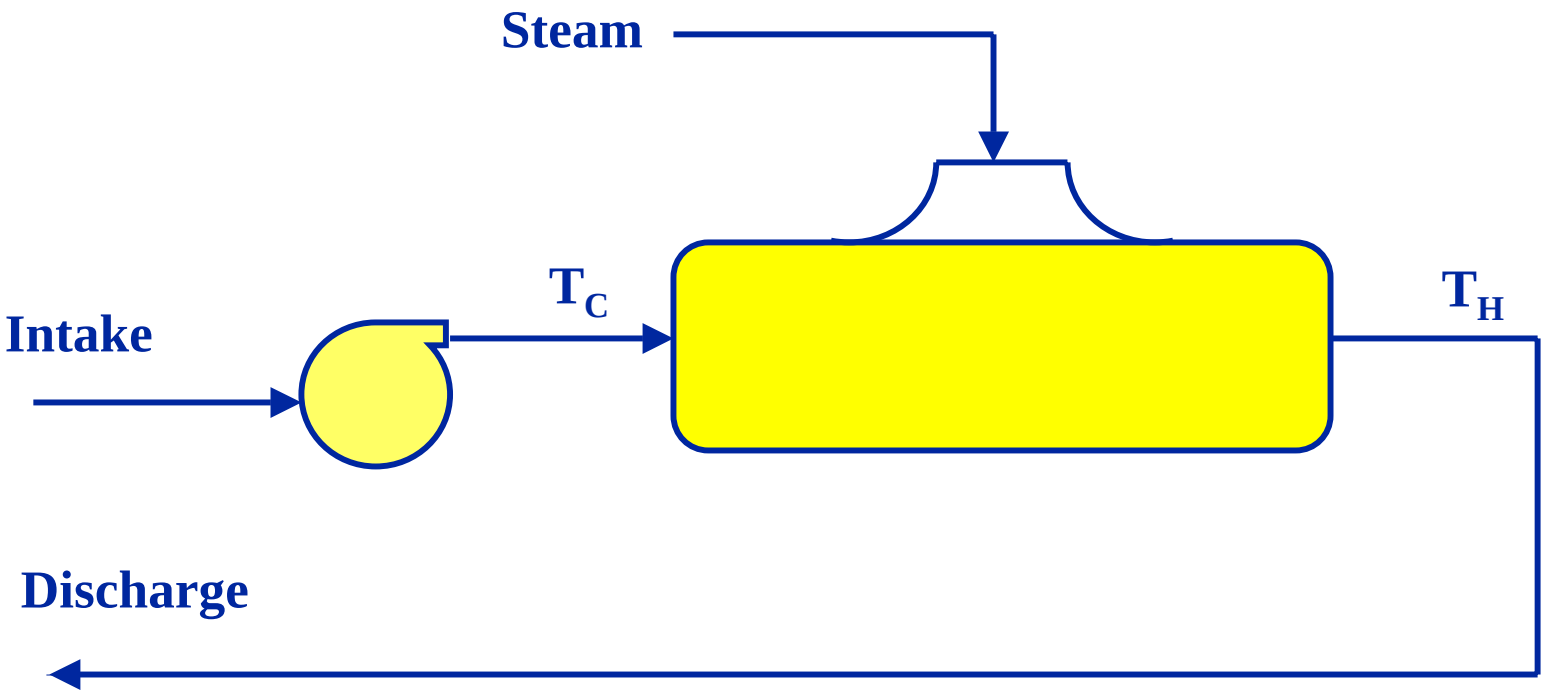
Tower installation

✓Circulating water piping and pumps

Intake/discharge modifications

Water treatment for use and for discharge

✓Re-optimization of cooling system design

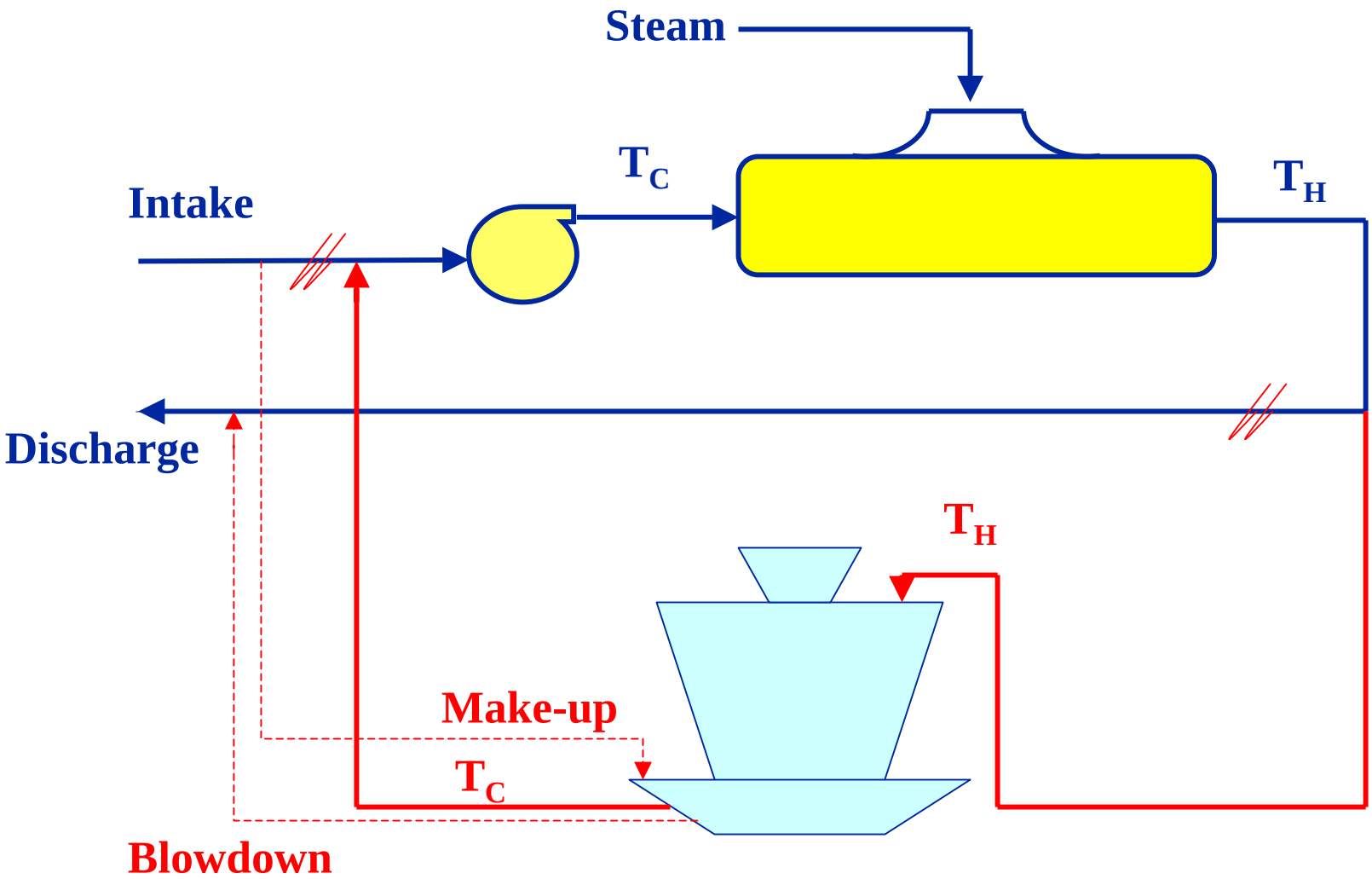


Circulating flow = 500 – 800 gpm/MW

T_{intake} = T_c = 60 F; $T_{discharge}$ = T_h = 75 - 80 F

T_{cond} = 82 – 95 F--------backpressure = 1.1 – 1.7 inHga

ONCE-THROUGH COOLING SYSTEM



"Optimized flow" = 300 – 600 gpm/MW

$T_{wet\ bulb}$ = 75 F; T_c = 85 - 90 F; T_h = 100 - 115 F

T_{cond} = 107 - 125 F--------backpressure = 2.4 – 4.0 inHga

CLOSED-CYCLE COOLING SYSTEM

Re-optimization

- Once-through systems---high flows; low range
- Closed cycle systems are off-optimum at once through conditions
- Reduce flow by ½
  - Major condenser modifications (one-pass to two-pass)
  - Turbine hall walls may have to be removed
  - Extended outage time

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INFORMATION SOURCES FOR COSTS

Utility studies

A&E estimates

Stone & Webster

The Washington Group

NETL/Parsons

EPA estimates

Distribution of Plants With Data (50)

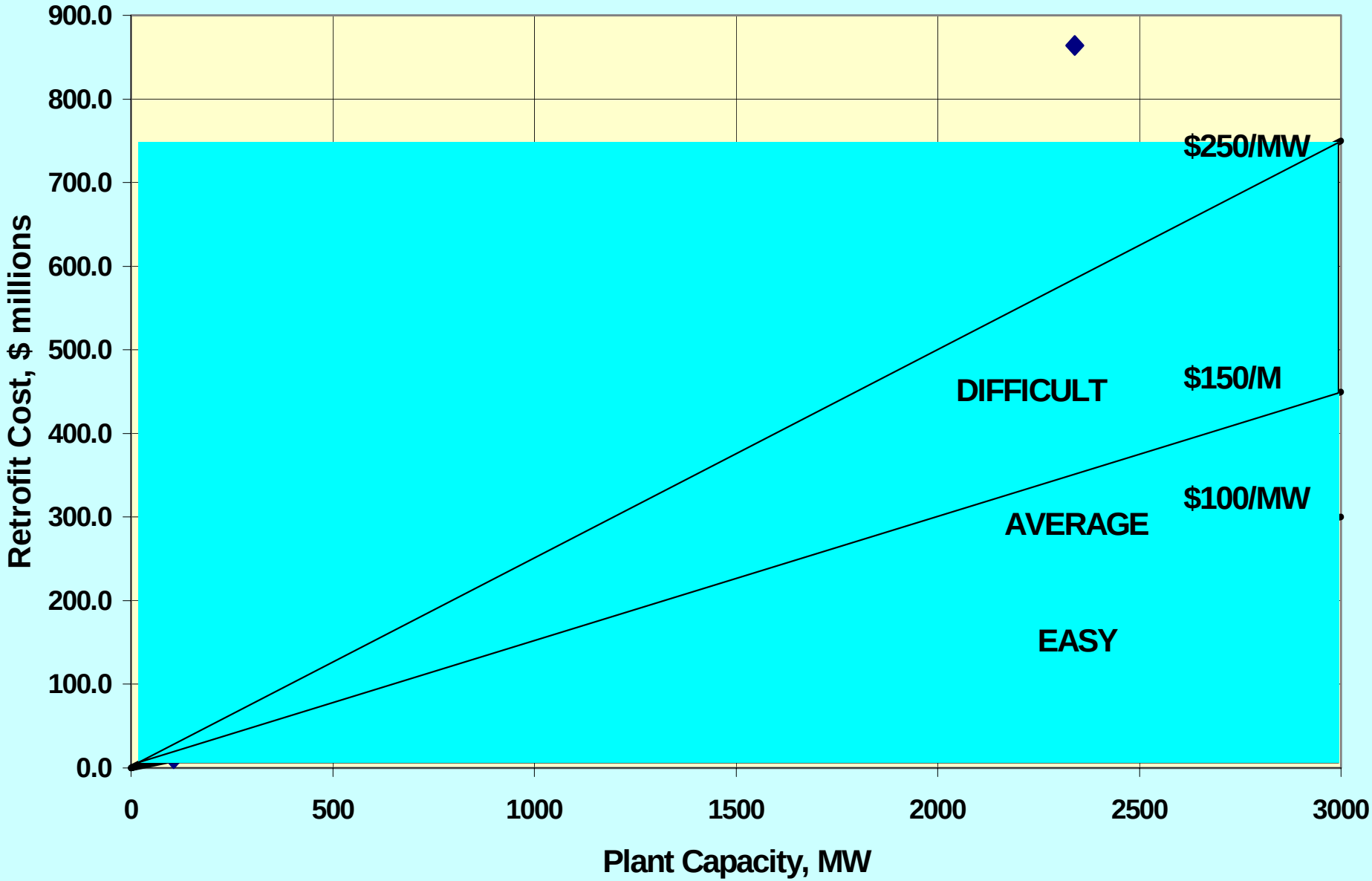
NUCLEAR (15)

	Saline	Brackish	Fresh
> 500 MW (15)	5	5	5
< 500 MW (0)	0	0	0

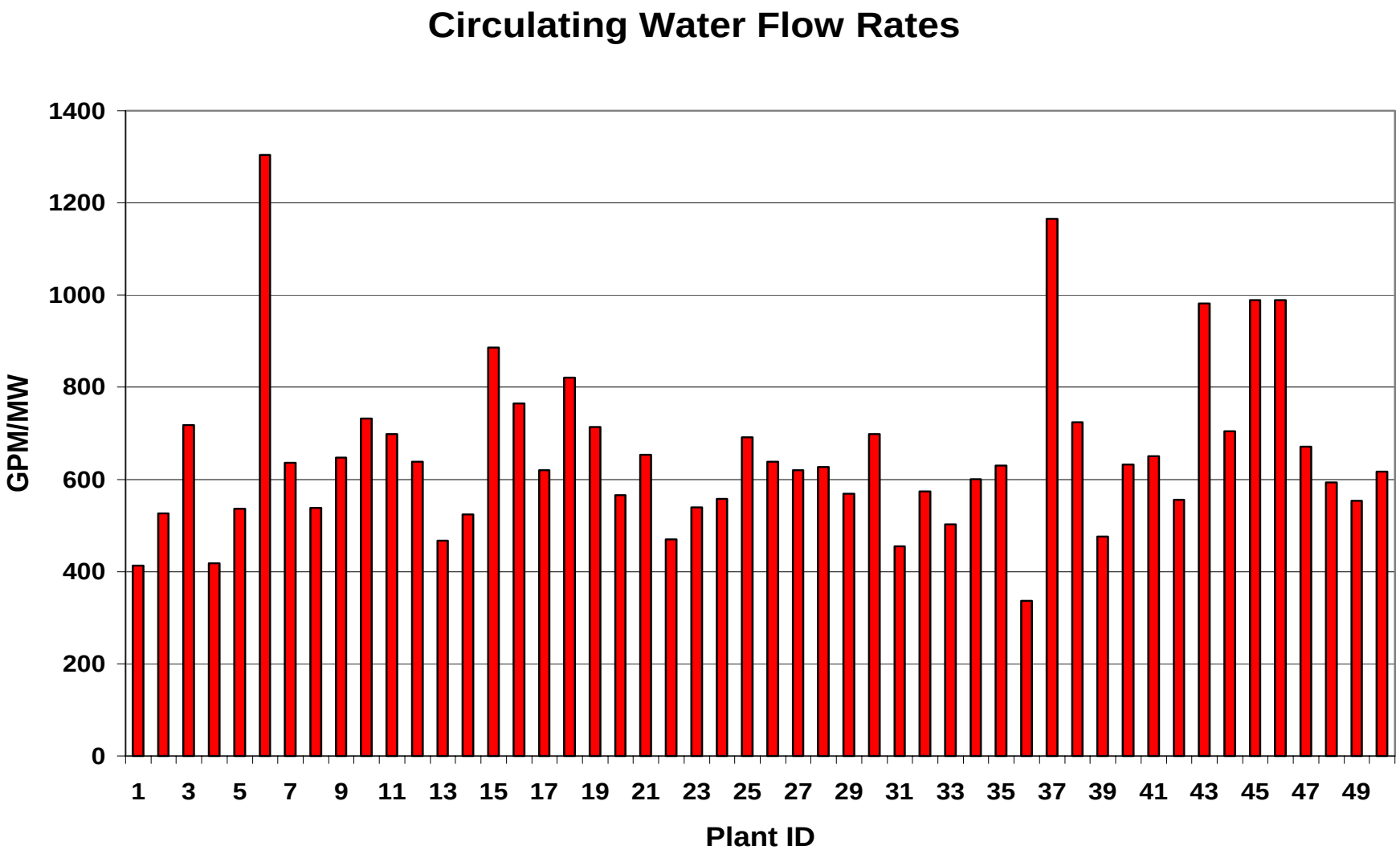
FOSSIL (35)

	Saline	Brackish	Fresh
> 500 MW (29)	2	8	19
< 500 MW (6)	1	1	4

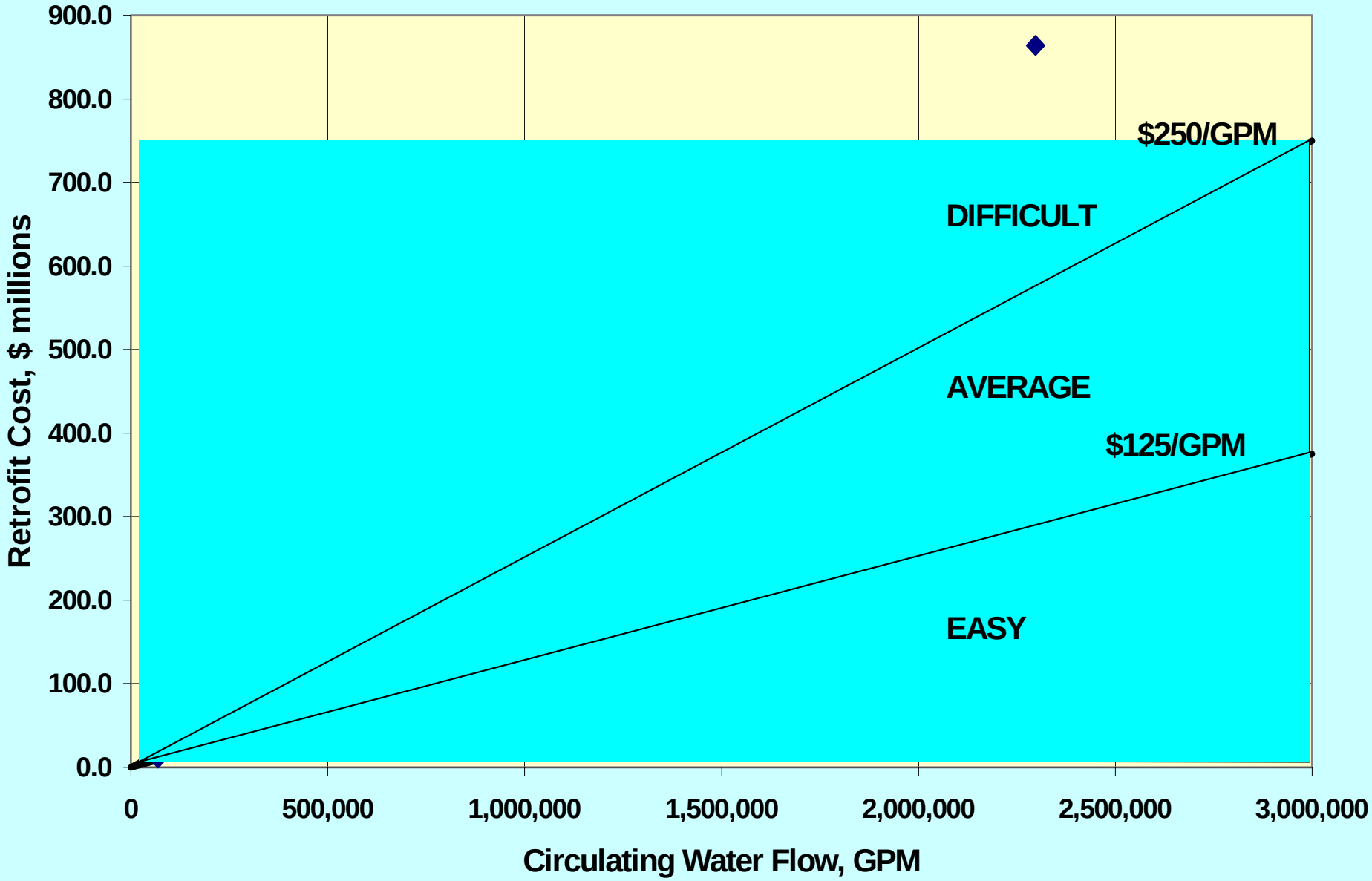
Scaled Plant Data vs. MW

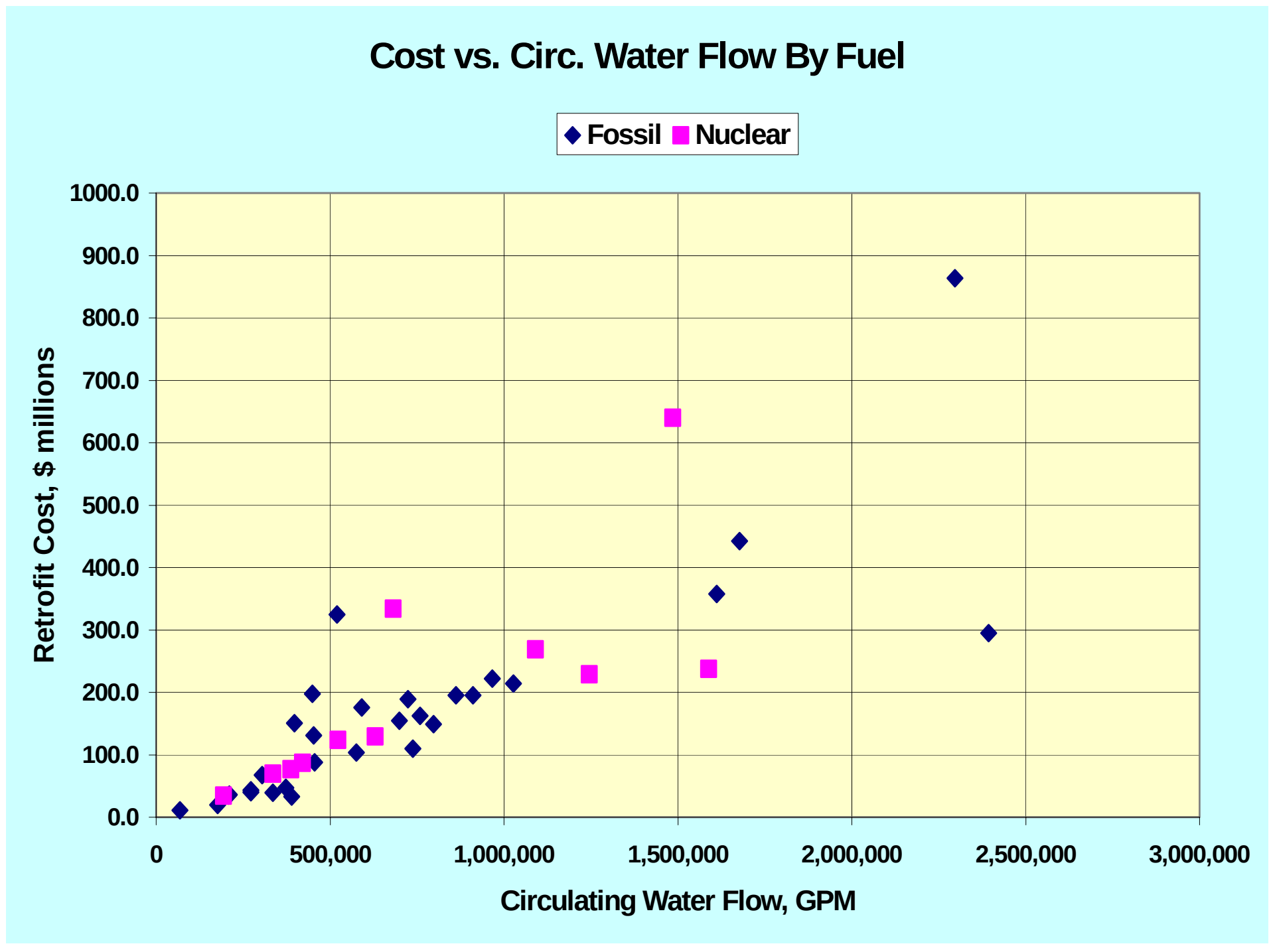


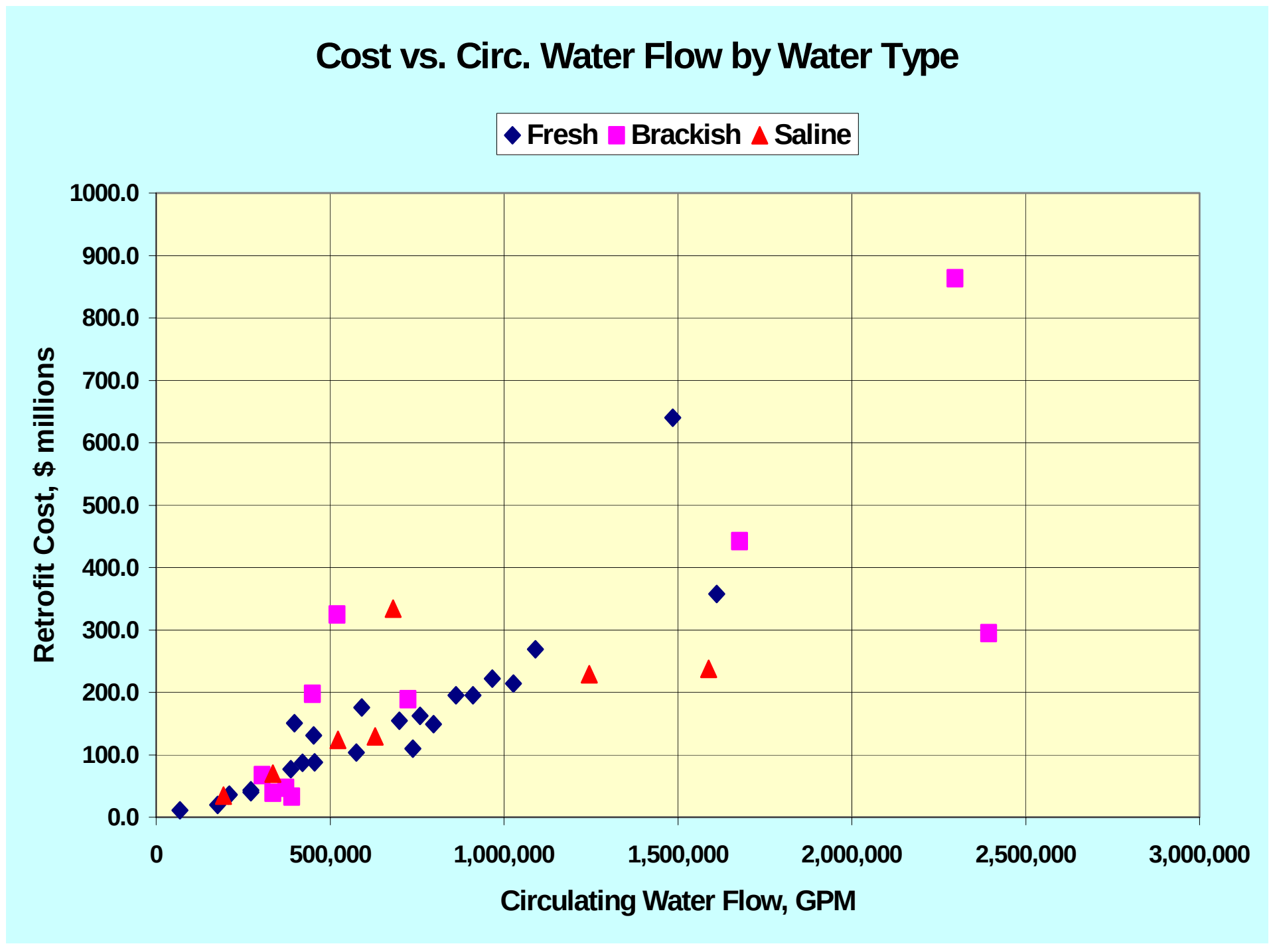
Cooling Water Flow vs. Plant Size



Scaled Plant Data vs. GPM




Cost vs. Circ. Water Flow By Fuel
Fossil
Nuclear
Retrofit Cost, $ millions
1000.0
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
0
500,000
1,000,000
1,500,000
2,000,000
2,500,000
3,000,000
Circulating Water Flow, GPM


Cost vs. Circ. Water Flow by Water Type
Fresh
Brackish
Saline
1000.0
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
Retrofit Cost, $ millions
0
500,000
1,000,000
1,500,000
2,000,000
2,500,000
3,000,000
Circulating Water Flow, GPM

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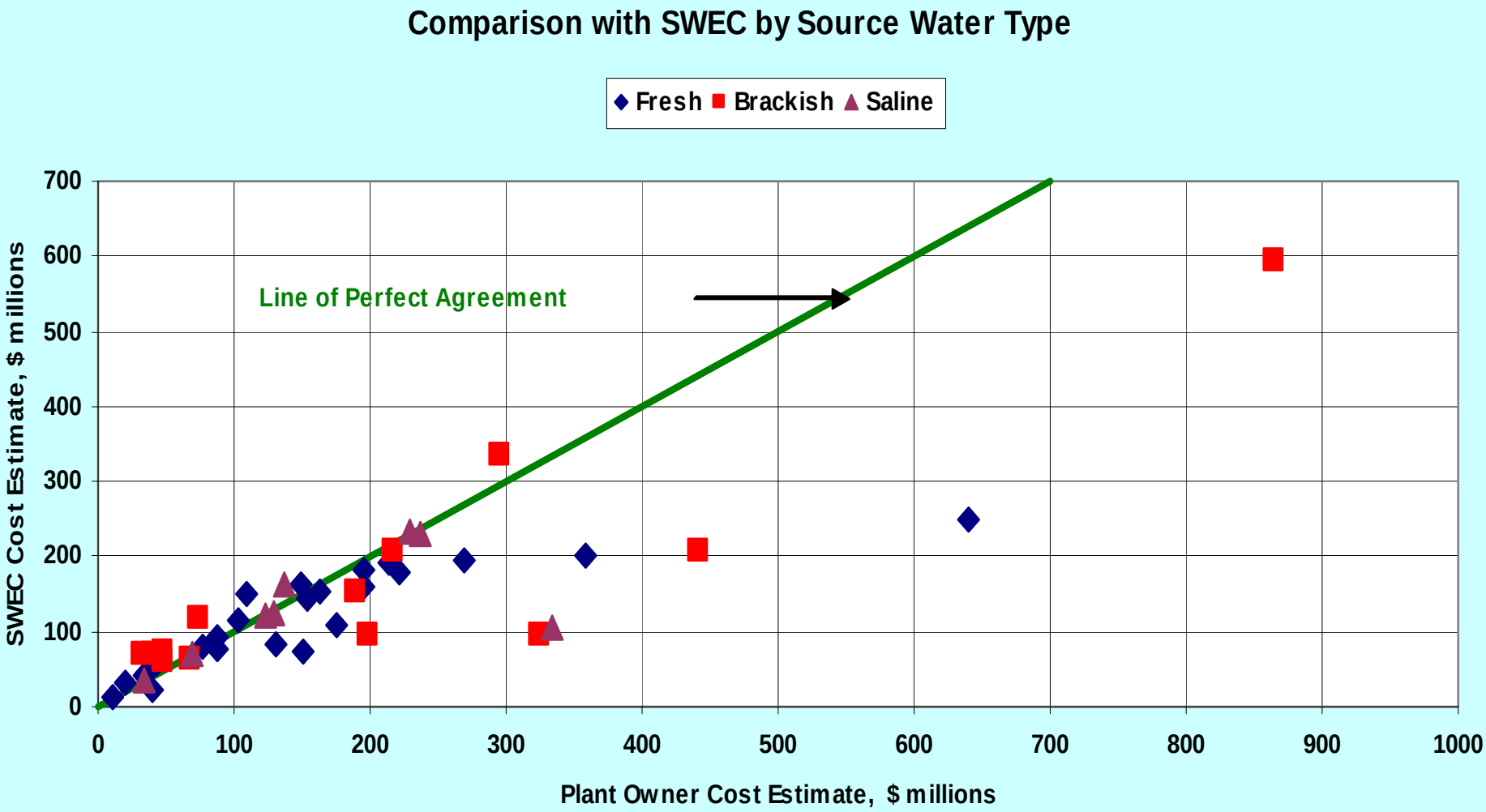
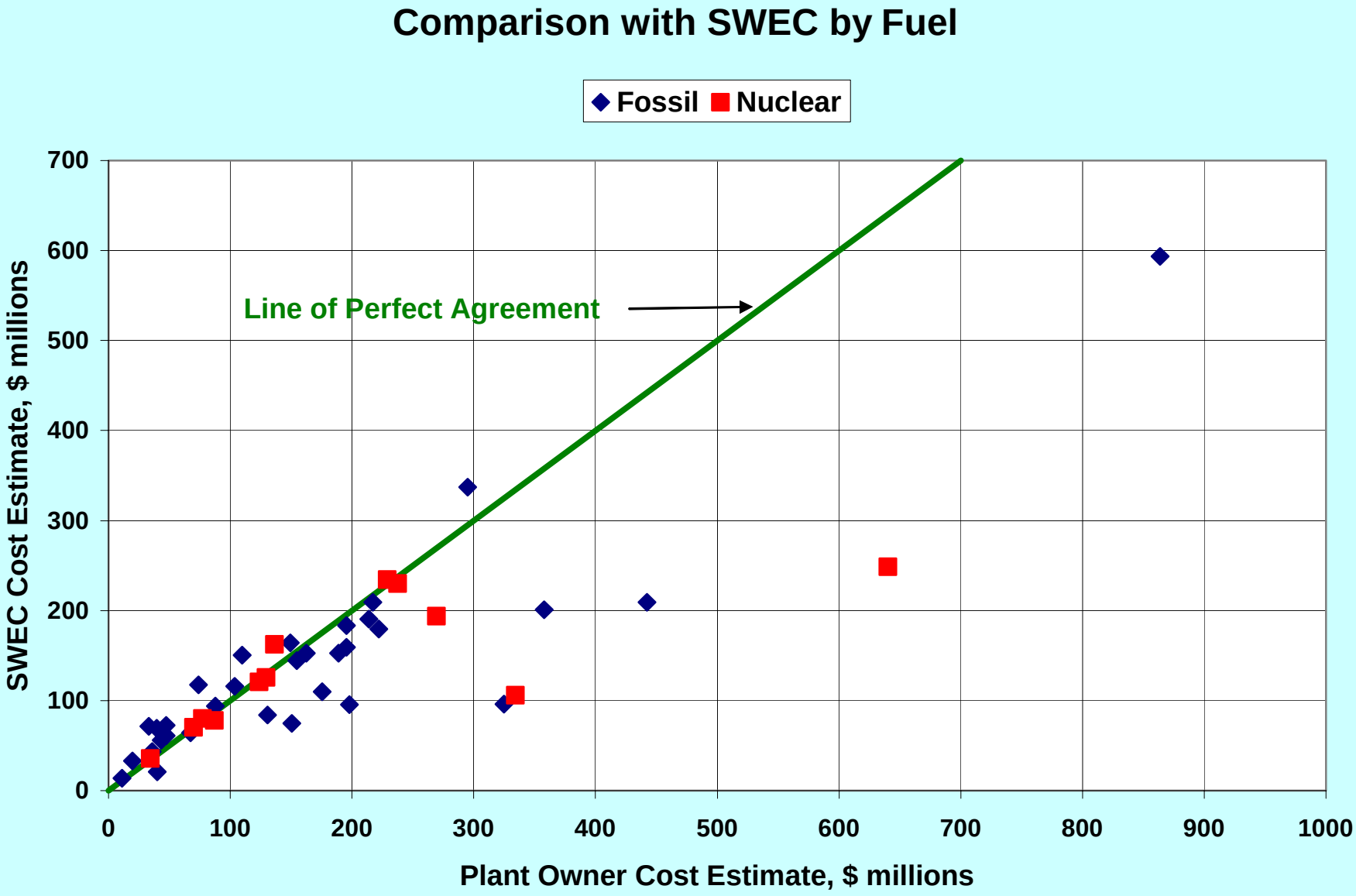
National Studies

- SWEC---
  - Compare to 6 base plants; scaled by flow
- Washington Group, Inc
  - Built up costs on component basis; scaled by flow
- NETL/Parsons
  - 4 site specific studies

SWEC REFERENCE PLANTS

PLANT	Fuel	Water Source	CAPACITY MW	FLOW GPM	GPM/MW	COST $	$/GPM	$/kW
X1	Coal	Estuary	250	174,627	699	36,000,000	206.2	144.0
X2	Coal	Estuary	620	279,403	451	57,000,000	204.0	91.9
X3	Oil	Estuary	440	259,701	590	48,000,000	184.8	109.1
X4	Ur	Marine	863	570,448	661	121,000,000	212.1	140.2
X5	Ur	Marine	1137	895,522	788	126,000,000	140.7	110.8
X6	Coal	River	82	35,373	431	6,900,000	195.1	84.1


Comparison with SWEC by Source Water Type
Fresh
Brackish
Saline
Line of Perfect Agreement
SWEC Cost Estimate, $ millions
Plant Owner Cost Estimate, $ millions
0
100
200
300
400
500
600
700
800
900
1000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Nuclear
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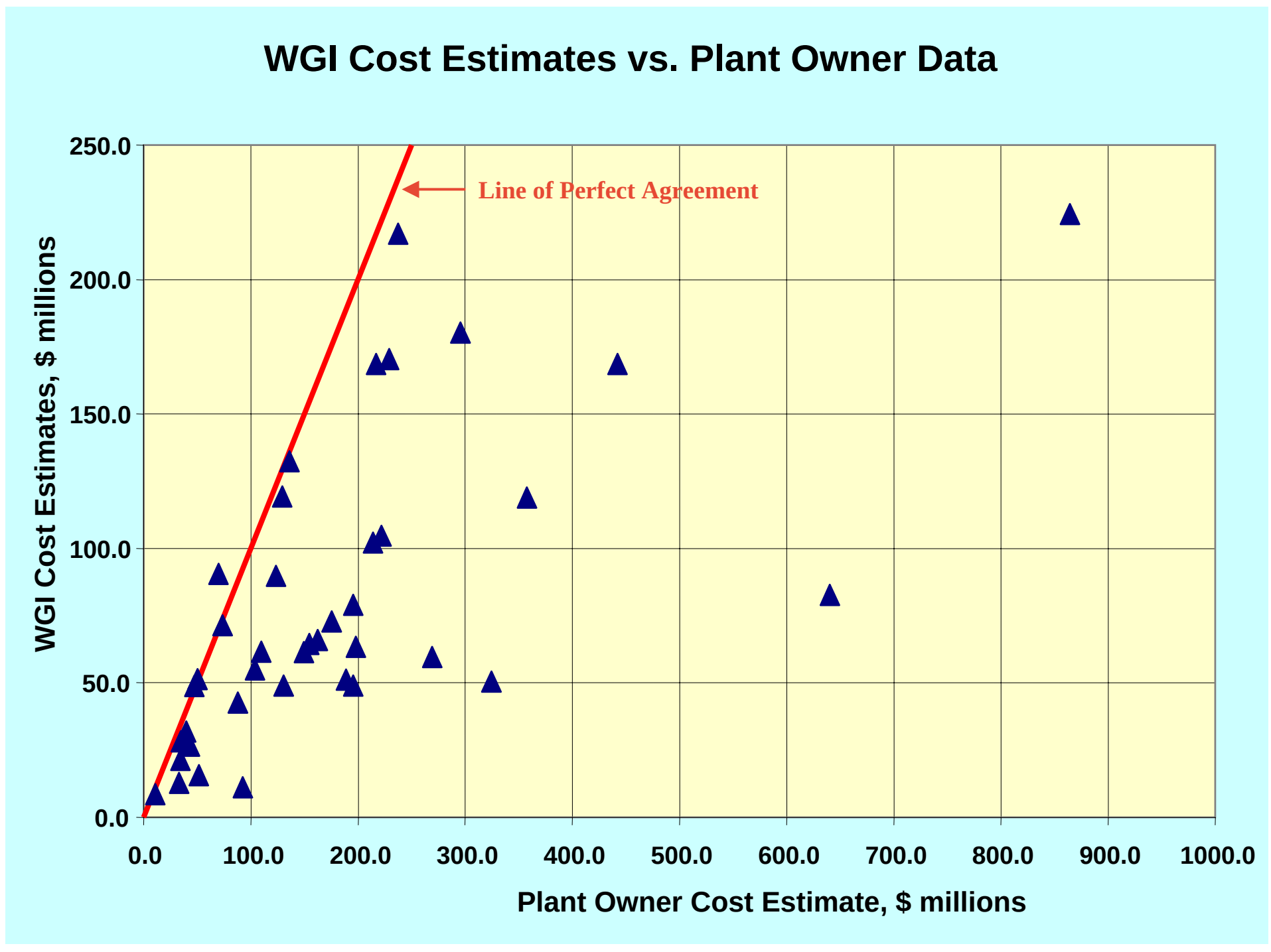
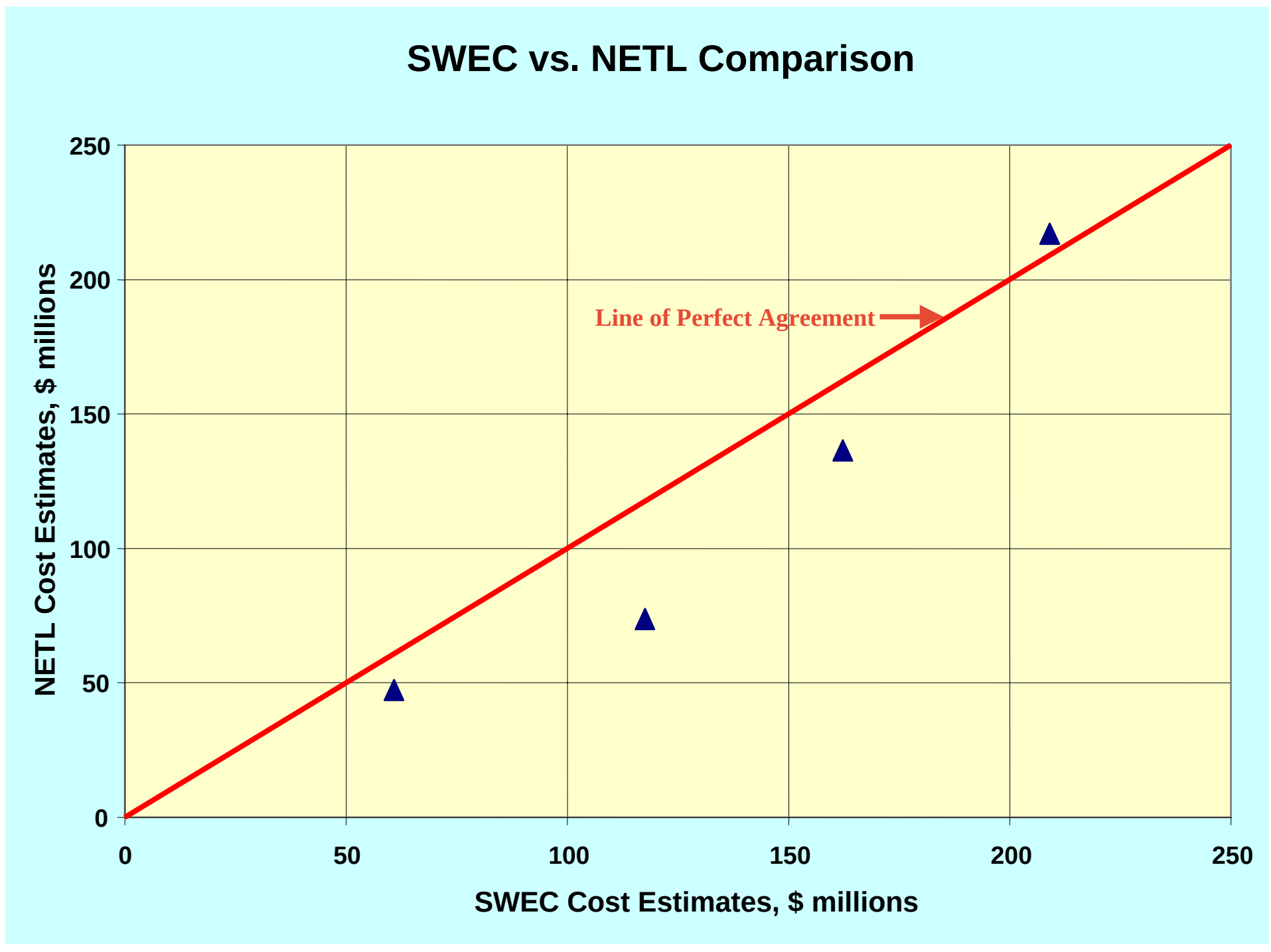
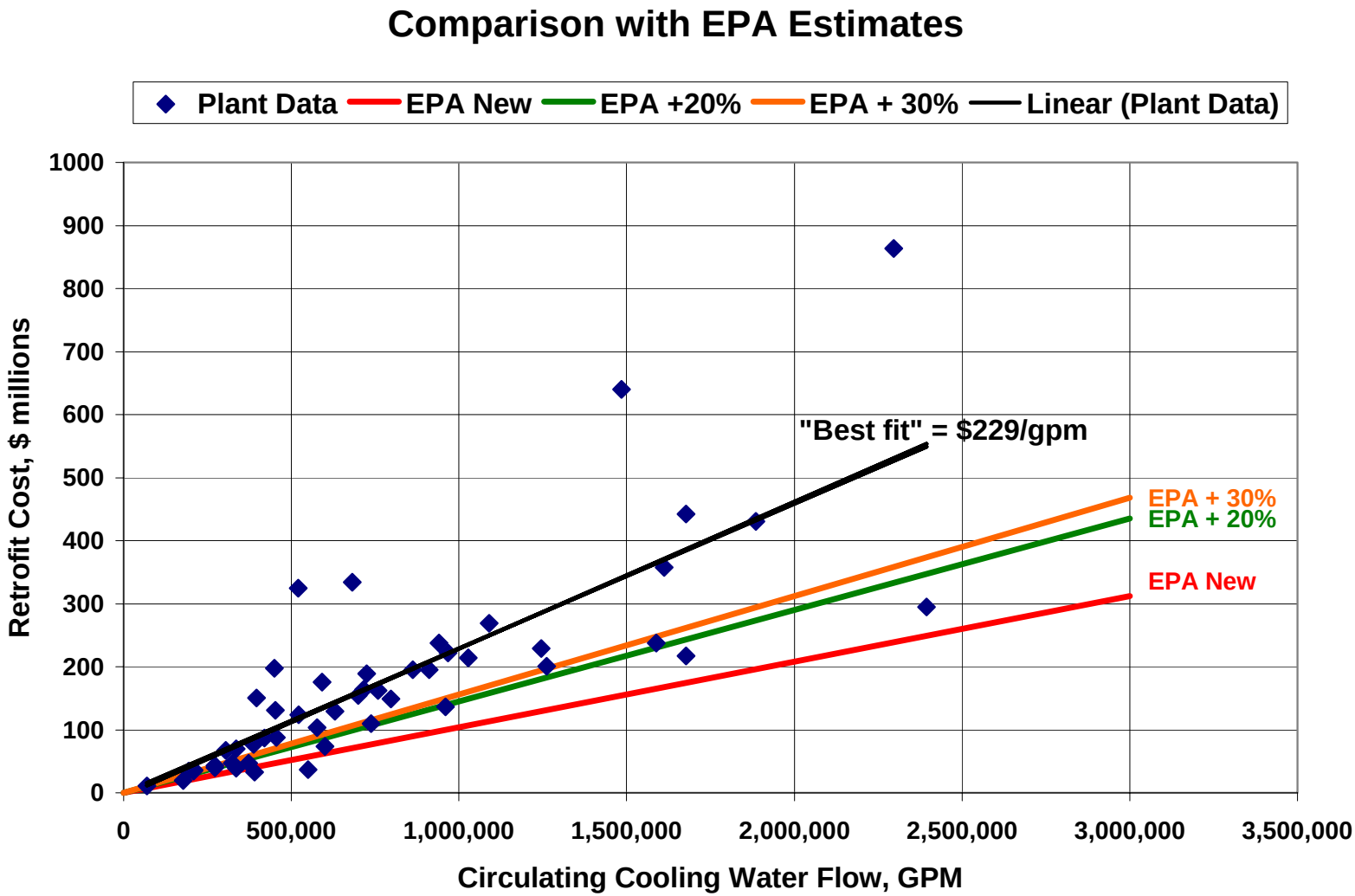
900
1000


WGI Cost Estimates vs. Plant Owner Data
Line of Perfect Agreement
WGI Cost Estimates, $ millions
Plant Owner Cost Estimate, $ millions
0.0
50.0
100.0
150.0
200.0
250.0
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
800.0
900.0
1000.0


SWEC vs. NETL Comparison
NETL Cost Estimates, $ millions
SWEC Cost Estimates, $ millions
Line of Perfect Agreement
0
50
100
150
200
250

EPA Estimates



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Retrofit Issues

Tower

Source water quality
Location on site
Site geology
Makeup/blowdown lines/pumps

Circulating water loop

Circ. water loop—higher head
Two sets of pumps
New circ. water lines
Condenser reinforcement

PLANT REPLIES TO COST ANALYSES

(based on replies from 56 plants)

ISSUES	PLANTS WITH SPECIAL CIRCUMSTANCES		%	
	ALL	44 of 56	ALL	44 of 56
Space	31	14	55	32
Separation Distance	46	35	82	80
Interferences	47	36	84	82
Site Geology	36	25	64	57
Plume/Drift	38	27	68	61
Noise	25	14	45	32
Aqueous Discharge	36	25	64	57
Condenser Modifications	22	11	39	25
Retirement	9	6	16	14

Cost roll-ups

SOURCE	COST IN BILLIONS
WGI	22.1
SWEC	28.0
ANL/DOE	27.7 – 29.8

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Other Costs

- Additional operating power
  - Pumping power > Once through pump power
  - Fan power
  - Net increase ~ 1.1 to 1.25%
- Additional maintenance
  - Tower is additional maintenance item
  - Water treatment for use & discharge
- Efficiency decrease
  - 10 F ~ 1in Hg backpressure ~ 1% heat rate

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Other Issues

Environmental effects from cooling towers

Consumptive water use

Makeup/blowdown treatment and discharge

Visible plumes

Drift/PM-10

Noise

CONCLUSIONS

- ✓ **RETROFIT COSTS VERY SITE-SPECIFIC**
- ✓ **INDIVIDUAL PLANT COSTS CAN BE VERY DIFFERENT FROM AVERAGE**
- ✓ **NATIONAL TOTALS REASONABLY CONSISTENT**

CONCLUSIONS

- ✓ O&M COSTS ARE IMPORTANT
- ✓ REOPTIMIZATION OF LARGE, NEW PLANTS IS VERY COSTLY
- ✓ NOT REOPTIMIZING IS ALSO VERY COSTLY
- ✓ A 20% RETROFIT FACTOR IS SIGNIFICANTLY LOW