Large Plant Studies

Parabolic Trough Review Meeting
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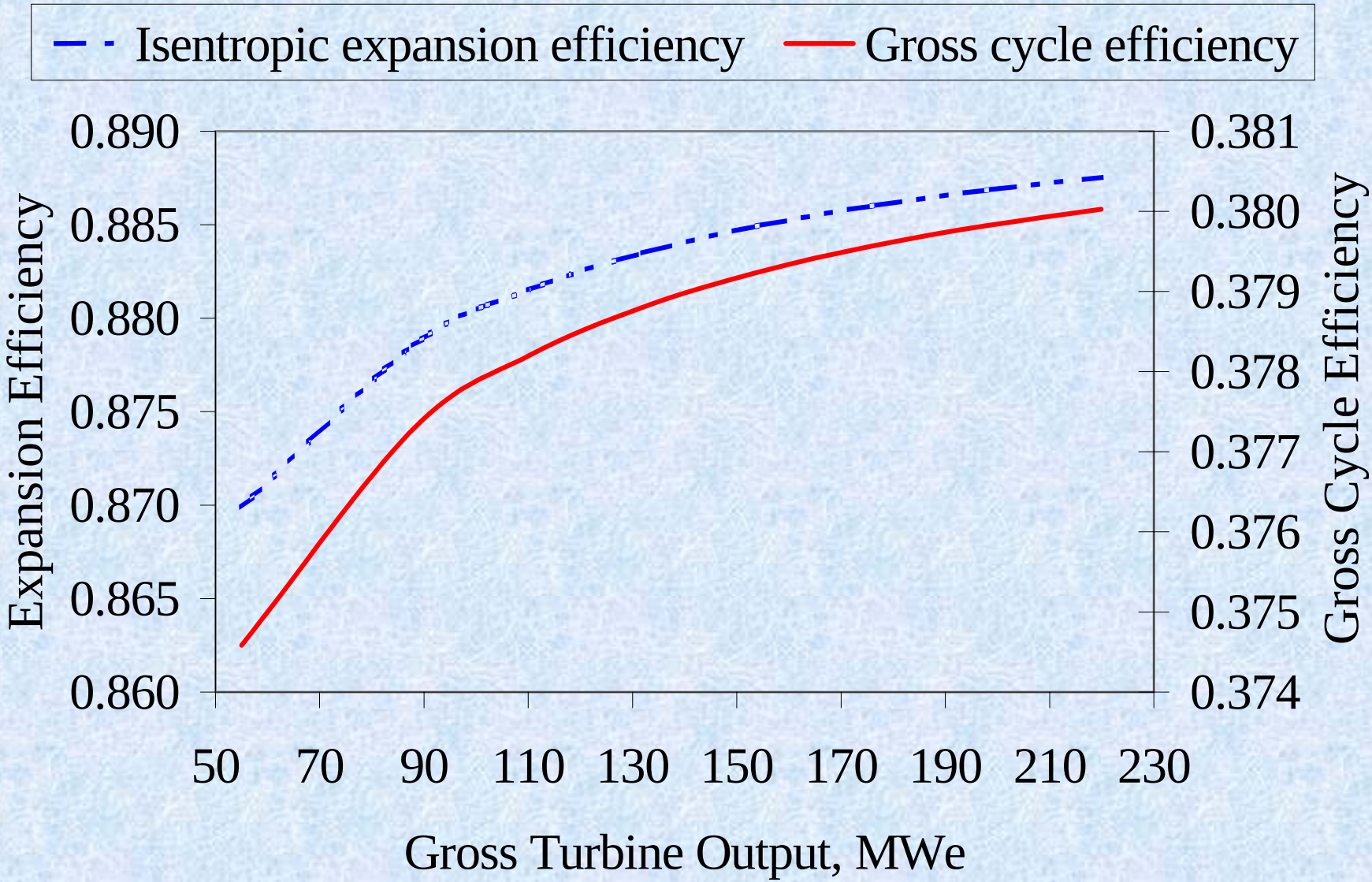
Bruce Kelly

Nexant, Inc.
A Bechtel-Affiliated Company
San Francisco, California

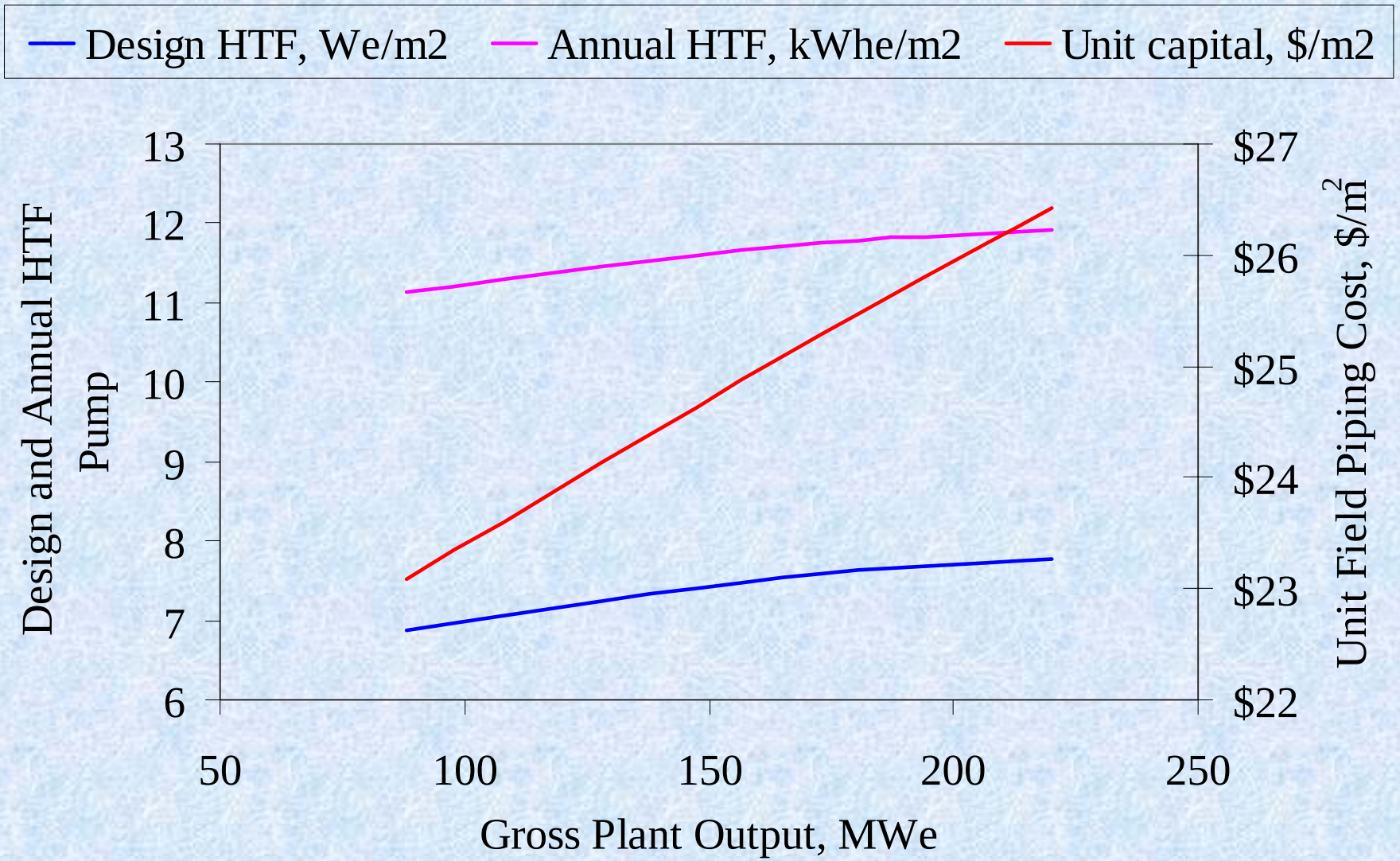
Study Basis

- 88 MWe, 165 MWe, and 220 MWe parabolic trough plants with, and without, thermal storage
- GateCycle Rankine cycle models
- Excelergy default performance and cost models
- Excelergy solar multiple optimization
- Barstow weather data; 30 year average

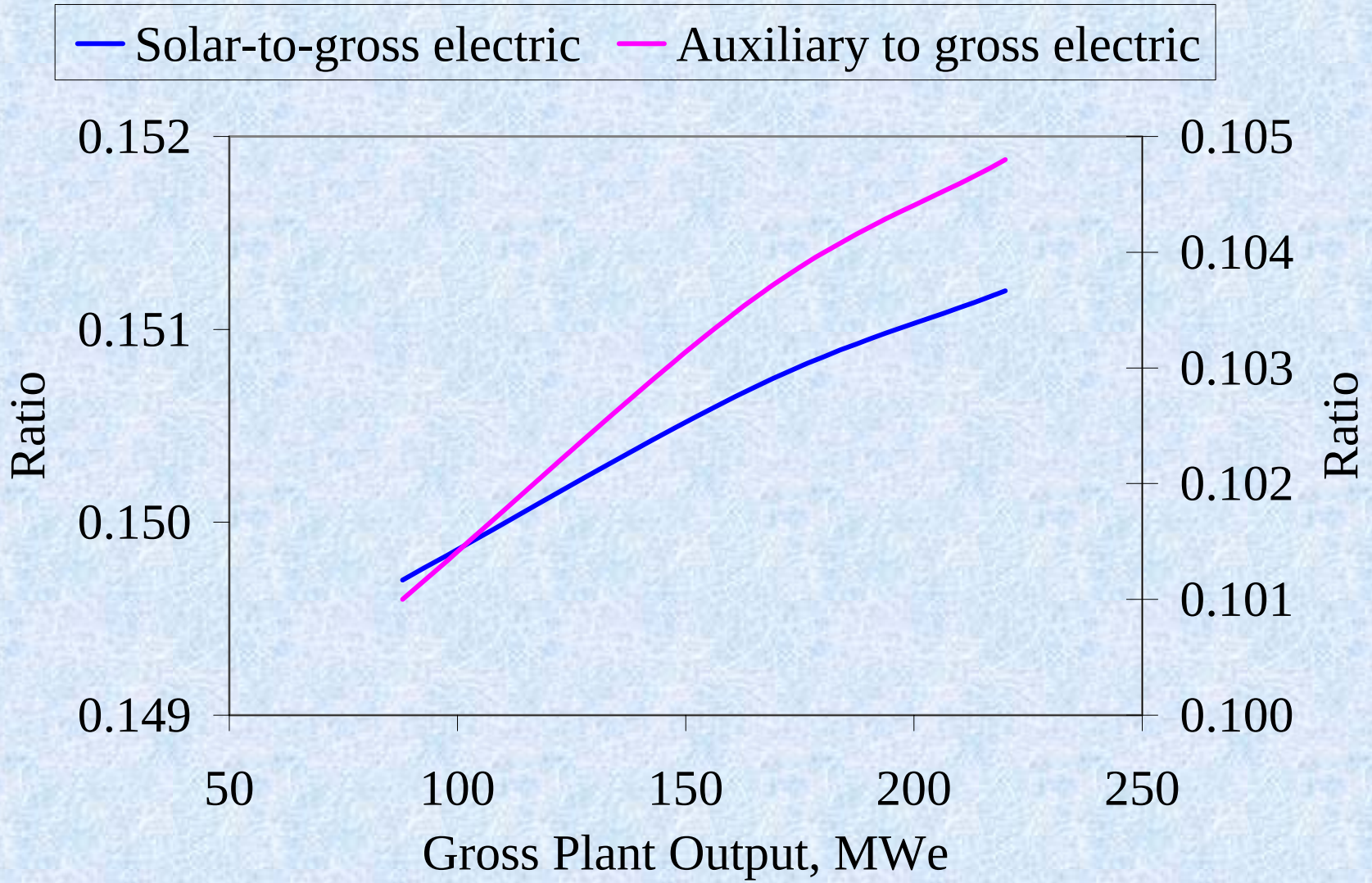
Rankine Cycle Performance



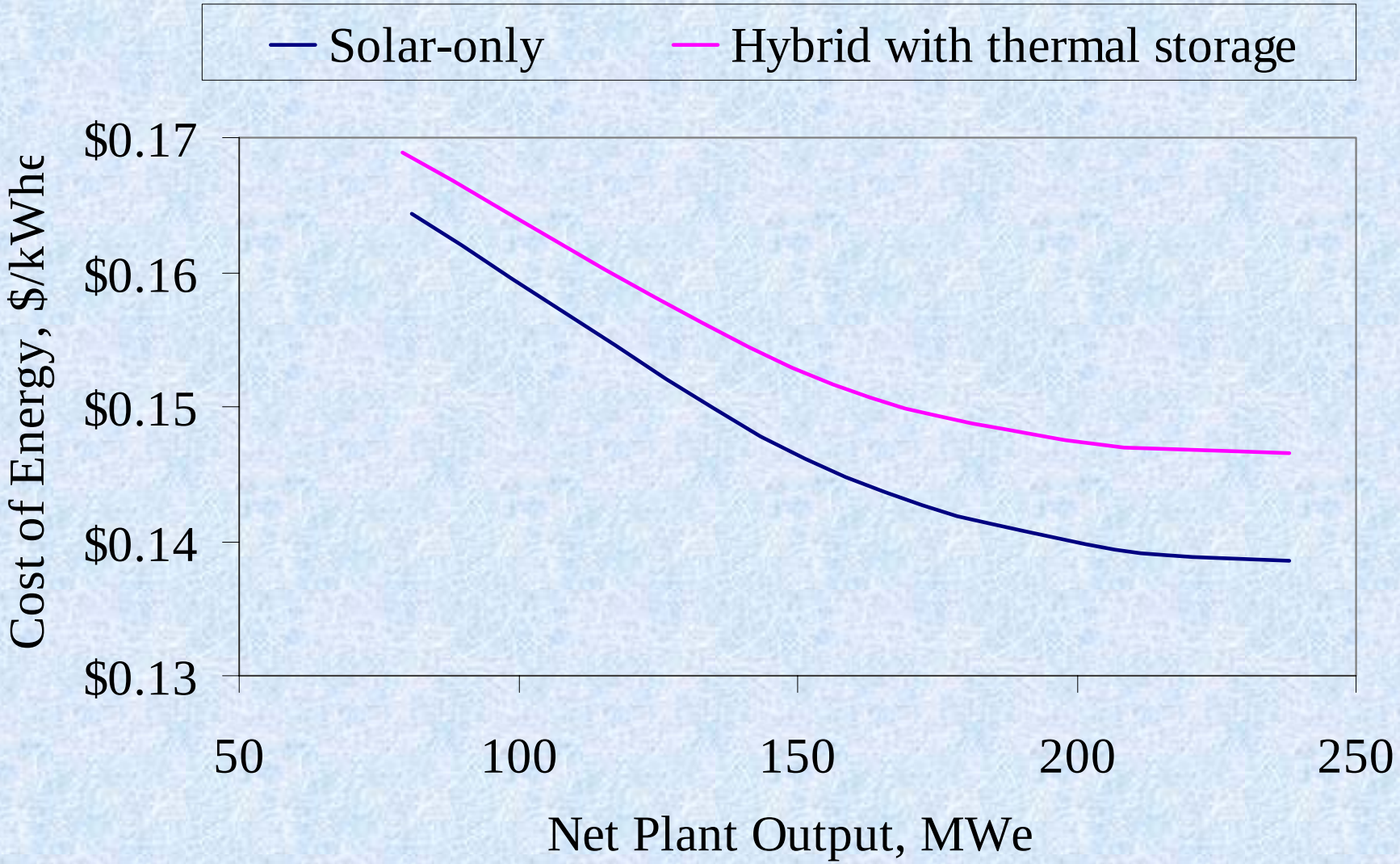
Collector Field Piping



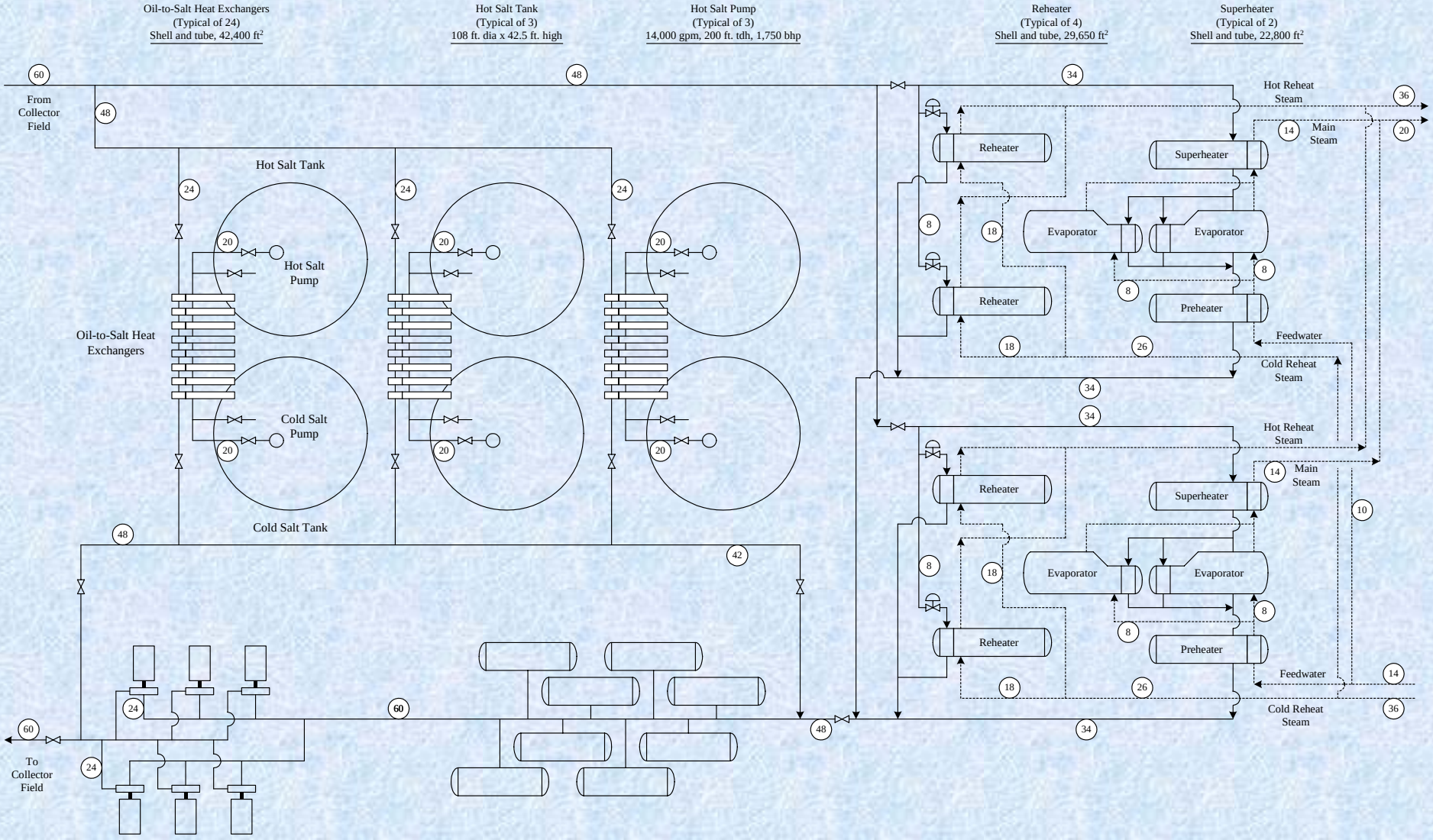
Annual Performance



Levelized Cost of Energy



250 MWe Plant HTF Flow Diagram



250 MWe Plant Capital Cost
Hybrid Plant with Thermal Storage

Item	$1,000	Contingency	$1,000	
Land	2,671	0%	2,671	
Structures and Improvements	3,371	15%	3,877	
Collector System	513,029	5%	538,681	
Thermal Storage System	98,181	5%	103,090	49 $/kWht
Heat Transport Fluid System	62,049	10%	68,254	
Electric Power Generation System	102,037	10%	112,240	449 $/kWe
Master Control System	2,270	15%	2,610	
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Total Field Cost	783,608	6%	831,423	
Engineering, Procurement, and Home Office	12,750	15%	14,662	
Construction Management and Field Procurement	5,005	15%	5,756	
Startup and Checkout	2,296	15%	2,640	
Contractor Fee (3 percent)	24,110	0%	24,110	
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	44,160	7%	47,167	
Total Overnight Construction Cost	827,767	6%	878,590	3,514 $/kWe

Observations
Large Plant Availability

- Multiple Equipment Items
  - Multiple items for thermal storage tanks, oil-to-salt heat exchangers, steam generators, expansion vessels, and heat transport fluid pumps
  - Improves plant reliability
  - Decreases plant availability - additional points of failure, plus additional support equipment such as valve actuators, instruments, and I/P transducers
- Large Auxiliary Loads
  - Multiple heat transport fluid pumps, each 3+ MWe
  - Daily startup must be coordinated with local utility

Observations

- Optimum plant sizes
  - Therminol without thermal storage: 250 MWe (peak Rankine cycle efficiency)
  - Therminol with thermal storage: 200 MWe (multiple equipment items limit economies of scale)
  - Inorganic without thermal storage: 350 MWe (lower m^2 collector field / MWe Rankine cycle; peak 100 bar Rankine cycle efficiency)
  - Inorganic with thermal storage: 250 to 300 MWe (<½ fluid volume per MWht; fewer equipment items)

Multiple Plant Concepts
Separated Power Blocks

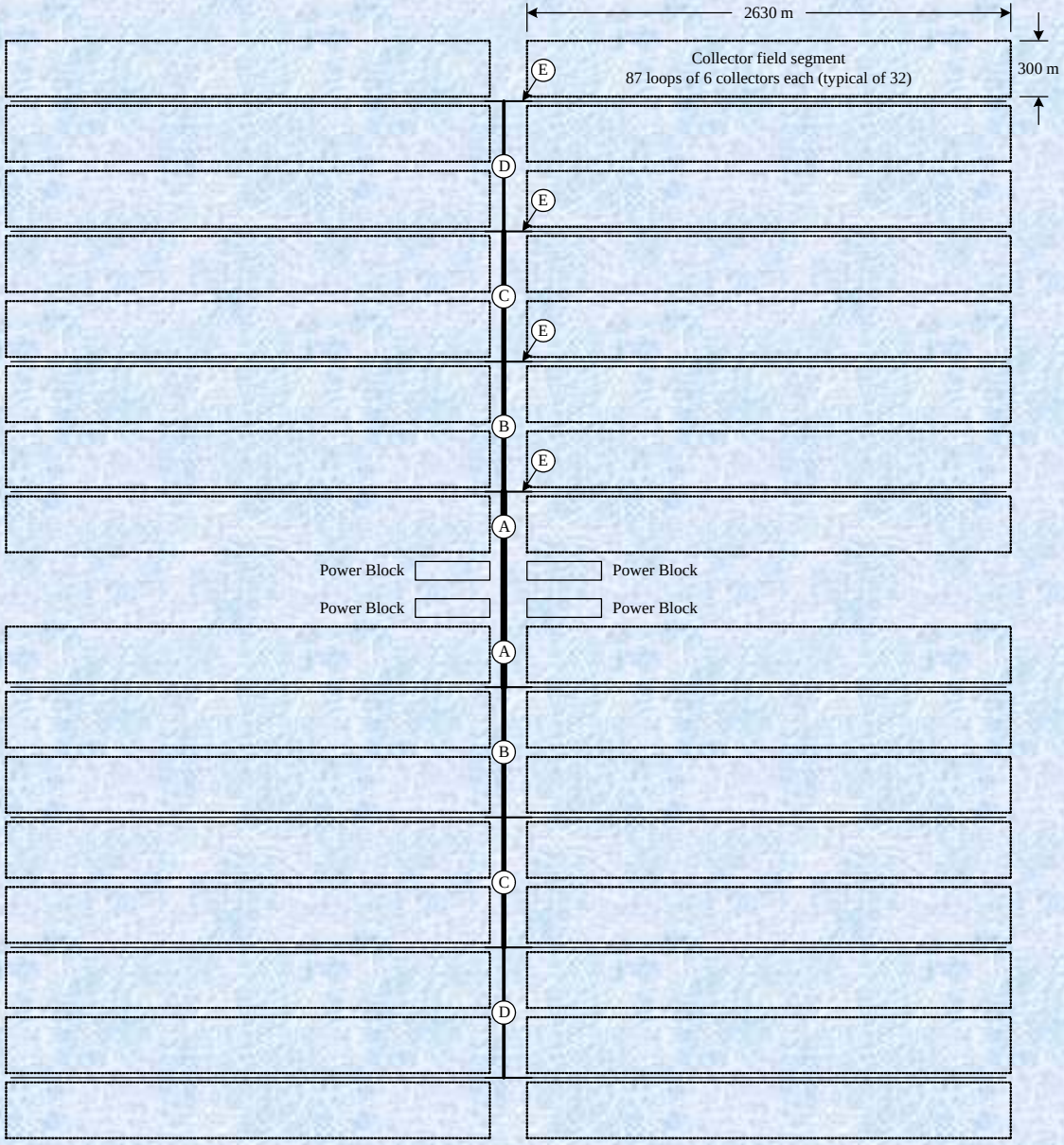
10 Percent Reduction in Levelized Energy Cost

- 55 percent to purchase of greater quantities of equipment and bulk materials (data on 80 2-unit plants; no data on 3+ unit plants)
- 1 percent to reuse of final design and procurement documents
- 25 percent to reuse of one organization for project development, and one for construction
- 20 percent to sharing of O&M administration staff among plants

Cost Reductions Not Available

- Construction schedule
  - Efficiency losses from larger project requires additional coordination and supervision
  - Higher demand for craft labor raises wage rates
  - Some reduction in schedule likely, but with minor influence on interest during construction
- Simultaneous financing
  - Each bank limits its exposure to a financial area
  - Limited number of banks competing to provide debt for solar projects

Adjacent Power Blocks



Adjacent Power Block Savings

- Plant availability and Rankine cycle operation
  - Steam production in winter insufficient for 4 Rankine cycles
  - Operate 1, 2, or 3 cycles, and perform maintenance on the 4th
  - Increases average turbine load and efficiency (+0.36%), and plant availability (94.0% to 97.9%)
- Operation and maintenance
  - 8 to 9% improvement in labor efficiency
  - Sharing foremen, control room operators, and plant equipment operators

Adjacent Power Block Liabilities

- Additional field piping headers increases field pressure losses by 3.45 bar
- Heat transport fluid pump power demand increases by 10.6 MWe (15 percent)
- Increases unit collector field piping and heat transport fluid pump cost by $\$10.50/m^2$ ($88/kWe)

Cost Summary

	1 x 250 MWe	4 x 250 MWe plant Separated power blocks	4 x 250 MWe plant Adjacent power blocks
Equivalent annual capital cost, $1,000	111,496	404,333	413,900
Annual operation and maintenance cost, $1,000	11,780	38,300	35,950
Annual energy production, MWhe	740,980	2,963,920	3,098,532
Levelized energy cost, $/kWhe	0.166	0.149	0.145
Savings due to multiple plants, percent	Base	-10.2%	-12.7%