Hybrid Cooling
Cost, Performance, Water Use—Trade-off Assessments

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Power Plant Cooling Systems

Then

Now

Pretty soon

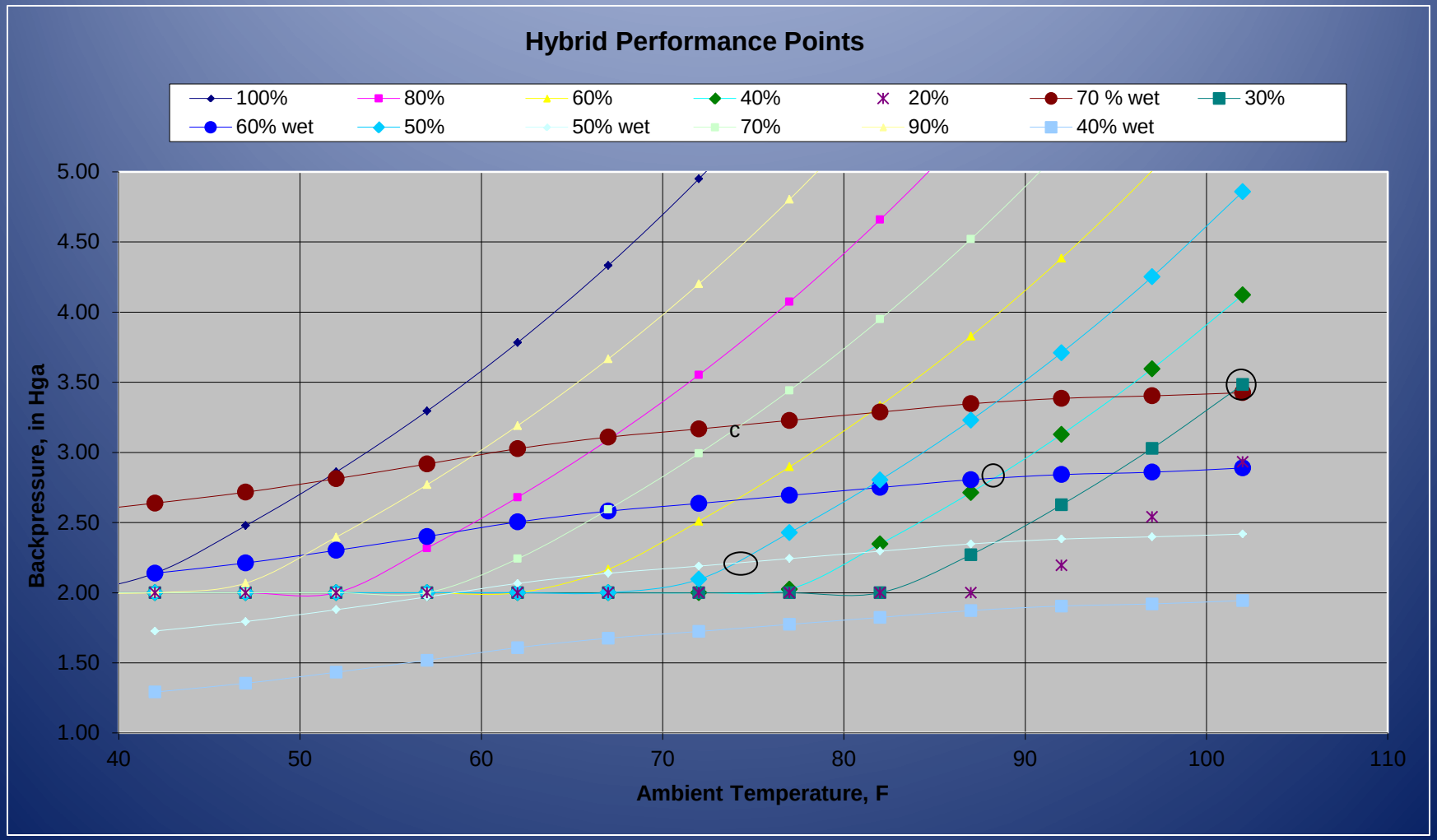
Once-through
Wet—cooling tower
Dry—air-cooled condenser
Hybrid—parallel wet/dry

Tradeoffs

- OTC
  - Lowest cost; best performance; no longer allowed
- Wet
  - Low cost; best hot day/annual performance; highest water use
- Dry
  - High cost; limited hot day output; lower efficiency; zero water use
- Hybrid
  - Cost >> wet, < dry; hot day performance ~ wet; intermediate (20% to 80%) water use

Issues and Challenges

- Current selection/optimization difficult



What's the Innovation?

- Simplification of selection/optimization

Met File Number	8
Met Site	Yuma, AZ

RUN STATUS	*OK*

Plant Name	ABC Generating	**Acceptable**
Type - Coal (CF) or Combined Cycle (CC)	CC	**Acceptable**
Steam Turbine Output, MW	170	**Acceptable**

Out-of-Range Entries	**0**
Hybrid ACC Solution	**Yes**
Hybrid Cooling Tower Solution	**Yes**
ACC Solution	**Yes**
Cooling Tower Solution	**Yes**

Hybrid Cooling System_Input

Overall System		**Input Range**	
1% DB Back Pressure, "Hg	6.00	4 to 8	**Acceptable**
Total Steam Flow, #/hour	1,022,366	500,000 to 3,500,000	**Acceptable**
Steam Quality, #/#	0.981	0.90 to 1.00	**Acceptable**
Altitude, feet	0	0 to 8,000	**Acceptable**
Hybrid ACC			
% ACC Load (1% DB)	70%	15% to 85%	**Acceptable**
Calc'd Hybrid ACC ITD (1% DB), F		*30.45*	
Hybrid Cooling Tower			
Design Approach, F	7.00	5 to 25	**Acceptable**
Range, F	20.0	18 to 25	**Acceptable**
Cycles of Concentration	7.0	1.5 to 25	**Acceptable**
Solution for Cooling Tower...		*Successful*	

Full-Load ACC_Input

Calc'd ACC ITD (1% DB), F		*36.55*	
1% DB Back Pressure, "Hg	7.00	2.50 to 8.00	**Acceptable**

Full-Load Cooling Tower_Input

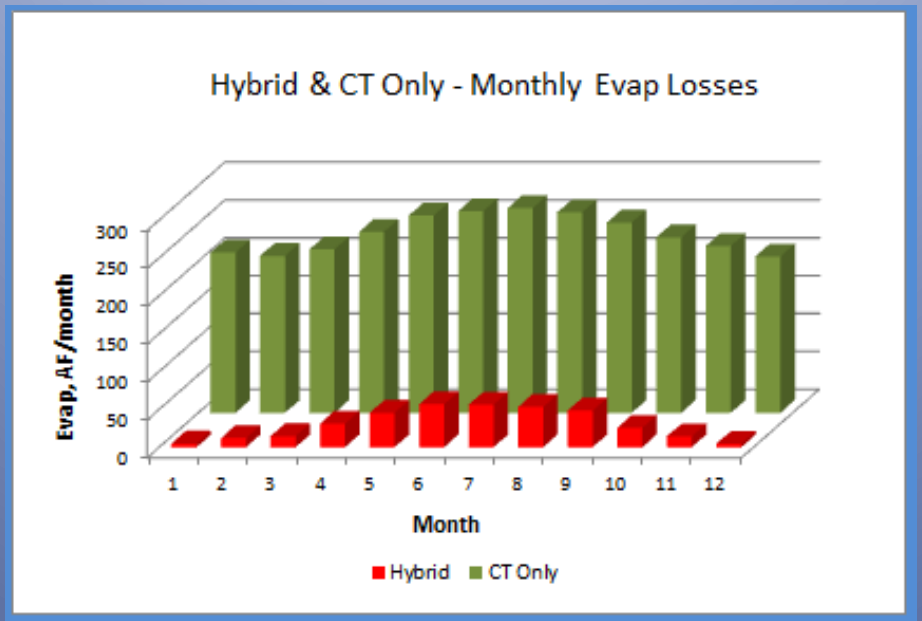
Design Approach, F	7.00	5 to 15	**Acceptable**
Range, F	20	18 to 25	**Acceptable**
1% WB Back Pressure, "Hg	3.10	1.5 to 5.0	**Acceptable**
Calculated Condenser TT	*16.80*	*--- OK*	
Cycles of Concentration	7.0	1.5 to 25	**Acceptable**

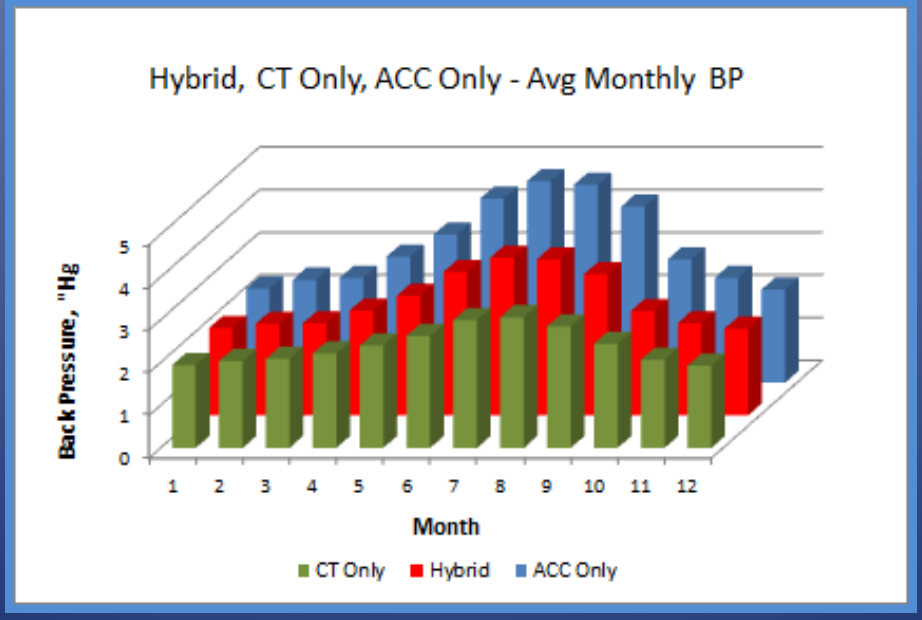
Economic_Input

Cost of Power, $/kwh	$0.0900	$0.01 to $0.20	**Acceptable**
Cost of Capital, %	7.00%	1% to 15%	**Acceptable**
Life of Project, years	30	5 to 50	**Acceptable**

	Hybrid	**ACC-Only**	**CT-Only**
Performance Summary			
Steam Flow, #/hour	1,022,366	1,022,366	1,022,366
Steam Quality, #/#	0.98	0.98	0.98
Altitude, feet	0	0	0
ACC Cells	24	25	----
Cooling Tower Cells	3	----	8
1% DB ACC Thermal Load	70%	100%	----
1% DB, F	110.30	110.30	----
1% WB, F	72.41	----	72.41
1% DB Backpressure, "Hg	6.00	7.00	----
1% WB Backpressure, "Hg	----	----	3.10
Yrly Avg Backpressure, "Hg	2.69	3.24	2.38
Summer (J-J-A) Avg BP, "Hg	3.57	4.56	2.90
Max BP (hottest hour), "Hg	5.57	8.21	3.16
Summer (J-J-A) Turbine Penalty	2.72%	5.40%	1.27%
Yrly Avg Turbine Penalty	1.13%	2.37%	0.57%
CT Operating Hours	5,099	----	8,760
Water Usage Summary			
Water Usage, AF/yr	428	----	3,319
Water Savings, AF/yr	2,891	3,319	----
Water Savings	87.12%	100%	----
Power Requirements Summary			
Power Requirement, kw	2,725	3,912	1,240
Energy Usage Summary			
ACC, kwh/yr	19,194,000	33,570,000	----
Cooling Tower, kwh/yr	3,631,000	----	19,235,000
Turbine Penalty, kwh/yr	16,861,000	35,343,000	8,437,000
Total Energy Usage, kwh/yr	39,686,000	68,913,000	27,672,000

Possible Output





Some Case Studies

Use for Results—Help with the Future

- **Long range planning**
  - For anticipated future plants
    - energy vs. water vs. cost
    - modification of site selections
- **Policy**
  - Estimating consequences of alternative directions
- **Permitting**
  - Assessment of applicant/intervenor claims

Things to do Next

- **Technology collaboration**
  - *Metamaterials-Enhanced Passive Radiative Cooling Panels*
  - *Spectrally-Tuned All-Polymer Technology for Inducing Cooling*
  - *Novel Desiccant Cycle for Flue Gas Water Recovery and Cool Storage-*
  - *Enhanced Air-Cooling System with Optimized Asynchronously Cooled Thermal Energy Storage*
  - *Plus many others*