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ORIGINAL

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December 10, 2001

VIA HAND-DELIVERY

Docket Control
Arizona Corporation Commission
1200 West Washington Street
Phoenix, Arizona 85007

Re: *Allegheny Energy Supply Company, L.L.C.*
Docket No. L-00000AA-01-0116

Dear Sir/Madam:

With this letter, Allegheny Energy Supply Company, L.L.C. files the original and 25 copies of the following exhibits for the December 13-14, 2001 hearings in this docket:

A-21: November 21, 2001 letter from Joseph Smith, Director, Arizona Department of Water Resources to Laurie Woodall.

A-22: La Paz Generating Facility Life Cycle Economic Analysis: Dry v. Wet Cooling with attached graph re: 2000 Palo Verde Weekly Pricing vs. Temperature Effects on Dry Cooled Plant Output.

A-23: Black and Veatch Wet Cooling v. Dry Cooling Cost Estimate Per 540 MW Block.

A-24: Proposed Certificate of Environmental Compatibility.

A-25: Information regarding Environmental and Public Service awards and activities relating to Allegheny, including (1) Environmental and Public Service Awards Presented to Allegheny Energy Supply, (2) Allegheny Energy Supply Environmental Stewardship 2001 Projects, (3) Allegheny Energy Supply Environmental Stewardship Matching Grant 2001 Award Winners and (4) What Have Our Environmental Friends Said About Allegheny?

A-26: Page 1.1.10 of Air Cooled Heat Exchangers and Cooling Towers: Thermal-flow Performance Evaluation and Design, D. Kroger (1998).

A-27: "Understanding Wet and Dry Cooling Systems," Wayne C. Micheletti and John M. Burns, presented at the 62nd International Water Conference, Pittsburgh, PA, October 22-24, 2001.

Very truly yours,

GALLAGHER & KENNEDY, P.A.

By
Todd C. Wiley

Original and 25 copies filed this
date with Docket Control

COPY of the foregoing hand-delivered
this 10th day of December, 2001 to:

Jason Gellman, Esq.
Legal Division
Arizona Corporation Commission
1200 West Washington
Phoenix, Arizona 85007

Utilities Division
Arizona Corporation Commission
1200 West Washington
Phoenix, Arizona 85007

COPY of the foregoing mailed and faxed
this 10th day of December, 2001 to:

Laurie Woodall (602/542-7798)
Line Siting Committee Chair
Office of the Attorney General
1275 West Washington
Phoenix, Arizona 85007

James D. Vieregg, Esq. (602/240-6925)
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2800 North Central Avenue
Phoenix, Arizona 85004-1047
Attorneys for AZURE

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651 Gateway Boulevard, Suite 900
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Linda Maqueira

TCW/lmm
12921-0004/975174

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AZ CORP COMMISSION
DOCUMENT CONTROL

ARIZONA DEPARTMENT OF WATER RESOURCES
500 North Third Street, Phoenix, Arizona 85004
Telephone 602-417-2410
Fax 602-417-2415

JANE DEE HULL
Governor

JOSEPH C. SMITH
Director

November 21, 2001

ORIGINAL

Ms. Laurie Woodall
Chairman, Siting Committee
Office of the Attorney General
1275 West Washington
Phoenix, Arizona 85007

Re: Allegheny's Application for CEC, Docket #116 L-00000AA-01-0116

Dear ~~Madam Chairman~~ Laurie:

During the Hearing on November 14, 2001, you requested, on behalf of the Siting Committee, as to whether the Arizona Department of Water Resources (Department) has available staff and is willing to commit such staff to work on three issues with the applicant in Docket #116. The Department does not believe that this is necessary. Each issue is discussed below.

Issue #1 - Should the Applicant be required to work with the Department to perform an aquifer pump test near the site of the proposed wellfield to prove the accuracy of the model provided by Vidler Recharge? Intervenor AZURE and Committee Member Williamson proposed this question.

As stated in the November 9, 2001 Preliminary Hydrologic Review prepared by Dale Mason, Modeling Section Manager, Arizona Department of Water Resources, the Department stands by its position that the model used in this case is valid. "The numerical model was reviewed by the ADWR staff in 1999 and found to reasonably simulate the response of the regional aquifer to historic pumping stresses from 1950 to the present." (Page 3). Despite testimony of AZURE's expert witness, a well formulated and calibrated model is a good tool for predicting the behavior of particular pumping patterns or recharge activity.

Should Committee Member Williamson or any other Member of the Committee wish, the Department would be willing to conduct a generic briefing for the Committee on modeling parameters. The particulars would be from a different part of the State but would demonstrate modeling technology. The Department models many areas of the State, and is considered by most State agencies to be an expert in hydrology and modeling. I would hope that Committee Members would give deference to the Department in these matters.

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AZ CORP COMMISSION
DOCUMENT CONTROL

Issue #2. Should subsidence monitoring be required in the area of the proposed plant and well-field? Several Committee Members and Intervenor AZURE suggested this. In the November 9, 2001 memo from Dale Mason, the Department suggested that additional subsidence investigations be performed. Applicant testified that it performed an investigation and concluded that subsidence does not exist today in the area of the proposed plant and wellfield.

We are satisfied with the investigation performed by the Applicant, however, as suggested to the Applicant at the hearing, the Department believes that a continuing monitoring program should be put in place. The Department believes this could be as simple as requiring a periodic check (i.e. five years) of monuments and discussions with agencies with infrastructure or jurisdiction near the plant site, such as the Central Arizona Project, the Bureau of Land Management and State Lands. This information could then be conveyed to the Department and the Commission for review. Should the Applicant not prepare a condition to monitor for subsidence, the Department will be prepared to offer a condition to effect such a monitoring program.

Issue #3. Should the Applicant be required to provide mitigation for any damage that may be caused by groundwater pumping over the life of the plant? Committee Member Palmer and I suggested this, along with Intervenor AZURE.

While the Department will not commit staff to negotiate with the Applicant at this time for an agreed upon mitigation plan, the Department may be prepared at the next hearing to propose a condition for mitigation recharge. Of course, if the Applicant proposes mitigation recharge during its rebuttal case, this may not be necessary.

When the transcript is available we will review for further insight into the discussion on these issues and any other issues, which the Committee wishes to be discussed between the Department and the Applicant.

Sincerely,

Joseph C. Smith
Director

JCS:kd

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La Paz Generating Facility

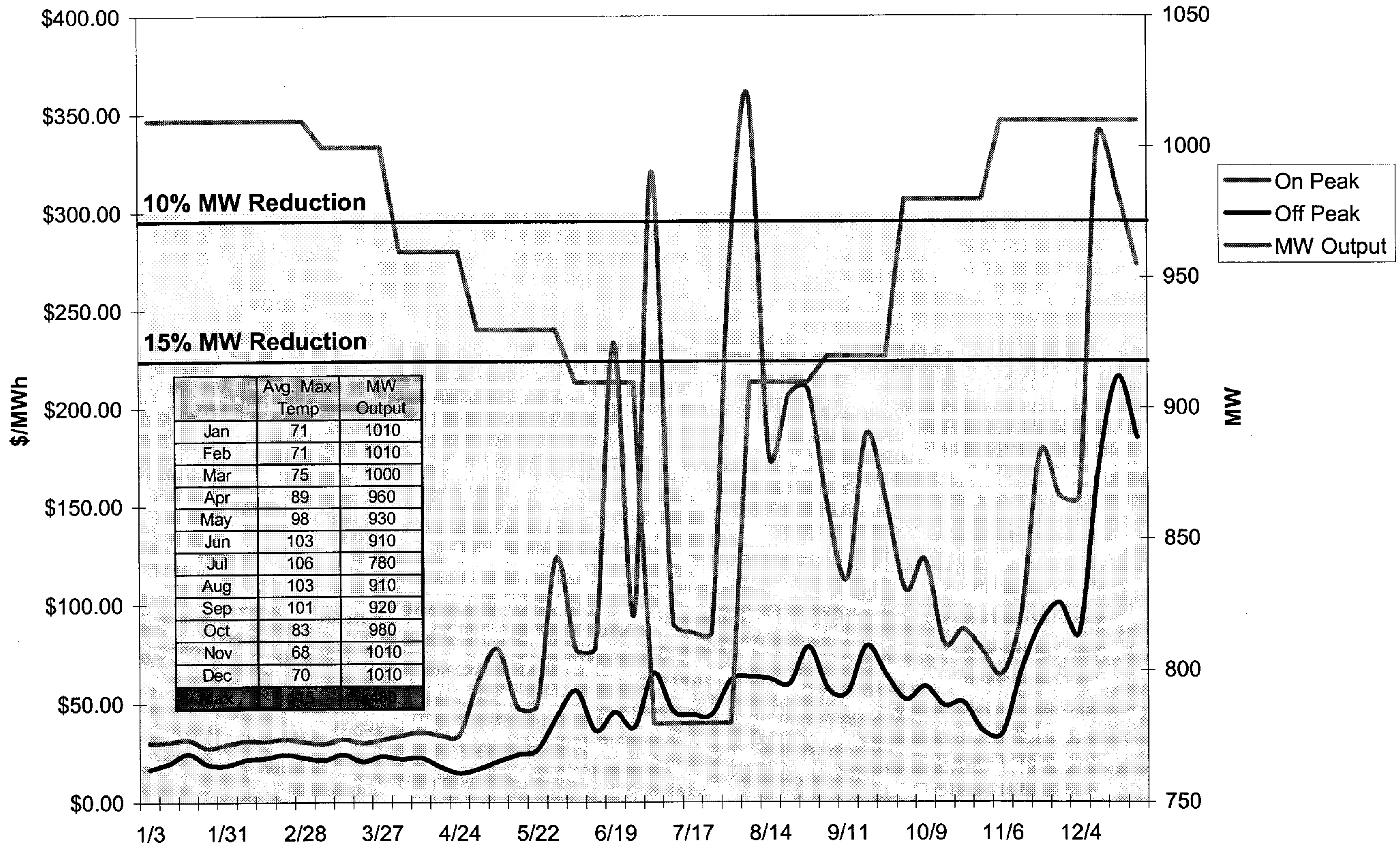
Life Cycle Economic Analysis: Dry v. Wet Cooling

		Wet Cooling	Dry Cooling (10% Generation Loss)	Dry Cooling (15% Generation Loss)
Net Output	MW	1080	972	918
Heat Rate	btu/kWh	6900	7200	7200
Variable O&M Cost ($2005)	$/MWh	$1.71	$2.21	$2.21
Capital Cost	$	Base	$45,000,000	$45,000,000
Capacity Value	$/kw-yr	$72	$72	$72
Water Consumption	Ac-Ft/Yr.	5330	267	267
Net Revenue/Year	$	Base	($25,000,000)	($33,000,000)
Maximum Generation/Year	MWh	9,460,800	8,514,720	8,041,680
Average Capacity Factor	%	82%	64%	64%
Net Generation/Year after Heat Rate and O&M Effect	MWh	7,796,000	5,415,000	5,020,000
30 Yr. Economic Loss	$	Base	($750,000,000)	($990,000,000)
Equiv. Economic Cost per Ac-Ft of Water	$	Base	($4,937)	($6,517)
Increased Cost per kWh of Dry Cooling	$/kWh	Base	$0.0088	$0.0105
Annual Increased Cost of 5,000,000 MWh to AZ Customers	$	Base	($44,397,527)	($52,715,100)
Annual Increased Gas Usage for 5,000,000 MWh after Heat Rate Effect	Cu. Ft.	Base	1,500,000,000	1,500,000,000

Notes:
1. The above analysis does not include any volatility in gas or energy prices. Averages are for illustrative purposes. Actual results will vary.
2. The above analysis does not reflect any economic impact due to increased criteria air pollutants with dry cooling.
3. Wet Cooling case does not include duct firing MWs.
4. All production related values are averages of the 2005-2009 estimated values.
5. Analysis assumes constant fixed O&M and a $0.50/MWh increase in variable O&M. This represents a 39% increase in total O&M per MWh.

La Paz Generating Facility

2000 Palo Verde Weekly Pricing vs Temperature Effects on Dry Cooled Plant Output



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La Paz Generating Facility
Black and Veatch Wet Cooling versus Dry Cooling Cost Estimate per 540MW block

TABLE 3

EQUIPMENT CAPITAL COST

	Wet Cooling	Dry Cooling
Surface Condenser	$1,182,000	N/A
Condenser Tube Cleaning System	$250,000	N/A
Air-Cooled Condenser[4]	N/A	$24,900,000
Plate and Frame Closed Cycle Cooling Water Heat Exchanger	$258,000	N/A
Air-Cooled Heat Exchanger	N/A	$2,265,000
Cooling Tower	$2,634,000	N/A
Cooling Tower Basin	$987,000	N/A
Circulating Water Pumps	$458,000	N/A
Circulating Water Piping	$2,744,000	N/A
Water Properties[5]	$4,500,000	$623,000
Water Pretreatment	$2,315,000	$1,145,000
Well Field Development (Wells, Pumps, Motors, Pipe, etc.)	$1,846,000	$510,000
Electrical Adder (extra MCC, Grounding, Switchgear, SUS, Cable and terminations, Cable Tray, Site Lighting)	Base	$3,000,000
Condensate Polishing System	Base	$980,000
Steam Duct to Condenser[6]	N/A	$2,000,000
Increased Indirect Costs	Base	$3,500,000
Total Installed Capital Cost	$17,174,000	$38,923,000
Differential Capital Cost	Base	$21,749,000

La Paz Generating Facility

Black and Veatch Wet Cooling versus Dry Cooling Cost Estimate per 540MW block

Notes:

1. All equipment pricing is given in 2001 dollars. Capital costs only without profit margins added.
2. Labor costs are based on union labor averaged at $45.00 per hour per a 6-10 schedule based on rates provided by AZURE in a proposed Project Labor Agreement
3. Cooling tower vendor offered budget pricing on 8 cell tower. Price for 10 cell based on 120% cost of 8 cell budget price.
4. Air Cooled Condenser installation cost basis used is from two duplicate in-house projects under construction. Labor rate approximately $80/hr due to higher skilled labor required.
5. Allegheny has already purchased the water properties required for wet cooling. The losses due to depressed current value of this property relative to the purchase price is not included in the cost for dry cooling.
6. Estimated number will depend on site arrangement optimization and property constraints. Dry cooling option may be difficult to fit within the limits of the current site boundary. Number is based on reasonable estimate of distances.
7. The size of the evaporation ponds is essentially unchanged for all options. Nearly all the cooling tower blowdown flow is reclaimed by the water treatment system and reused as makeup back to the tower. With the wet cooling option, flow streams such as steam cycle blowdown, flow from the CT evap coolers, etc. drain to the tower basin as makeup flow to the tower. The net effect not having the tower basin available for these "waste" streams is that the size of the flow stream to the evaporation pond is essentially unchanged for all options.

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BEFORE THE ARIZONA POWER PLANT AND TRANSMISSION

LINE SITING COMMITTEE

IN THE MATTER OF THE APPLICATION OF ALLEGHENY ENERGY SUPPLY COMPANY, LLC FOR A CERTIFICATE OF ENVIRONMENTAL COMPATIBILITY FOR CONSTRUCTION OF A 1,080 MW (NOMINAL) GENERATING FACILITY IN SECTION 35, TOWNSHIP 3 NORTH, RANGE 11 WEST IN LA PAZ COUNTY, ARIZONA AND AN ASSOCIATED TRANSMISSION LINE AND SWITCHYARDS BETWEEN AND IN SECTION 35, TOWNSHIP 3 NORTH, RANGE 11 WEST AND SECTIONS 23-26, TOWNSHIP 3 NORTH, RANGE 11 WEST ALSO IN LA PAZ COUNTY, ARIZONA.	DOCKET NO. L-00000AA-01-0116 CASE NO. 116

CERTIFICATE OF ENVIRONMENTAL COMPATIBILITY

Pursuant to notice given as provided by law, the Arizona Power Plant and Transmission Line Siting Committee (the "Committee") held public hearings in Parker and Phoenix, Arizona, on September 4, 2001, November 13-14, 2001 and December 13-14, 2001, in conformance with the requirements of Ariz. Rev. Stat. § 40-360, et. seq., for the purpose of receiving public comment and evidence and deliberating on the application of Allegheny Energy Supply Company, LLC, or its assignees ("Allegheny" or "Applicant"), for a Certificate of Environmental Compatibility ("Certificate") authorizing construction of a 1080 MW (nominal) generating facility and an associated transmission line and switchyards in La Paz County, Arizona (the "Project"), all as more particularly described and set forth in the Application (the "Application").

The following members and designees of members of the Committee were present on one or more of the hearing days:

Laurie Woodall	Chairman, Designee for Arizona Attorney General, Janet Napolitano
Richard Tobin	Department of Environmental Quality
Gregg Houtz	Department of Water Resources
Ray Williamson	Arizona Corporation Commission
Mark McWhirter	Department of Commerce
Michael Palmer	Appointed Member
Jeff McGuire	Appointed Member
Wayne Smith	Appointed Member
Michael Whalen	Appointed Member

Applicant was represented by Michael M. Grant and Todd C. Wiley of Gallagher & Kennedy, P.A. Arizona Corporation Commission Utilities Division Staff ("Staff") was represented by Christopher C. Kempley and Jason D. Gellman. Intervenor Arizona Unions for Reliable Energy ("Unions") was represented by James D. Vieregg of Morrison & Hecker, L.L.P. and Mark R. Wolfe of Adams, Broadwell, Joseph & Cardozo. La Paz County, by its County Attorney R. Glenn Buckelew, filed a notice of limited appearance in support of the grant of Allegheny's Application.

At the conclusion of the hearing, after consideration of the Application, the evidence and the exhibits presented, the comments of the public, the legal requirements of Ariz. Rev. Stat. §§ 40-360 to 40-360.13 and in accordance with A.A.C. R14-3-213, upon motion duly made and seconded, the Committee voted to make the following findings and to grant Allegheny the following Certificate of Environmental Compatibility (Case No. 116):

The Committee finds that the record contains substantial evidence regarding the need for an adequate, economical and reliable supply of electric power and how the Project would contribute towards satisfaction of such need without causing material adverse impact to the environment.

Applicant and its assignees are granted a Certificate authorizing the construction of a 1,080 MW (nominal) electric generating plant as more particularly described in Section

4(a)(i) of the Application and an associated 500 kv transmission line and switchyards as more particularly described in Section 4(b)(i) of the Application and Exhibit G-7.

This Certificate is granted upon the following conditions:

1. Applicant and its assignees will comply with all existing applicable air and water pollution control standards and regulations, and with all existing applicable ordinances, master plans and regulations of the state of Arizona, the county of La Paz, the United States and any other governmental entities having jurisdiction, including but not limited to the following:

a. all zoning stipulations and conditions, including but not limited to any landscaping and dust control requirements and/or approvals;

b. all applicable air quality control standards, approvals, permit conditions and requirements of the Arizona Department of Environmental Quality ("ADEQ") and/or other State or Federal agencies having jurisdiction, and the Applicant shall install and operate selective catalytic reduction and catalytic oxidation technology at the level determined by the ADEQ. The Applicant shall operate the Project so as to meet a 2.5 ppm NOx emissions level, within the parameters established in the Title V and PSD air quality permits issued by ADEQ. Applicant shall install and operate catalytic oxidation technology that will produce carbon monoxide ("CO") and volatile organic compound ("VOC") emissions rates determined as current best available control technology ("BACT") by ADEQ;

c. all applicable water use and/or disposal requirements of the Arizona Department of Water Resources ("ADWR"), Section 6-503 of ADWR's Third Management Plan and the ADEQ regulations;

d. all applicable regulations and permits governing transportation, storage and handling of chemicals.

2. Allegheny shall construct a 100 KW solar photovoltaic array for use in conjunction with the Project's electricity use requirements. Allegheny will also participate in future solar workshops conducted by the Commission.

3. Subject to the availability of Central Arizona Project ("CAP") water and

delivery facilities, Allegheny will acquire over the next 30 years directly, through another or by contract with the Arizona Water Banking Authority ("AWBA") an aggregate amount of 30,000 acre feet of CAP water or that aggregate amount of water which may be acquired with $3 million, whichever is less. The water acquired is intended to be recharged at the Vidler Recharge Facility ("Vidler"), but may be recharged elsewhere by the Applicant or AWBA. Water recharged shall not be subject to withdrawal by Applicant. Allegheny may also meet all or a portion of its obligation hereunder by acquiring on another person or entity's behalf CAP water to be used in lieu of groundwater which would have been withdrawn and used by such person or entity. If Allegheny has used or recharged CAP water in relation to the Project's water needs, the amount of such use or recharge shall be treated as a credit against Applicant's obligation under this condition.

4. In consultation with the Arizona Department of Water Resources, Allegheny will develop a monitoring program of monument inspection and information gathering from agencies with infrastructure or jurisdiction near the plant site concerning subsidence. The data gathered pursuant to the monitoring program shall be regularly reported to the Department and Commission.

5. In the year following the commencement of groundwater withdrawals in relation to the Project, Applicant shall submit annual reports to the Arizona Department of Water Resources pursuant to A.R.S. 45-437.C.1 reporting the quantity of groundwater withdrawn and the Notice(s) of Authority appurtenant thereto.

6. Authorization to construct the facility will expire five years from the date the Certificate is approved by the Arizona Corporation Commission unless construction is completed to the point that the facility is capable of operating at its rated capacity by that time;

provided, however, that prior to such expiration the facility owner may request that the Arizona Corporation Commission extend this time limitation.

7. Applicant shall initially connect the 500 kV Plant Switchyard to the 500 kV Transmission Grid Interconnection Switchyard with a single 500 kV transmission line, but shall allocate spaces in the Plant Switchyard and shall direct SCE to allocate spaces in the Transmission Grid Interconnection Switchyard for (i) a second 500 kV Transmission line should future reliability studies indicate that such addition is necessary to maintain reliability or (ii) a second Devers/Palo Verde transmission line.

8. Applicant's plant interconnection must satisfy the Western Systems Coordinating Council's ("WSCC") single contingency outage criteria (N-1) and all applicable local utility planning criteria without reliance on remedial action such as, but not limited to, reducing generator output, reducing generator unit tripping or load shedding.

9. The Applicant's plant switchyard shall utilize a breaker and a half scheme.

10. Applicant will pay up to $25,000,000 towards upgrading transmission capacity out of the Palo Verde hub in relation to the Devers Palo Verde, North Gila and Palo Verde Westwing lines for delivery to Arizona markets. This may be done in one of two ways. Applicant may either apply such funding for upgrades to the existing Devers to Palo Verde 500 kV and/or other transmission lines and switchyard facilities, as set forth in Southern California Edison's (SCE's) La Paz system impact study and facilities study, or apply such funding towards the building of new transmission lines out of Palo Verde. If the former option is chosen, Applicant will contact SCE to determine the earliest opportunity for the transmission line to be upgraded and Applicant will use commercially reasonable efforts to assure that such upgrades are completed before this plant commences commercial operation.

11. Prior to construction of any facilities, Allegheny shall provide to the Commission the system impact study and the facilities study performed by Southern California Edison regarding the La Paz project. To the extent that these studies do not provide the following information, Allegheny shall provide the Commission additional technical study evidence that sufficient transmission capacity exists to accommodate the full output of the Project and that the full output of the Project will not compromise the reliable operation of the interconnected transmission system. The SCE studies or additional supplemental technical study shall include a power flow and stability analysis report showing the effect of the full output of the Project on the planned Arizona electric transmission system and shall document physical flow capability for the full output of the plant to its intended market. In addition, Allegheny must provide the Commission with updates of the information required in this condition not more than one year and not less than three months prior to commercial operation of the full output of the plant.

12. Prior to construction of any Project transmission facilities, Applicant shall provide the Commission with copies of the transmission interconnection and transmission service agreement(s) it ultimately enters into with SCE or any transmission provider(s) with whom it is interconnecting, within 30 days of execution of such agreement(s).

13. Applicant will become and remain a member of WSCC, or its successor, and file an executed copy of its WSCC Reliability Management System (RMS) Generator Agreement with the Commission. Membership by an affiliate of Applicant satisfies this condition only if Applicant is bound by the affiliate's WSCC membership.

14. Applicant shall apply to become and, if accepted, thereafter remain a member of the Southwest Reserve Sharing Group or its successor, thereby making its units

available for reserve sharing purposes, subject to competitive pricing.

15. Applicant shall offer for Ancillary Services, in order to comply with WSCC RMS requirements, a total of up to 10% of its total plant capacity to (A) the local Control Area with which it is interconnected and (B) Arizona's regional ancillary service market, (i) once a Regional Transmission Organization (RTO) is declared operational by FERC order, and (ii) until such time that an RTO is so declared, to a regional reserve sharing pool.

16. Within 30 days of the Commission decision authorizing construction of this project, Applicant shall erect and maintain at the site a sign of not less than 4 feet by 8 feet dimensions, advising:

a. That the site has been approved for the construction of a 1,080 MW (nominal) generating facility;

b. The expected date of completion of the facility; and

c. Phone number for public information regarding the project.

In the event that the Project requests an extension of the term of the certificate prior to completion of the construction, Applicant shall use reasonable means to directly notify all landowners and residents within one-mile radius of the project of the time and place of the proceeding in which the Commission shall consider such request for extension. Applicant shall also provide notice of such extension to La Paz County.

17. Applicant shall first offer wholesale power purchase opportunities to credit-worthy Arizona load-serving entities and to credit-worthy marketers providing service to those Arizona load-serving entities.

18. Pursuant to applicable Federal Energy Regulatory Commission ("FERC") regulations, Applicant shall not knowingly withhold its capacity from the market for reasons other

than a forced outage or pre-announced planned outage. Allegheny shall not be required to operate its Project at a loss.

19. In connection with the construction of the project, Applicant shall use commercially reasonable efforts, where feasible, to give due consideration to use of qualified Arizona contractors.

20. Applicant shall continue to participate in good faith in state and regional transmission study forums to identify and encourage expedient implementation of transmission enhancements, including transmission cost participation as appropriate, to reliably deliver power from the Project throughout the WSCC grid in a reliable manner.

21. Applicant shall participate in good faith in state and regional workshops and other assessments of the interstate pipeline infrastructure.

22. Applicant shall pursue all necessary steps to ensure a reliable supply and delivery of natural gas for the Project.

23. Within five days of Commission approval of this CEC, Applicant shall request in writing that El Paso Natural Gas Company ("El Paso") provide Applicant with a written report describing the operational integrity of El Paso's Southern System facilities from mileposts 660-670. Such request shall include:

a. A request for information regarding inspection, replacement and/or repairs performed on this segment of El Paso's pipeline facilities since 1996 and those planned through 2006; and

b. An assessment of subsidence impacts on the integrity of this segment of pipeline over its full cycle, together with any mitigation steps taken to date or planned in the future.

Applicant shall file El Paso's response under this docket with the Commission's Docket Control. Should El Paso not respond within thirty (30) days, Applicant shall docket a copy of Applicant's request with an advisory of El Paso's failure to respond. In either event, Applicant's responsibility hereunder shall terminate once it has filed El Paso's response or Applicant's advisory of El Paso's failure to respond.

24. Applicant shall operate the Project so that during normal operations the Project will not exceed (i) U.S. Department of Housing and Urban Development ("HUD") or Federal Transit Administration ("FTA") residential noise guidelines or (ii) Occupational Safety and Health Administration ("OSHA") Worker Safety Noise Standards.

25. Applicant will use low profile structures and stacks, non-reflective and/or neutral colors on surface materials and low intensity directive/shielded lighting fixtures to the extent feasible for the Project.

26. Allegheny will fence the generating facility and evaporation ponds to minimize effects of plant operations on terrestrial wildlife and will keep the berms surrounding the evaporation ponds clear of vegetation to limit pond attractiveness to birds.

27. In consultation with the Arizona Game & Fish Department, Applicant will develop a monitoring and reporting plan for the evaporation ponds. The plan will include the type and frequency of monitoring and reporting to the Game & Fish Department and the U.S. Fish and Wildlife Service.

28. Allegheny will continue cactus ferruginous pygmy owl surveys through the Spring of 2002, based on established protocol. If survey results are positive, the U.S. Fish and Wildlife Service and Arizona Department of Game and Fish will be contacted immediately for further consultation.

29. Allegheny will retain a qualified biologist to monitor all ground clearing/disturbing construction activities. The biological monitor will be responsible for ensuring proper actions are taken if a special status species is encountered (e.g., relocation of a Sonoran desert tortoise).

30. Applicant will salvage mesquite, ironwood, saguaro and palo verde trees removed during project construction activities and use the vegetation for reclamation in or near its original location and/or landscaping around the plant site.

31. Allegheny will retain an Arizona registered landscape architect to develop a landscape plan for the perimeter of the generating facility. The landscape plan will use native or other low water use plant materials. The Applicant will continue to consult with La Paz County regarding the landscape plan.

32. Allegheny will use a directional drilling process to bore under Centennial Wash in constructing the gas pipeline to minimize potential impacts to the mesquite bosque associated with the wash.

33. The Applicant will continue to consult with La Paz County in relation to its comprehensive planning process to develop appropriate zoning and use classifications for the area surrounding the Project.

34. Allegheny will use its best efforts to avoid the two identified cultural resource sites. If Sites AZ S:7:48 and 49 (ASM) cannot be avoided by ground disturbing activities, the Applicant will continue to consult with the State Historic Preservation Office to resolve any negative impacts which usually entails preparing and implementing a data recovery research design and work plan.

35. If a federal agency determines that all or part of the Project represents a

federal undertaking subject to review under the National Historic Preservation Act, Allegheny will participate as a consulting party in the federal compliance process (i.e., 36 C.F.R. 800) to reach a finding of effect and to resolve adverse effects, if any.

36. Should cultural features and/or deposits be encountered during ground disturbing activities, Allegheny will comply with A.R.S. § 41-844, which requires that work cease in the immediate area of the discovery and that the Director of the Arizona State Museum be notified promptly.

37. If human remains or funerary objects are encountered during the course of any ground disturbing activities related to the development of the subject property, Applicant shall cease work and notify the Director of the Arizona State Museum in accordance with Ariz. Rev. Stat. § 41-865.

38. Allegheny will retain a qualified archaeologist to monitor ground clearing/disturbing construction activities and to appropriately instruct workers on detection and avoidance of cultural resource sites.

GRANTED this ______ day of ______________, 2001.

ARIZONA POWER PLANT AND
TRANSMISSION LINE SITING COMMITTEE

By ________________________________
Laurie Woodall, Chairwoman

12921-0004/947199 v6

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ENVIRONMENTAL AND PUBLIC SERVICE AWARDS PRESENTED TO ALLEGHENY ENERGY SUPPLY

2001 *- West Virginia Business Environmental Leadership Award for Allegheny Energy Supply's Gypsum Processing Facility at Pleasants Power Station*

2001 *- Certificate of Appreciation from West Virginia Envirothon*

2001 *- Congratulatory recognition from the Charleston Gazette newspaper for Earth Day Tire Collection Project*

2001 *- Certificate of Appreciation for commitment toward the development of the Monongahela River Pennsylvania Senior Environmental Corps and the protection of Pennsylvania's surface water*

2001 *- Pennsylvania Department of Environmental Protection Certification of Appreciation for commitment to improving Pennsylvania's environment and for support and participation in River Sweep 2001*

2001 *- The Ohio River Valley Water Sanitation Commission Award for outstanding contributions to River Sweep 2001 and for sincere respect for the Ohio River Basin*

2001 *- Certificate of Appreciation from the Southwest PA Ozone Action Partnership, Inc. in recognition of outstanding accomplishments and contributions during Ozone Action Season*

2001 *- First place in the Southeastern Electric Exchange Real Estate and Right-of-Way Industry Excellence Awards Program*

2001 *- Right-of-Way Vistas Line of Distinction Award for excellence in vegetation management practices on utility rights-of-way*

2000 *- West Virginia Department of Environmental Protection Environmental Leadership Award for Harrison Power Station for contribution to water education in West Virginia. [Harrison employees helped to conduct three Project WET (Water Education for Teachers) workshops]*

2000 *- Pennsylvania Congress of Parents and Teachers 2000 Business Partnership Award for outstanding contribution to the mission and programs of the PTA*

2000 *- Individual awards from the Ohio River Valley Water Sanitation Commission and the Pennsylvania Department of Environmental Protection for support and participation in River Sweep 2000*

2000 *- The Mon-Yough Trail Council award for continued support of Youghtoberfest, a festival held each year to raise money for the Youghiogheny Trail*

2000 *- The Southwest Pennsylvania Ozone Action Partnership's Coach Ozone Hall of Fame Most Valuable Player Award for participation and commitment to cleaner, healthier air*

1999 *- Certificate of Appreciation, North Branch Potomac River Symposium*

1999 *- Recognition for Corporate Sponsor, National Wild Turkey Federation*

1999 *- Environmental Partnership Award, PA CleanWays State Organization*

1999 *- Excellence in Environmental Engineering from Southeastern Electric Exchange, Constructed Wetlands Project, Springdale, PA*

1998 & 1999 *- Continuing Commitment to the Environment Award, Mon Yough Trail Council*

1997, 1998, & 1999 *- Certificate of Appreciation, Ohio River Valley Water Sanitation Commission, River Sweep*

1997, 1998, & 1999 *- Environmental Leadership Award, PA CleanWays Westmoreland Chapter*

1998 & 1999 *- Certificate of Appreciation, Third Annual West Virginia Envirothon Competition*

1998 *- Certificate of Appreciation, National Parks & Conservation Association*

1998 *- Conservation Partner Award, Westmoreland County Conservation District*

1998 *- Exceptional Sponsor, 54th Annual Northeast Fish & Wildlife Conference*

1998 *- Outstanding Contribution Award, Pheasants Forever, Laurel Highlands Chapter*

1997 & 1998 *- Grateful Recognition, Ohio River Valley Water Sanitation Commission Ohio River Users Program*

1997 & 1998 *- Recognition for participation in Southwestern Pennsylvania's Voluntary Initiative for Pollution Prevention Program*

1997 *- Pennsylvania Governor's Award for Environmental Excellence, Constructed Wetlands, Springdale, Pa.*

1997 *- Industrial Excellence Award, Pennsylvania Water Environmental Association, Constructed Wetlands, Springdale, Pa.*

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Allegheny Energy Supply Environmental Stewardship 2001 Projects

Allegheny Energy's Environmental Stewardship Team has provided and committed funding, manpower and sponsorship to the following projects and programs for 2001:

- *Allegheny Trail Alliance, primary corporate sponsor of "Youghtoberfest"*
- *Appalachian Conservation Biology, habitat inventory*
- *Appalachian Trail Conference, corporate membership;*
- *Blackshere Elementary School Environmental Classroom, Marion County, W.Va., contribution*
- *Cowanshannnock Creek Watershed Association (Pa.), trail expansion project, contribution*
- *Fairview 4-H Club, Parkersburg, W.Va., contribution and employee volunteer*
- *Fayette County, Pa., Envirothon, sponsorship*
- *Fayette County, Pa., Children's Water Festival, contribution*
- *Friends of the Cheat, Kingwood, W.Va., contribution and sponsorship*
- *Friends of Deckers Creek, Deckers Creek, W.Va., contribution*
- *Friends of the Ohio, contribution*
- *Greene County (Pa.) Watershed Alliance, contribution*
- *Greensburg-Hempfield (Pa.) Business Park Stewardship Project, contribution and employee volunteers to plant trees and flowers*
- *Independence Marsh Foundation-Burgettstown Area School District Outdoor Classroom, contribution*
- *Independence Marsh Foundation, storm water drain stenciling, contribution*
- *Marion County 4-H Camp Mar-Mac, contribution and employee volunteer*
- *Maryland Envirothon, corporate sponsorship*
- *Meadowbrook Mall Earth Week activities, Bridgeport, W.Va., employee participation, scholarship awards*

- *Monongahela River Pennsylvania Senior Environment Corp., Washington, Pa., contribution*
- *National Wild Turkey Federation, contributions and employee volunteers*
- *National Wild Turkey Federation, (Pa.), contribution and corporate sponsorship of the Juniors Acquiring Knowledge, Ethics, and Sportsmanship (J.A.K.E.S.) event*
- *Northeastern Cave Conservancy, contribution and employee volunteer*
- *PA CleanWays, corporate sponsor of litter awareness placemat project*
- *PA CleanWays, employee volunteer*
- *PA CleanWays, sponsor and distribute children's litter activity books to schools*
- *PA CleanWays, Tree Bank planting project sponsorship*
- *Pennsylvania Department of Environmental Protection, tree planting project, contribution*
- *Pennsylvania Environmental Council, membership*
- *Pennsylvania State University Air Quality Learning Center, State College, Pa., contribution*
- *Pheasants Forever, Laurel Highland Chapter, United, Pa., contribution*
- *Pittsburgh Voyager, Greene County River Exploration Project, contribution*
- *Point Marion, Pa., Boy Scouts, contribution and employee volunteer*
- *Renfrew Institute for Cultural and Environmental Studies, Waynesboro, Pa., sponsor wetlands education program*
- *River Sweep 2001, corporate sponsorship and employee volunteers*
- *Roaring Run Watershed Association, Apollo, Pa., contribution*
- *Sewickley Creek, Pa., Watershed Association, contribution and employee volunteers*
- *Shepherd (W.Va.) College, funding for Geographic Information Systems Laboratory, part of the environmental studies program*
- *Smart Growth Partnership of Westmoreland County, Pa., partnership to promote education and planning*
- *Southwestern PA Ozone Action Partnership, sponsorship and employee volunteers*

- *Stonecoal Lake (W.Va.) Fishing Club, contribution and employee volunteer*
- *Trout Unlimited, contributions and employee volunteers*
- *University of Maryland Center for Environmental Science Appalachian Laboratory, three-year grant to help support education achievement awards*
- *Washington County (Pa.) Soil Conservation District, contribution to Children's Groundwater Festival*
- *Water Education for Teachers - "Project WET" - Harrison Power Station, Haywood, W.Va., sponsorship*
- *West Virginia Botanical Garden, contribution and employee volunteer*
- *West Virginia Division of National Resources, 2002 West Virginia Youth Environmental Program, award sponsorship*
- *West Virginia Division of Natural Resources, Youth Conservation Programs, contribution*
- *West Virginia Envirothon, sponsorship*
- *West Virginia Junior Envirothon, sponsorship*
- *West Virginia Scenic Trails Association, contribution and employee volunteer*
- *Westmoreland County Envirothon, Westmoreland County, Pa., primary corporate sponsorship*
- *Youghtoberfest Festival, Mon/Yough Trail Council, McKeesport, Pa., sponsorship*

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Allegheny Energy Supply Environmental Stewardship Matching Grant 2001 Award Winners

Allegheny Energy has established a matching grant program to reward and recognize employees who donate their time to worthy nonprofit and environmental organizations that are doing outstanding work protecting and enhancing our environment. The grants are awarded based on the number of hours of volunteer service an employee performs with a qualifying environmental service organization. The following are a few examples of 2001 Environmental Stewardship matching grants on behalf of Allegheny Energy employees who made volunteer contributions to these groups.

- *The Laurel Highlands Chapter of Pheasants Forever, on behalf of Rick Herd*
- *The PA CleanWays state organization, on behalf of Pam Pershing*
- *The Sewickley Creek Watershed Association, on behalf of Larry Myers*
- *Trout Unlimited of the Cumberland Valley, on behalf of Kieran Frye*
- *Trout Unlimited, Chestnut Ridge Chapter No. 670, on behalf of Eugene Gordon*
- *The Greenbrier Valley Chapter, National Wild Turkey Federation, $1,000 (maximum per organization) on behalf of David Lindsey and Robert Davis*
- *The West Virginia Botanical Garden, on behalf of Diane Ribustello*
- *Stonecoal Lake Fishing Club, on behalf of Wade Evans*
- *Point Marion, Pa., Boy Scout Troop 662*
- *Fairview 4-H Club, on behalf of John Tennant*
- *Northeastern Cave Conservancy, on behalf of Aaron Jarvis*
- *The West Virginia Scenic Trails Association, on behalf of Roger Raikes*
- *The Marion County 4-H Camp Mar-Mac Association, on behalf of Robert Payton*

WHAT HAVE OUR ENVIRONMENTAL FRIENDS SAID ABOUT ALLEGHENY?

Allyn G. Turner, Director, West Virginia Department of Environmental Protection, Division of Water Resources: "Congratulations on another successful Ohio River Sweep! I would like to extend my appreciation to your organization for your support and contributions to the 2001 River Sweep. Your commitment to the protection and restoration of the Ohio River through this annual event is to be commended."

Joan R. Jessen, Festival Coordinator, Washington County Watershed Alliance, Groundwater Coalition Education Committee: "The Steering Committee for the Washington County Children's Groundwater Festival has appreciated very much the help that Allegheny Energy gave to the festival again this year, both the funds you contributed and the printing of the game sheets for the Exhibit Hall."

Carolyn A. Hefner, Conservation Education and Public Outreach Program Manager, West Virginia Envirothon: "The participation of Allegheny Energy is well recognized throughout West Virginia. All of our media recognizes your ongoing contributions and participation. The partnership that we have developed has impacted many students in making decisions about their future careers. Also, they have been enlightened about the environment which will make them responsible citizens prepared to make sound conservation based judgments about natural resource issues."

Rod Cross, Director of Operations, Rivers Conservation and Fly Fishing Youth Camp: "Thank you very much for the Environmental Stewardship Matching Grant check. It will be put to good use at this year's camp. I would like to especially commend you on the support that you give to people like Kieran Frye and Eugene Gordon, who give so much of themselves in the name of conservation and the environment."

Holly DiBiasi, Coordinator of Development, University of Pittsburgh at Greensburg: "Your generous gift is designated to the Smart Growth Partnership of Westmoreland County and will help to support the costs associated with the project, as well as strengthen the available resources. The UPG Foundation and the Smart Growth Partnership are most grateful to you for your gift."

Elmer D. Weibley, Chairman, Washington County Envirothon Committee:
"On behalf of the Board of Supervisors of the Washington County Soil Conservation District and the Washington County Envirothon Committee, I would like to thank you for your sponsorship of the 2001 event. Your support is critical to the success of this important activity. We wish to thank you again for being our partner in this worthwhile effort."

Heather Knupsky, Environmental Education Coordinator, Fayette County Conservation District: "The Fayette County Conservation District would again like to express our gratitude to Allegheny Energy for the generous donation for the purchase of the T-shirts for Envirothon participants. It was a long day of competition for all of the students and they really appreciated the shirts. It was nice to see local businesses supporting environmental programs for area students. Once again, we appreciate your generosity and hope to work with Allegheny Energy again next year."

Don Stevenson, President, Roaring Run Watershed Association: "The board of directors of the Roaring Run Watershed Association want to thank you for your generous donation toward our current project. It is through the kindness of groups like yours that we are able to protect more land for the enjoyment of future generations. Years from now, visitors to our trail will be able to view the splendid scenery and historic sites along our trail, or spend and afternoon fishing in the Kiskiminetas River, a river that was considered dead 20 years ago, that is fast becoming one of the finest bass fishing areas in Western Pennsylvania."

Diana Haid, State Environmental Coordinator, West Virginia Youth Conservation Program, Division of Natural Resources: "Approximately 1,400 participants attended our 38th Annual Youth Environmental Day activities on Saturday, May 19, 2001, at North Bend State Park. Special announcements were made by Ed Hamrick, Director of the Division of Natural Resources, that Allegheny Energy provided the box lunches for all participants and that the name of the program was changed from Youth Conservation Program to Youth Environmental Program. Emily Fleming joins me in expressing our grateful appreciation for your support and personal interest in this statewide environmental education program."

John A. Markle, Westmoreland Intermediate Unit, Greensburg, Pa.: "I wanted to personally thank Allegheny Power for the role it has played in creating educational opportunities for our students and citizens in our region. We recently received a grant in the amount of $100,000 for the development of the Youghiogheny River Environmental Education Center (that) will allow school groups, community organizations, and other individuals to view, study, and research the Youghiogheny River Basin and its impact on the environment. When this project came to its first critical point, it was Allegheny Power who provided funds. Without the money Allegheny Power provided, the project would have ended before it began."

Paul Trianosky, State Director, Nature Conservancy of West Virginia, Charleston, W.Va.: "Thanks to Allegheny Power for the generous gift (which) will aid in the establishment of a handicapped-accessible boardwalk for our Cranesville Swamp Preserve. The addition of handicapped access will make the preserve even friendlier to a variety of visitors and solidify this preserve as a flagship of the Nature Conservancy."

Geraldine Heavner, Secretary, Allegheny Highlands Trail, Cumberland, Md.
"The Allegheny Highlands Trail of Maryland members are very appreciative to Allegheny Power for its financial contribution of $15,000 a year for three years for the development of this trail. Your support shows that Allegheny Power is a strong corporate supporter of this project."

Gregory M. Phillips, Manager, Westmoreland Conservation District, Greensburg, Pa.: "Thank you for Allegheny Power's generous support of the construction of the Center for Environmental Education in Westmoreland County. In addition, we would like to acknowledge your generous support for a number of other projects, including:

- 10 years of support for the Westmoreland County Envirothon.
- Sponsorship for our 50th anniversary Arbor Day planting this year.
- Supporting our 1998 Conservation Awards Banquet.
- Providing electrical service to research areas at our Monastery Run stream cleanup project.
- Partnering with the District and Sewickley Creek Watershed Association to stabilize Jacks Run stream bank."

Sue Wiseman, Executive Director, PA CleanWays, Greensburg, Pa.: "Your ongoing support truly demonstrates your corporation's commitment to both the environment and the communities you serve. Allegheny Power has been a major sponsor since our inception. Not only has PA CleanWays benefited from the direct support that Allegheny Power has provided over the years, but our corporate nonprofit environmental partnership set the stage for other partnerships with our organization and beyond. I thank Allegheny Power for being a pioneer in working with community groups for the benefit of the environment."

Dr. David L. Dunlop, President, Shepherd College, Shepherdstown, W.Va.: "Allegheny Power has joined with the college's new Environmental Studies Program to fund the purchase of computer equipment for a laboratory in the Robert C. Byrd Science and Technology Center on the Shepherdstown Campus. This laboratory will provide students engaged in environmental research with modern equipment and software (and) support projects...related to environmental concerns."

John A. Lichiello, Alternate Transportation Advocacy Committee, Parkersburg, W.Va.: "(Thank you) for your assistance in developing a recreational trail system in Parkersburg, W.Va. Your financial and in-kind commitment, your encouragement and leadership have been a cornerstone in the effort to establish this most needed and anticipated community facility. Without Allegheny's help, the Pond Run Bridge Project and Ohio Riverfront Trail...would not be possible."

Carolyn A. Hefner, Chairperson, West Virginia Envirothon Committee, Charleston, W.Va.: "Your support is a significant factor in making this event a success and to help the WV Envirothon fulfill their financial goal. The committee attributes the success of the WV Envirothon competition to the outstanding dedication and mutual interest shared by Allegheny Power..."

Greg Good, Government Liaison, Mon Valley Green Space Coalition, Morgantown, W.Va.: "Allegheny Power supported a National Trails Day event which the Green Space Coalition organized for June of last year. This event was part of a series of events...which ranged from streamside cleanups to trail construction in city parks of Morgantown and on the Caperton Rail Trail. 1998 was a very successful year for our organization and we are thankful that Allegheny Power has been a part of this success."

Debra A. Hull, President, Stonecoal Lake Fishing Club, Weston, W.Va.: "Our club would like to thank Allegheny Power for their contributions to Stonecoal Lake Fishing Club. We have used this money to make Stonecoal Lake a better place for the public to fish. We appreciate your efforts to help the environment."

Sheila Young, Leader, Fairview 4-H Club, Fairview, W.Va.: "I would like to thank Allegheny Power for providing our club with financial support over the past two years. This donation has been used to continue projects focused in the areas of environmental and community beautification as well as providing an opportunity for our members to attend county and state 4-H camps."

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requirements and waste water include the use of wet-cooling systems designed to operate with high cycles of concentrating dissolved solids in the circulating water, the use of various types of dry-cooling systems which make no consumptive use of water, and the use of various types of cooling tower systems which combine dry- and wet-cooling technology.

General studies to determine the comparative economics of alternative heat rejection systems should not fail to consider all of the potential advantages offered by the use of water conserving systems. For example, dry-cooled or dry/wet-cooled plants need not be located at the same site as the base case wet-cooled plant with which they are being compared and should take into account the siting flexibility afforded by the use of the water conserving systems. Fuel cost savings resulting from locating a coal-fired plant at the mine mouth where there may not be enough water available to permit the use of wet-cooling could be substantially greater than the accompanying increase in transmission costs. Further, the use of a water conserving heat rejection system could permit expansion of existing generating facilities at a site without sufficient water to serve additional wet-cooled capacity, thereby taking advantage of existing support and service facilities and rights-of-way. Even with an adequate water supply at a given site, the use of a water conserving system could, in some cases, reduce indirect project costs and lead times by reducing environmental study, public hearing, and permit requirements. Other factors, including the changes in micro climate, corrosion of equipment, piping and structural steel, emission of chemicals, poor visibility and freezing of ground or road surfaces located near cooling towers plumes as well as potential health hazards [86CR1, 97CU1] (legionnaires' disease) in poorly maintained systems, cannot be ignored in practice. The impact of all these factors on the comparative economics of alternative heat rejection systems will depend upon the unique circumstances of each particular application.

For the foreseeable future, wet-cooling towers are expected to remain the economical choice, in most cases, where an adequate supply of suitable make-up water is available at a reasonable cost. Decreasing water availability and increasing water costs and more stringent environmental and water use and accessibility regulations will, however, make a water conserving heat rejection system a practical and economical choice for more power plant [77SU1, 94KO1] and other applications [59MA1], especially if the effectiveness of such systems can be improved [80MC1].

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Understanding Wet and Dry Cooling Systems

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IWC-01-38

Keywords: cooling towers, dry cooling, combined-cycle power plants

Summary: Evaporative cooling towers, an integral part of most industrial operations, typically represent the single largest demand for plant makeup water and can be a major source of discharge wastewater. As a result, in new industrial facilities, dry cooling systems recently have been receiving increasing attention as an alternative to cooling towers. Evaluating new cooling system options requires a solid understanding of not only the readily apparent design and operating differences, but also the subtle, yet equally important, performance and cost implications.

BACKGROUND

The need to control elevated temperatures in a variety of industrial processes makes the choice of cooling medium and system an important operating and economic decision. Historically, water has been the cooling medium of choice because it was readily available, relatively inexpensive and reusable up to a point. For more than twenty years, evaporative systems (i.e., cooling towers) have been the predominant means for using water to cool process equipment.

Nowhere is this more apparent than in the steam-electric power industry, where large amounts of water are needed to condense turbine exhaust steam. In fact, the USEPA estimates that 92.4% of all industrial cooling water is used in steam-electric power generation.[1] This trend will very likely continue. Over the next twenty years, the Energy Information Administration projects that the nation's electric generating capacity will increase by 217 GW.[2] Most (62%) of this new capacity will be produced by combined-cycle (CC) power plants, all of which will need cooling for the steam-electric generation portion.

Growing competition from municipal and agricultural users has decreased the amounts and increased the prices of good quality water resources available to industrial users. At the same time, environmental regulations on the blowdown discharged from cooling towers have become much more stringent. Because dry (air-cooled) systems consume no water, generate no blowdown and create no visible plume, they may be seen as an economically and environmentally attractive alternative to wet cooling systems in new industrial facilities.

But when considering cooling options for new facilities, there are some important similarities and differences between wet and dry systems that should be fully understood before making a selection. Differences in heat transfer are particularly important because of the associated influences on the performance and costs of these systems.

CHARACTERISTICS OF WET AND DRY COOLING SYSTEMS

Industrial cooling systems are designed to transfer heat from one or more process operations to the surrounding atmosphere. For steam-turbine generators, this "waste" heat is produced when the turbine exhaust steam is condensed to recover high-purity water for recycle to the boiler. Steam condensation also creates a vacuum at the turbine outlet. This vacuum (monitored as turbine backpressure) allows the turbine to utilize more of the steam's energy and increases the overall efficiency of electric power generation. Lower steam temperatures in the condenser will produce a greater vacuum on the steam turbine (reflected by a lower turbine backpressure) and mean a better generating efficiency and higher total plant generation capability. In this way, the cooling system directly influences power plant performance.

All wet cooling systems use water to absorb heat via indirect contact with steam in a condenser. The condenser is a large shell-and-tube heat exchanger, with steam on the shellside and cooling water passing through the tubes. For systems with cooling towers, the water is pumped in a loop through the condenser to the tower and back to the condenser (see Figure 1). Because of this recycle circuit, this type of cooling system is frequently referred to as "closed-loop" or as "recirculated".

Heat absorbed by cooling water in the condenser is released to the air that passes through the cooling tower.

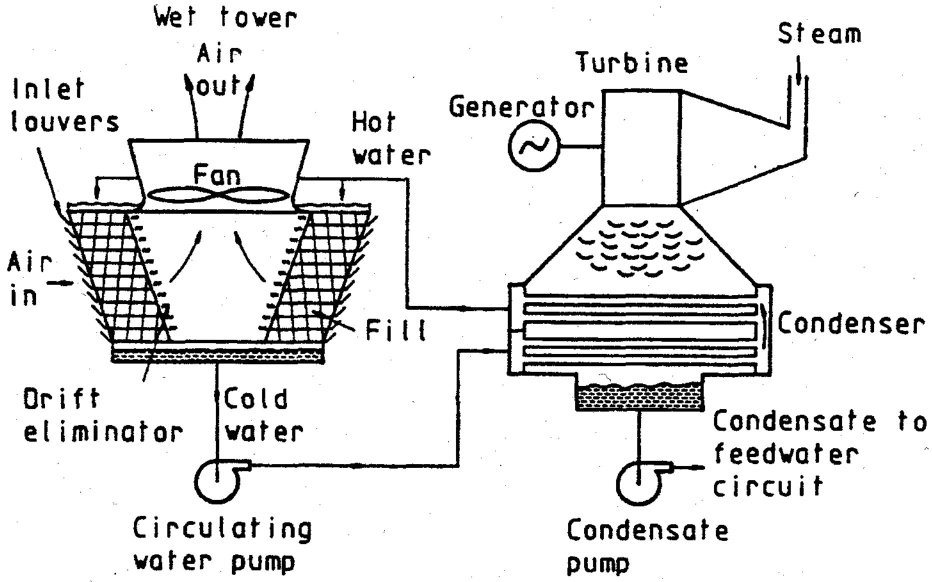

FIGURE 1
WET COOLING SYSTEM WITH MECHANICAL INDUCED-DRAFT TOWER[3]

Due to intimate direct air-water contact in the cooling tower fill,approximately 65-85% of this heat rejection is associated with the evaporation of a portion of the cooling water; the remaining 15-35% is due to simultaneous sensible heating of the inlet air. This process lowers the temperature of the water passing through the tower so that it can be recirculated back to the condenser and used for cooling again.

Because the surrounding air is the ultimate heat sink for the thermal energy released in the cooling tower, the atmospheric conditions are key elements in determining cooling system design and performance. The cooling ability of a tower is measured by how close it can bring the outlet cooling water temperature to the wet-bulb temperature of the surrounding air. The lower the inlet air wet-bulb temperature (indicating colder air and/or lower humidity), the colder the tower can make the outlet cooling water temperature. As a matter of physics, the cold water temperature can never be lower than the inlet air wet-bulb temperature.

When designing wet cooling towers, this difference between the anticipated inlet air wet-bulb temperature and the target cold water temperature is a value known as the "cooling approach". The approach for most wet cooling towers at high design-point wet-bulb temperatures is usually between 5 and 10 °F. A lower approach can be achieved by building and operating a larger tower. But doing so will increase the cooling tower capital and O&M costs. So, for power plant cooling towers, the design approach is generally about 8 °F. During operation in cold weather, this design approach can be expected to increase considerably due to atmospheric conditions.

Although the term "dry cooling" implies the total absence of water, it really means the transfer of heat to the atmosphere without the evaporative loss of water. For example, automobiles use a type of dry cooling system to control engine temperatures. Water is circulated through the engine block to absorb the heat of combustion, then through the radiator to dissipate that thermal energy by sensible heat transfer with the surrounding air, and finally back to the engine block. The system is said to be "dry" (or completely closed) because none of the water evaporates and makeup is only required to offset minor losses, such as leaks.

The automobile example is also said to be "indirect" because water is used as a medium for transferring the thermal energy from the heat source (the engine) to the heat sink (the atmosphere). Conceptually, an indirect, dry tower would seem to be a likely alternative to the standard wet cooling tower. However, the extremely poor thermal

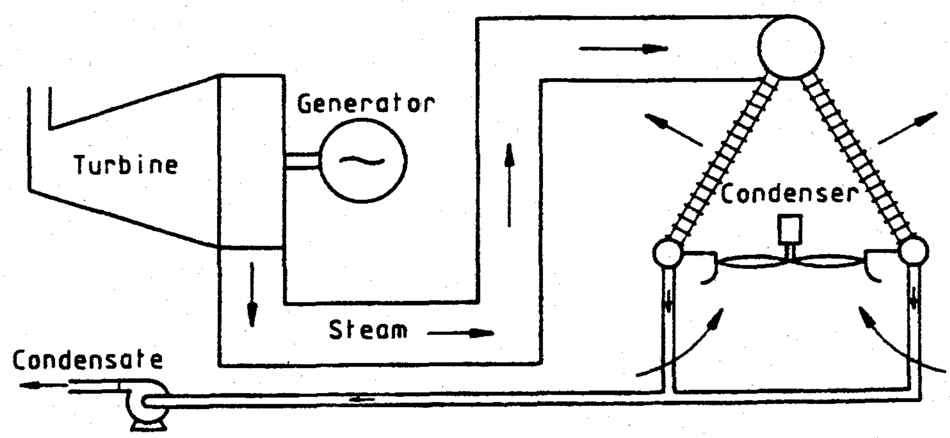

FIGURE 2
DRY COOLING SYSTEM WITH DIRECT AIR-COOLED CONDENSER (ACC)[3]

performance and very high cost have been factors that have precluded the selection of indirect dry cooling as a viable system design for new power plants in the United States. This particular cooling approach has been limited to a few special cases, primarily in Eastern Europe and the Middle East.

Instead, for new power plants, a "direct" dry cooling system is more applicable. In direct dry cooling, the turbine exhaust steam is piped directly to a finned-tube, air-cooled condenser (ACC), also referred to as the dry cooling tower (see Figure 2). The steam exhaust duct has a large diameter and as short a length as possible to minimize pressure losses. Because finned-tube, air-cooled condensers have a low heat transfer coefficient, they are commonly quite large. To reduce the required land area, the finned tubes on the ACC are frequently arranged in an A-frame or delta pattern. Air is forced across the finned tubes by fans to improve heat rejection to the atmosphere. The A-frame design also provides an improved fan air-flow coverage to the entire tube bundle.

Since an ACC relies strictly on sensible heat transfer, a large quantity of air must be supplied, requiring a correspondly larger number of fans than would be used in a wet cooling tower. Forced-draft fans are installed on the cooler, inlet air side of the condenser to: a) reduce the power consumption for the necessary air mass flow rate, b) allow the use of less expensive materials of construction, and c) improve access and ease of maintenance. Unfortunately, a forced-draft fan system often does not produce a uniform air flow distribution through the dry tower, resulting in a relatively low warm-air escape velocity from the top of the tube bundle. In a wind, this low velocity can be extremely important because it increases the potential for recirculation of the hot plume back through the tower instead of drawing in fresh ambient air.[4] Compared to wet cooling towers with the high-velocity plumes produced by induced-draft fans, the low exit air velocities associated with dry towers exacerbate recirculation in these systems. Therefore, anti-recirculation fences or windwalls may be required to prevent such problems.[5]

While the performance of wet cooling systems depends primarily upon the ambient wet-bulb temperature and is determined by the design approach, the performance of dry cooling systems depends upon the ambient dry-bulb temperature and is determined by a design value referred to as the "initial temperature difference" or ITD. For dry cooling, the ITD is the difference between the turbine exhaust steam temperature and the anticipated inlet air dry-bulb temperature. Reported design ITD values range from 25 to 55 °F. And just as the design approach for wet cooling systems can be reduced by increasing the tower size, a lower design ITD for dry cooling systems can be achieved by building and operating a larger ACC. However, the capital and O&M costs for an ACC are more sensitive to size than for a wet cooling tower. Therefore, when the heat rejection is substantial (as in the case of power plants), economics dictate that the size of the ACC be minimized, resulting in a larger design ITD.

Because ambient dry-bulb temperatures are usually higher than wet-bulb temperatures and tend to experience more dramatic daily and seasonal variations, the design and operation of dry cooling systems linked to steam turbine-generators can be more problematic than for wet cooling systems. If the dry cooling system is unable to meet design heat transfer conditions in the condenser, then the turbine backpressure will increase and the plant's power generation efficiency will decrease. With a reasonably flexible steam turbine design, a higher backpressure and the associated decline in generating efficiency (or energy penalty) can be operationally tolerated up to a point. But as the turbine backpressure increases, eventually an alarm will warn operators that the turbine-generator is approaching limits set by the equipment manufacturer. If steam cooling and condensation worsen, then the steam flow to the turbine must be reduced (known as a plant derate because the amount of electricity which can be generated by the entire plant is reduced). Though it is difficult to absolutely categorize a high-temperature limit, when ambient dry-bulb temperatures exceed 90 °F, the relative performance of a dry cooling system will usually begin to suffer appreciably.

HYBRID COOLING SYSTEMS

In some circumstances, a combination of wet and dry cooling systems has been helpful in addressing certain site-specific issues. The nature of these "hybrid" systems can vary significantly depending upon the particular situation and objectives. Some hybrid systems are designed to compensate for the decline in performance of a dry cooling system at higher ambient dry-bulb temperatures. These hybrid systems essentially incorporate a wet-cooling component with a surface condenser in a parallel steam path to provide supplemental evaporative cooling when needed. This type of wet/dry system is currently not in widespread use and typically has been limited to situations with small cooling requirements.

By far, the most common type of hybrid system is designed to eliminate the visible plume leaving the tower of a wet cooling system. Hybrid plume-abatement systems basically consist of an indirect dry cooling system located immediately above the cooling tower portion of a wet cooling system. Hot cooling water from the condenser is fed first to indirect-contact, finned-tube, air-cooled heat exchangers and then to the direct-contact fill in the wet tower. When operating in the plume-abatment mode, ambient air is drawn through both the dry and wet segments in parallel paths. The two air streams are then mixed and exhausted from the stack of the induced-draft fan at the top of the tower. The hot, dry air from the air-cooled heat exchangers increases the temperature and decreases the relative humidity of the cooler, saturated air from the fill in the wet tower so that the final mixture does not have a visible plume. Operators can control the degree of visual plume abatement by adjusting hinged damper doors along the air inlet to the dry cooling section to govern the air flow and, consequently, the volume, temperature and relative humidity of hot, dry air in the outlet mixture. Hybrid plume abatement systems are not water-conserving systems.

EVALUATING COOLING SYSTEM OPTIONS

When considering cooling system options for a new facility, any number of site-specific factors can influence the evaluation and selection process. But, in general, the key environmental factors will most likely be:

- Water availability and quality
- Wastewater discharge limitations
- Meteorological conditions
- Drift and plume aesthetics
- Fish protection
- Worker and community health and safety
- Noise

The primary economic factors are:

- Water availability and quality
- Wastewater discharge treatment
- Geographic location (as related to land availability and cost, and construction cost)
- System performance over variable operating conditions

Based on these lists, dry cooling systems offer several obvious advantages. There are no makeup water requirements or wastewater discharge concerns. Aquatic impacts and drift or plume problems are nonexistent. And any health or safety issues related to waterborne contaminants and pathogens or water treatment chemicals are eliminated.

But the extensive design and operating experience with wet cooling systems in a broad range of industrial applications cannot be ignored. This history has established wet cooling towers as the low-cost, closed-loop standard for stable performance over variable operating conditions at virtually any site throughout the U.S. and the world. And given the evolving competitive market in the U.S. electric power industry, the major emphasis will undoubtedly be on cost and performance at new power generation facilities. With this in mind, a generic base-case combined-cycle plant was studied to compare the cost and performance characteristics of wet and dry cooling systems at five different U.S. sites (Albany, NY; Atlanta, GA; Madison, WI; Amarillo, TX and Sacramento, CA).

BASE CASE PARAMETERS

The generic base case selected for study was a 750-MW combined-cycle power plant with two 250-MW gas turbine-generators followed by one 250-MW steam turbine-generator. Since exhaust steam condensation from the single steam turbine represents the largest cooling demand, only this portion of the plant is considered in the detailed analysis. The smaller auxiliary cooling loads were estimated to add 5% to the overall capital costs of both the wet and dry cooling systems.

To further simplify the analyses, a single steam turbine design was assumed for both wet and dry cooling systems. In the past, steam turbine/condenser designs for large fossil and nuclear power plants have been optimized to reflect the type of cooling system, as well as other site-specific conditions. However, more recently, designers have been relying on more flexible steam turbines which operate over a wider range of backpressures, even if it means accepting an energy penalty under certain conditions. An exhaust steam flow of 1.7 million lbm/hr (at 5% moisture) was assumed as representative for a 250-MW steam-turbine designed to operate at 2.5 in Hga.

The base-case cooling tower is a mechanical-draft, counterflow design with a concrete basin and FRP support structure. The fill is a modern, low-clog plastic film fill. The total tower would consist of twelve cells in a back-to-back configuration. The area of each cell would be about 42 feet by 54 feet, so that the overall footprint of the tower would be 325 feet long and 85 feet wide. The maximum height of the tower (measured at the top of the fan stack) would be about 55 feet. Each cell would have a single, 30-ft diameter, low-noise, induced-draft fan.

The condenser is a modern, single-pass, shell-and-tube design with carbon steel shell, waterbox, tubesheet and supports, and 22 BWG 304 stainless steel tubes. The overall size was determined using Heat Exchange Institute (HEI) steam surface condenser standards for a cooling water velocity of 7 ft/sec and an 85% cleanliness factor.

The air-cooled condenser (dry cooling tower) was made of carbon steel finned tubing arranged in the "A-frame" configuration with an exhaust steam manifold at the top and condensate collection lines at the bottom on either side. The ACC footprint was estimated to be 250 feet by 250 feet (1.4 acres). The maximum ACC height (at the top of the A-frame) would be about 105 feet. A total of forty 30-ft diameter, low-noise, forced-draft fans would be required.

Other base case design details for the wet and dry cooling systems are summarized in Table 1.

TABLE 1
BASE-CASE COOLING SYSTEM DESIGN SPECIFICS

Wet Cooling System	
Cooling tower approach	8 °F
Cooling tower range	24 °F
Ambient wet-bulb temperature	Regional Mean
Wet-bulb temperature recirculation	+ 2 °F
Evaporation (% of total heat load)	70
Cycles of concentration	5
Condenser terminal temp. difference	6 °F
Dry Cooling System	
Initial temperature difference (ITD)	54 °
Ambient dry-bulb temperature	Regional Mean
Dry-bulb temperature recirculation	+ 3 °F

ESTIMATED CAPITAL AND O&M COSTS

Capital costs for both wet and dry cooling systems were developed using estimating methods commonly employed by architect-engineers for large utility projects, and included all system elements beginning at the turbine exhaust flange. Algorithms based on prior bid costs were used to estimate specific installed cooling tower costs. The majority of the other cost components were individually determined using published data[6] and other recent cooling system cost estimates or previous equipment quotes, in combination with an assessment of the quantity of materials involved or a size delineation. In addition, the following details also apply to all capital cost estimates.

- Low-noise fans (with 10 dba attenuation) were included due to the general sensitivity of most communities to the relatively pervasive noise from cooling towers (wet and dry).
- A 1% hot-weather incidence value was selected as typical for both wet and dry cooling towers.[7]
- Wiring costs[8] and local construction costs[6] were based on factors specifically developed for this purpose.
- The usual project allowances for indirect costs such as management, engineering, and contingencies were included.
- All costs were adjusted to a July 1999 basis using standard factors.[6]

Table 2 is an itemized comparison of the resulting capital cost estimates for wet and dry cooling systems at one location.

TABLE 2
ITEMIZED CAPITAL COST ESTIMATES FOR WET AND DRY COOLING SYSTEMS
(Albany, NY $Million, July 1999)

	Wet Cooling	Dry Cooling
Cooling Tower	6.64	28.06
Fans	2.58	11.64
Condenser	6.05	
Auxiliary Cooling	0.89	2.13
System Miscellaneous	2.19	1.58
General Miscellaneous	0.28	1.02
Total Direct Costs	18.63	44.43
Indirect Factors	6.52	15.55
Total Costs	25.15	59.98

Wet cooling tower costs include the tower and basin; dry cooling tower costs include the ACC, steam duct, foundation and support structure. System miscellaneous costs include the cooling water intake and cooling water pumps and piping (for the wet system), and a tube wet-down/cleaning system, special controls, insulation and heat tracing (for the dry system). General miscellaneous costs include site preparation, access roads, fire/lightening protection, painting and acceptance testing (for both systems).

Table 3 is a comparison of the total estimated capital costs at all five locations.

TABLE 3
TOTAL CAPITAL COST ESTIMATES FOR WET AND DRY COOLING SYSTEMS
($Million, July 1999)

	Wet Cooling	Dry Cooling
Albany, NY	25.2	60.0
Atlanta, GA	23.2	56.2
Madison, WI	25.4	60.7
Amarillo, TX	21.3	52.1
Sacramento, CA	28.0	66.0

For the base-case example (250-MW steam turbine at a new 750-MW combined-cycle power plant), the total estimated capital costs for a dry cooling system were consistently greater than those for a wet cooling system by an average of 140% at all five sites studied. The higher costs can be attributed to the larger, more expensive ACC and the increased number of fans. Although there was appreciable capital cost variability for either the wet or the dry cooling systems between the different sites, the majority of this variation reflects local construction cost factors and not climatic conditions.

Operating and maintenance (O&M) costs were based on a combination of several cost factors. For both wet and dry systems, the annual labor and materials maintenance costs for all cooling system components were assumed to be 1% of the capital costs. This figure reflects past estimates[8], as well as recent experience with power plant towers, condensers, circulating water pumps and intakes. The cost of system auxiliary power was determined by: 1) estimating the power requirements (fans for dry systems and fans and pumps for wet systems), 2) adjusting these power requirements by assuming a 90% CC plant capacity factor, and 3) multiplying the adjusted power requirement by a unit cost of $25/MW-hr.

A comparison of the estimated annual O&M costs at all five locations is presented in Table 4.

TABLE 4
ANNUAL ESTIMATED O&M COSTS FOR WET AND DRY COOLING SYSTEMS
($Million, July 1999)

	Wet Cooling	Dry Cooling
Albany, NY	0.94	1.82
Atlanta, GA	0.92	1.78
Madison, WI	0.94	1.83
Amarillo, TX	0.90	1.74
Sacramento, CA	0.96	1.88

The largest proportion of the estimated annual O&M costs is for system auxiliary power: 70-75% for wet systems and 65-70% for dry systems. For wet systems, this power cost is split almost evenly between pumps and fans. For dry systems, the power cost is associated entirely with fans.

An important annual cost not included in these estimated O&M costs is the potential energy penalty (i.e., the reduced plant generating capacity) for each system. The energy penalty is directly related to the climatic conditions of a specific site and would be expected to vary considerably throughout the country. However, for both wet and dry cooling systems, the energy penalty normally is greatest during the hottest periods of the year (usually assumed to be only 1% of the time during the four warmest months or 29.2 hours/year). For the remainder of the year, the energy penalty should be much smaller. Unfortunately, the periods of greatest energy penalty typically coincide with the times of peak electricity consumption. Therefore, any generating shortfall at that time represents a serious problem in meeting customer demand and a potentially significant revenue loss.

Since the performance of dry cooling systems is linked to the ambient dry-bulb temperature (which can fluctuate significantly on a daily basis), dry cooling systems are particularly sensitive to climatic variations. This influence can be seen in Table 5 which shows the maximum energy penalties estimated for both wet and dry cooling systems compared to the base 250-MW capacity.

The magnitude of the maximum energy penalty for dry cooling systems relative to wet cooling systems demonstrates the substantial economic impact that cooling system selection can have on power generation costs. Depending upon the prevailing price of replacement power, the maximum energy penalty costs could be quite high, as shown in Figure 3. And, as replacement power costs increase, the estimated maximum energy penalty costs for dry cooling could begin to approach the value of other elements in the anticipated annual O&M cost. On the other hand, wet cooling systems are expected to incur relatively minor energy penalty costs.

TABLE 5
ESTIMATED MAXIMUM ENERGY PENALTY FOR WET AND DRY COOLING SYSTEMS (MW)

	Wet Cooling	Dry Cooling
Albany, NY	0.0	29.1
Atlanta, GA	0.7	30.4
Madison, WI	0.6	34.4
Amarillo, TX	- 2.3	39.1
Sacramento, CA	0.0	45.2

CONCLUSIONS

Selecting a cooling system for a new industrial facilty means balancing a number of site-specific constraints. Dry cooling systems offer some environmentally attractive

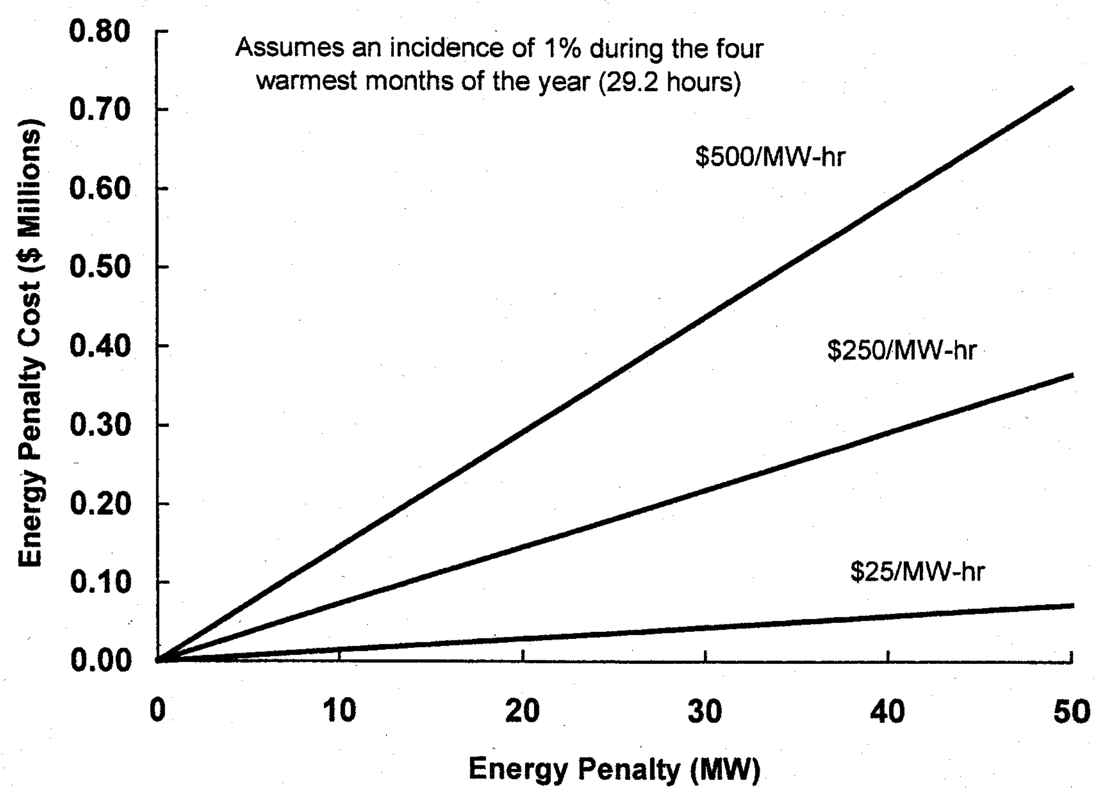

FIGURE 3
ENERGY PENALTY COSTS AS A FUNCTION OF REPLACEMENT POWER COSTS

advantages, particularly if new facility permitting may be a concern. However, these advantages have a large price when compared with the economics and performance of wet cooling systems. For example, an evaluation of wet and dry cooling systems for a 250-MW steam turbine-generator at a new 750-MW combined-cycle power plant shows that:

- The estimated capital cost for a dry cooling system is 140% greater than for a wet cooling system,
- The estimated annual O&M cost for a dry cooling system is 94% greater than for a wet cooling system,
- The performance of dry cooling systems (which are directly related to the ambient dry-bulb temperature) is more sensitive to climatic conditions and more likely to vary over wider ranges on both a daily and seasonal basis than the performance of wet cooling systems (which are directly related to the ambient wet-bulb temperature), and
- The decline in system performance (calculated as the maximum energy penalty) for dry cooling could range from 29-45 MW, depending upon local climatic conditions; for wet cooling, the maximum energy penalty is negligible.

Therefore, by almost any economic measure, wet cooling would generally be the preferred cooling system option for a new industrial facility. Dry cooling systems are most likely to be selected only in limited special situations with very unique constraints that make wet cooling systems technically impractical or environmentally unacceptable.

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