Turbine Inlet Cooling : An Overview

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Turbine Inlet Cooling Association Webinar

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Presentation Outline

- Background: What is the problem that needs a solution?
- What is TIC?
- Benefits of TIC: Economic and Environmental
- Commercially Available TIC Technologies
- Factors Affecting the Performance of TIC Technologies
- Factors Affecting the Economics and Selection of TIC Technology
- Summary of the Presentation

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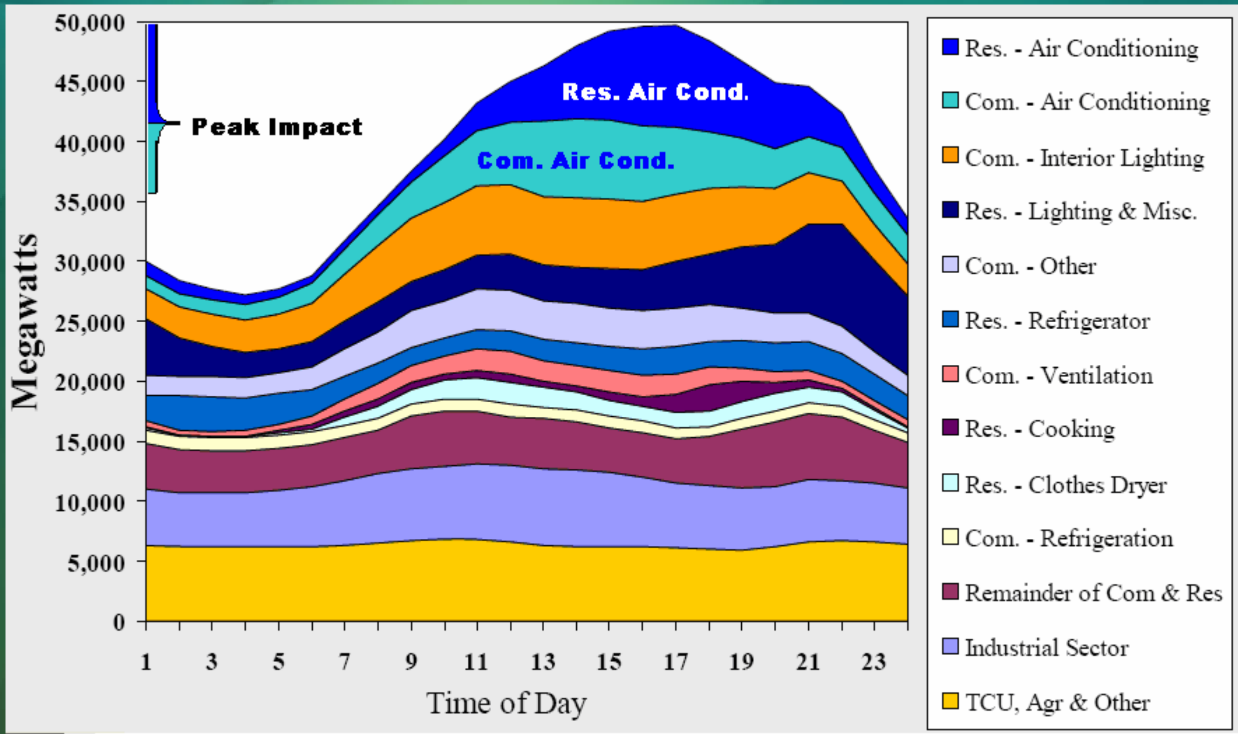
High Summer Temperatures Lead to High Air Conditioning Loads that become Major Contributors to the Peak Power Demand



Source: Scot Duncan Presentation at ASHRAE June 2007

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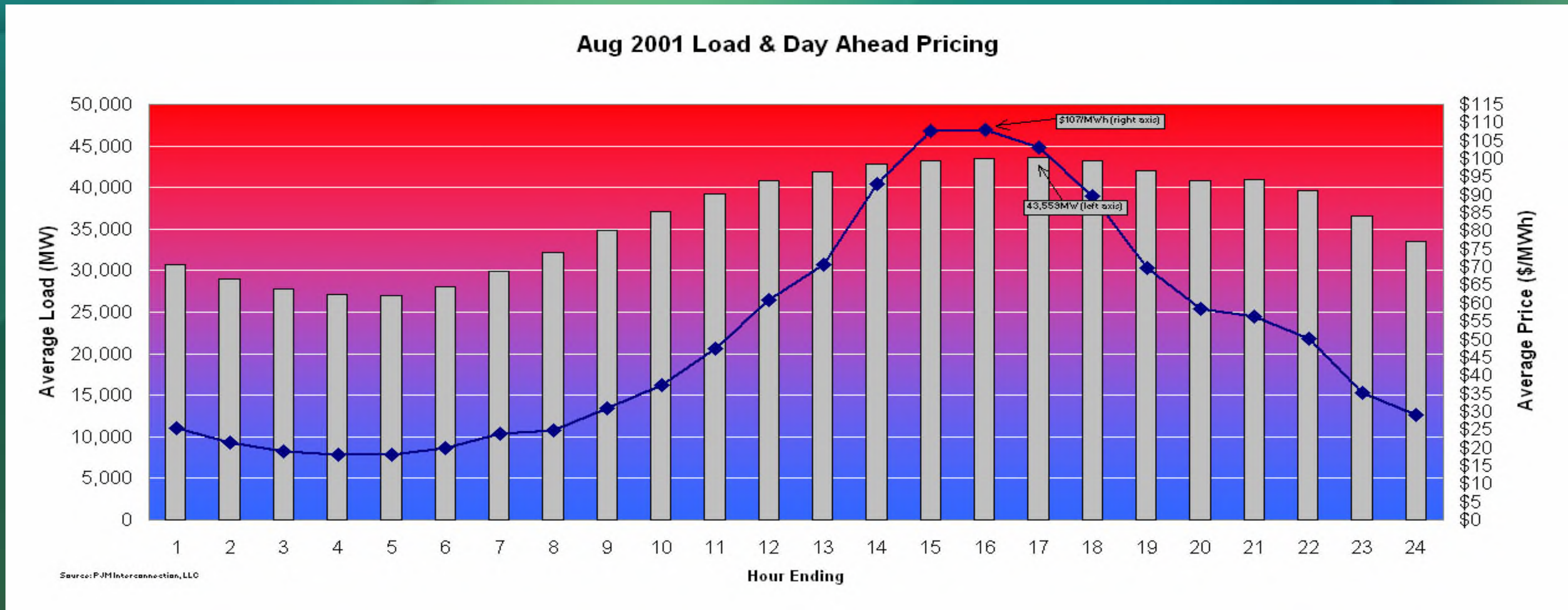
Power Demand and Electric Energy Price Rise with Hot Weather



- Price of electric energy for the ratepayers goes up during the peak demand period: as much as 7 times that during the off-peak period

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Power Plant Operation Priority for Reducing Emissions

1. Cogeneration (Highest Energy Efficiency)
2. Combustion Turbine in Combined Cycle
3. Combustion Turbine in Simple Cycle
4. Old Steam Turbine (Lowest Energy Efficiency)

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Note: All systems using same fuel

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Some Unfortunate Characteristics of All Combustion Turbine Power Plants

- **During hot weather, just when power demand peaks,**

  1. Power output decreases
     - Up to 35% below rated capacity
     - Extent of the decrease depends on the CT design
  2. Efficiency decreases leading to increased fuel consumption (higher heat rate) and increased emissions per kWh
     - Up to 15% below rated capacity
     - Extent of the decrease depends on the CT design

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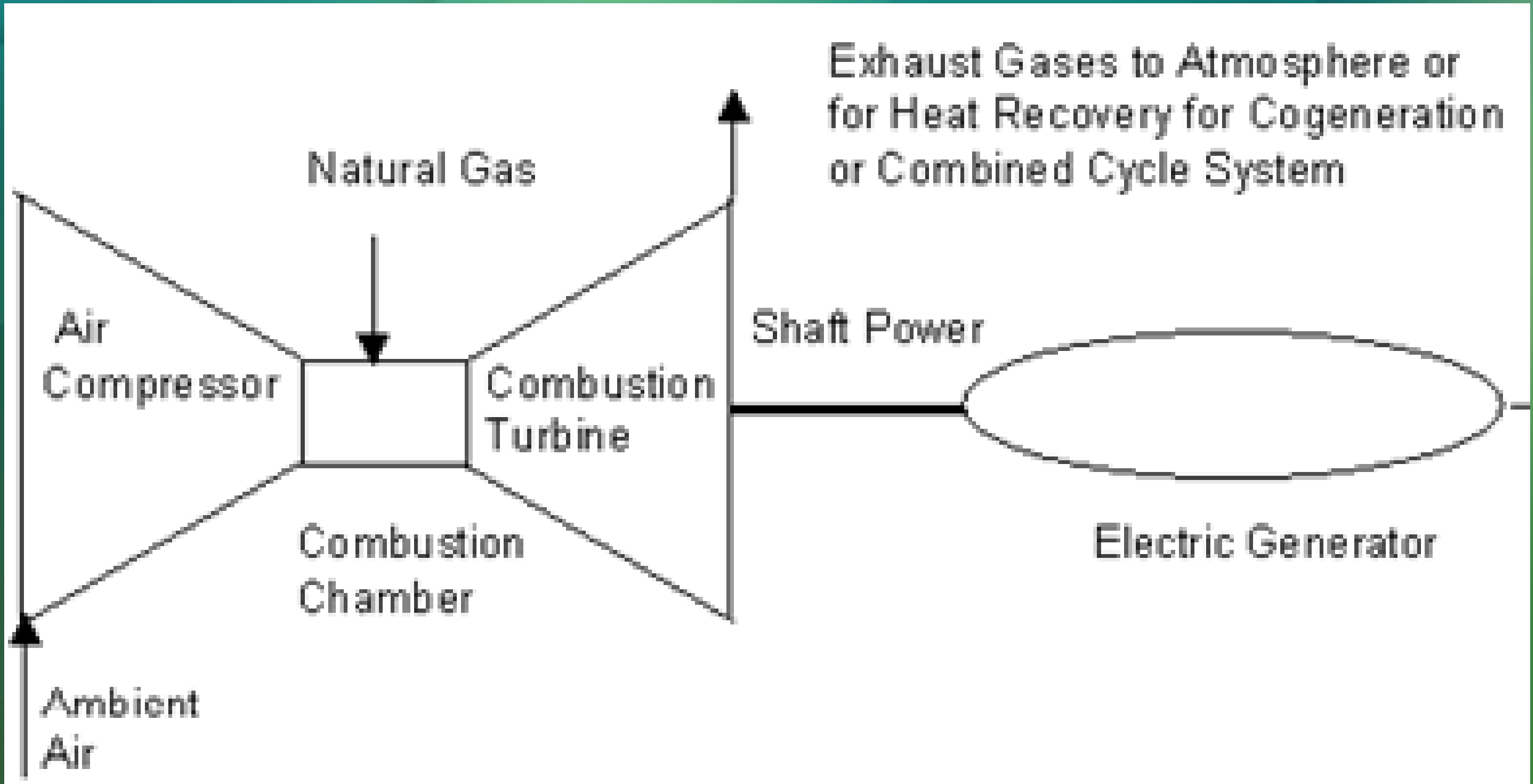
Major Components of a Combustion Turbine System



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Why CT Power Output Capacity Decreases with Increase in Ambient Temperature?

- Power output of a turbine is proportional to the mass flow rate of hot gases it receives from the combustion section
- Mass flow rate in the combustion section is proportional to the mass flow rate of the compressed air it receives from the compressor
- Mass flow rate capacity of a compressor is limited by its volumetric capacity for sucking in the inlet air
- Increase in ambient temperature reduces the air density that decreases the mass for the same volumetric flow rate through the compressor
- Reduced mass flow rate of compressed air reduces the mass flow rate of the hot combustor gases that leads to reduced power out put of the combustion turbine

Why CT Efficiency Decreases with Increase in Ambient Temperature?

- Compressor power requirement increases with increase in air temperature
- Compressor of a CT system consumes almost two-third of the turbine's gross output
- Increased power required of the compressor reduces the net electric power available from the CT system

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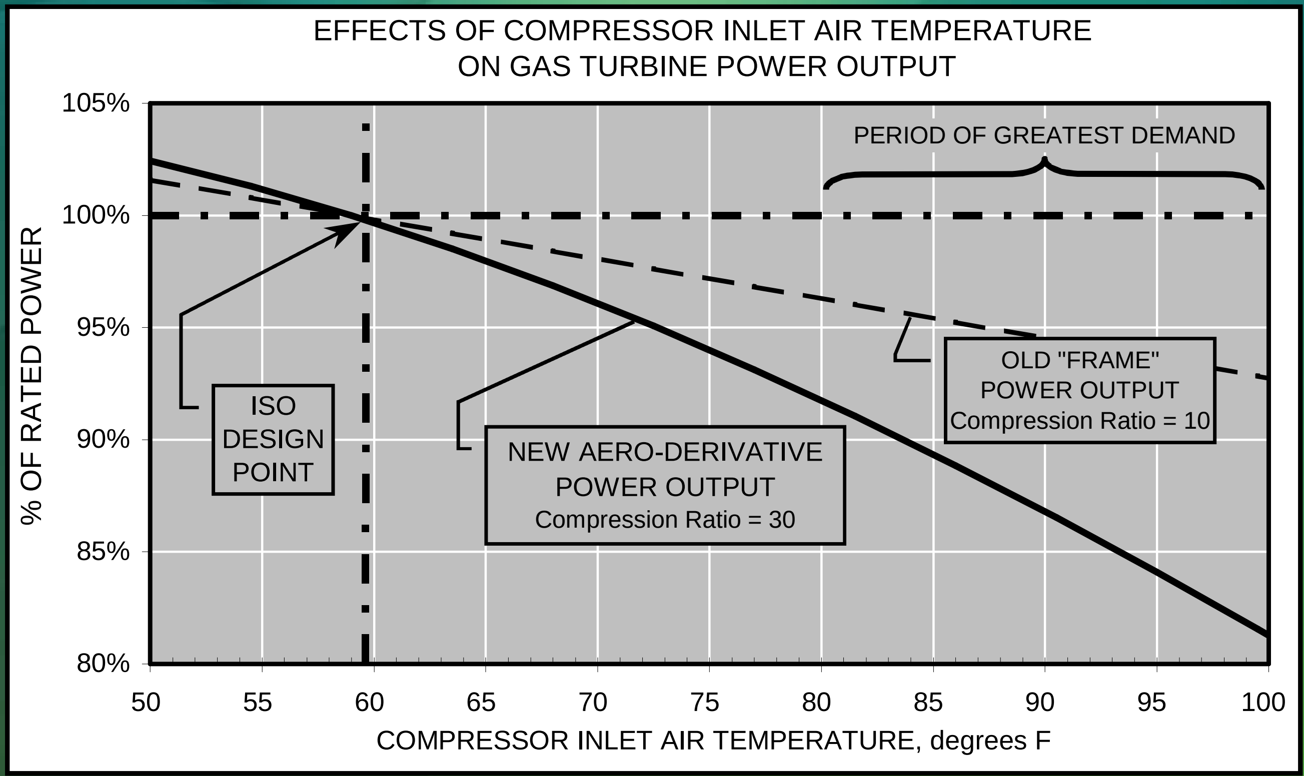
Effect of Hot Weather on CT Generation Capacity Depends on CT Design



Up to 19% capacity loss at peak demand for this CT

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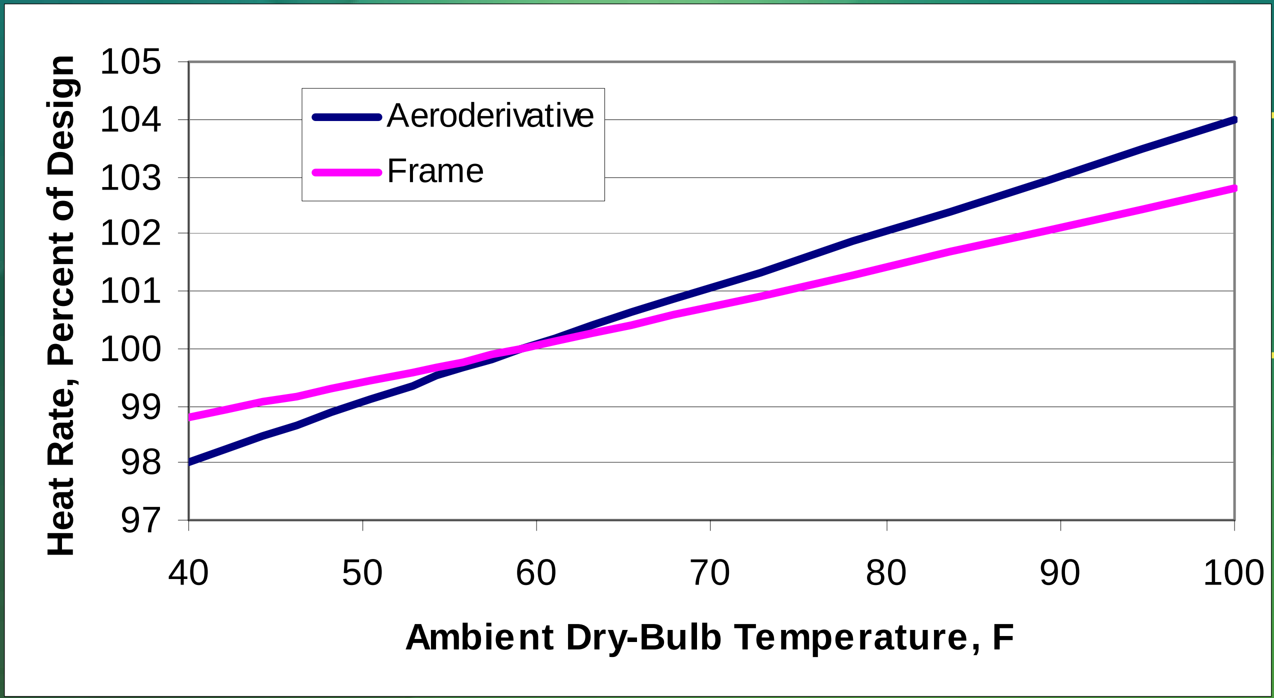
CT Power Plants Energy Efficiency Decreases (i.e. Heat Rate Increases) with Increase in Ambient Temperature



Fuel Use Increase (i.e. Energy Efficiency loss) at peak demand

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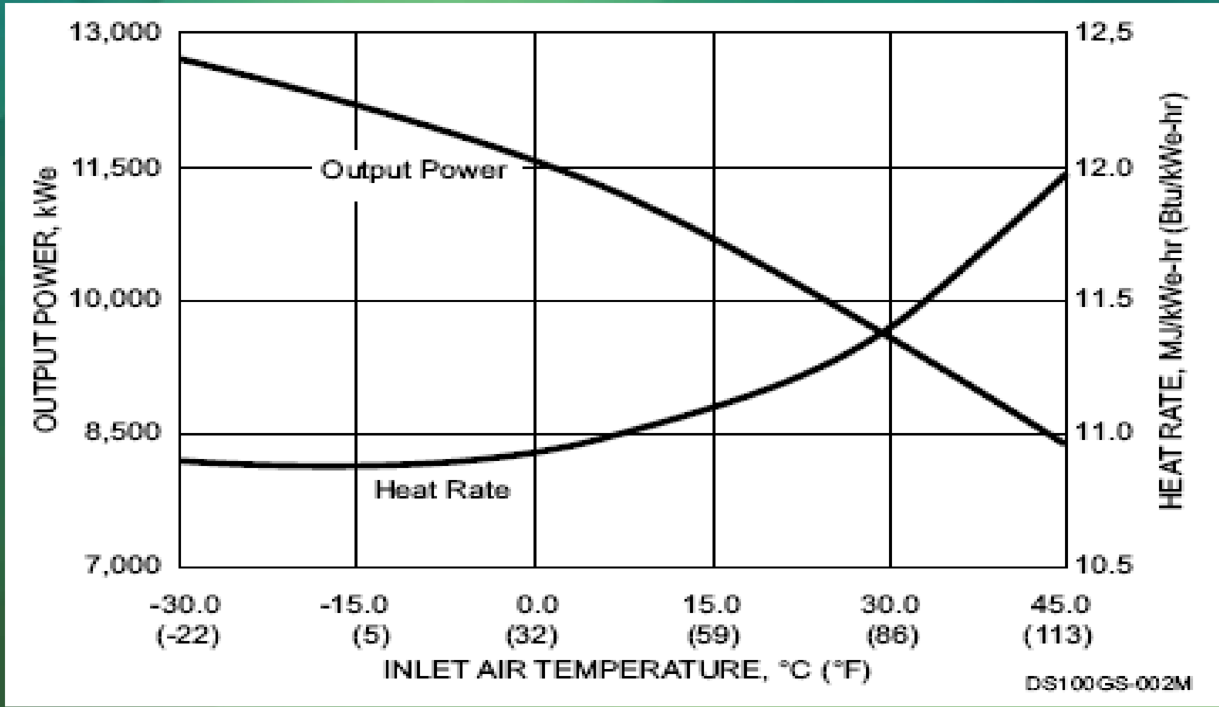
Smaller Capacity Systems More Sensitive to Ambient Temperature

Capacity Loss of over 21% from ~10,750 kW to ~8,500 kW



Efficiency loss of over 8 % from HR of ~ 11,100 to ~12,000 Btu/kWh

Source: Solar Turbines

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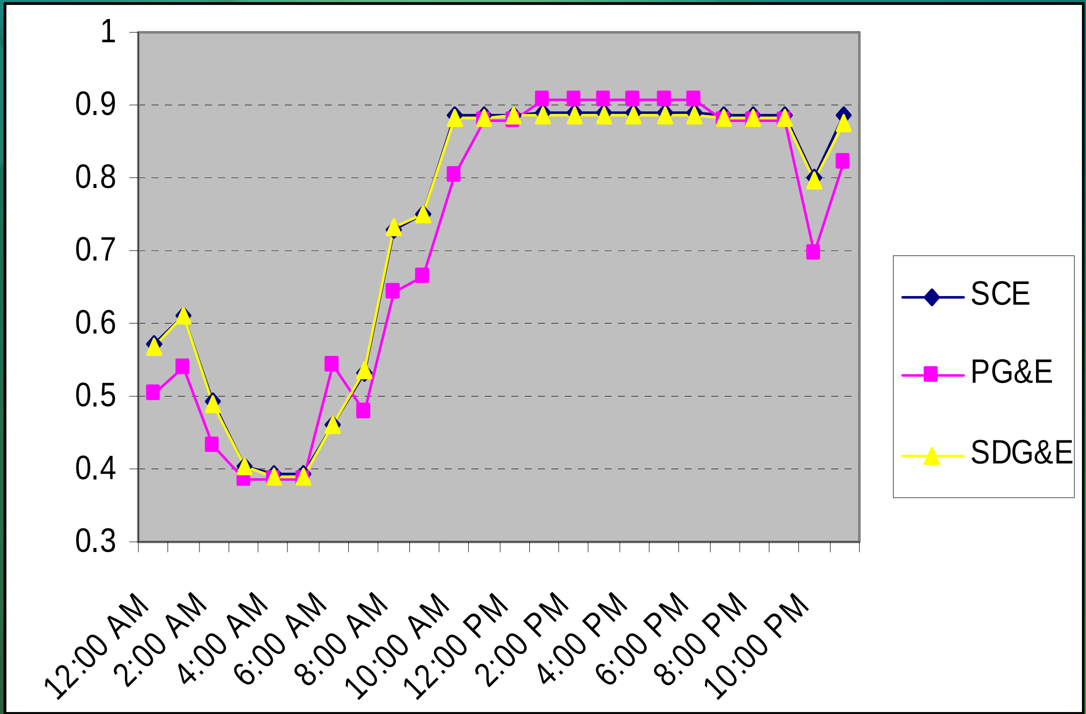
Example of Emissions (lbs/kWh) of CO_2 During On-Peak and Off-Peak (California) Periods



Y-Axis Unit: CO_2 Emissions, Lbs/kWh

Source: Scot Duncan Presentation at ASHRAE June 2007

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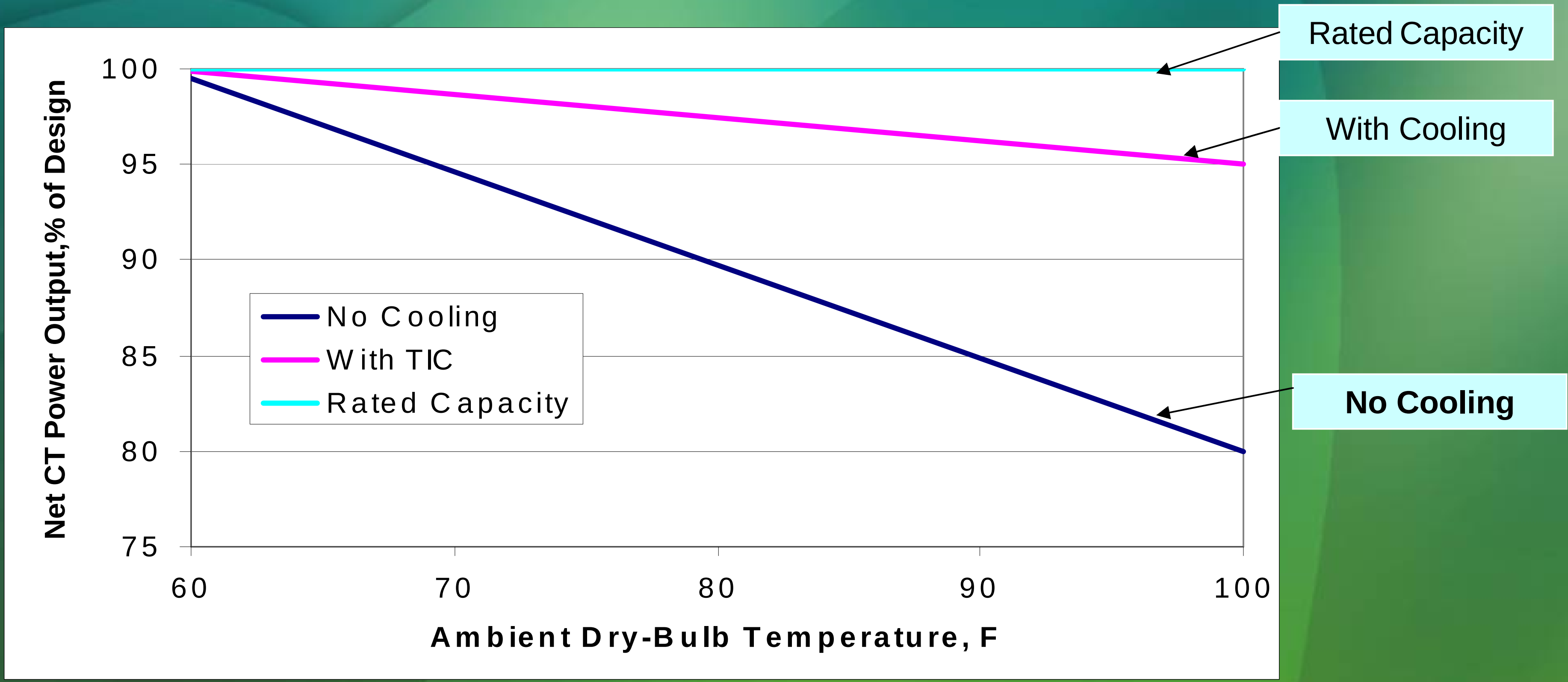
Turbine Inlet Cooling (TIC) Overcomes the Effects of the CT Performance During Hot Weather



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Environmental Benefits of Turbine Inlet Cooling

- Reduces the need for operating inefficient and higher-emission power plants and thus,
  - Reduces emissions of pollutants (SOx, NOx, particulates)
  - Reduces emissions of green house gas (CO_2)

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Turbine Inlet Cooling (TIC) Reduces Need for New Power Plants

- Example, TIC for a nominal 500 MW CC plant eliminates the need for a new nominal 40-50 MW SC peaker and its associated siting, emissions, interconnection and other issues

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U.S. Generation Capacity Reduction During Summer

Fuel	Winter Capacity, MW	Summer Capacity, MW	Summer Capacity Loss, MW
Coal	316,363	314,294	2,069
Petroleum	60,878	56,781	4,097
Natural Gas	432,309	401,272	31,037

Source: U.S. Department of Energy's Energy Information Agency 2009 Database

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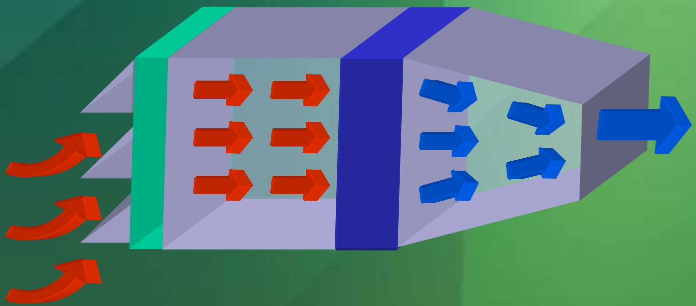
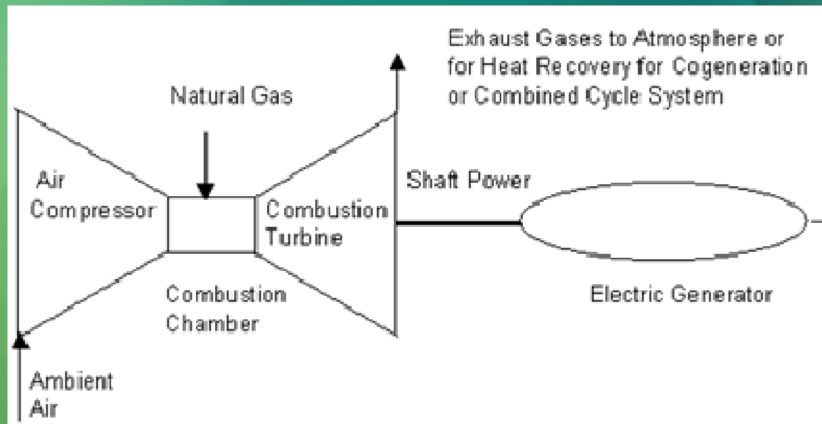
What is Turbine Inlet Cooling?





- **Cooling the inlet air that enters the compressor section of the CT system**

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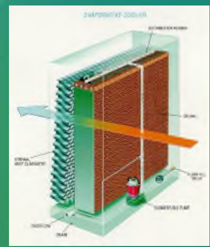
Turbine Inlet Cooling Technologies

- **Direct Evaporation**

  - Wetted Media, Fogging



- **Indirect Evaporation**

- **Chilled Fluid using mechanical or absorption chillers:**

  - Indirect or Direct Heat Exchange

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Turbine Inlet Cooling Technologies

- **Thermal Energy Storage (TES)**

  - Chilled Fluid or Ice

- **Wet Compression**
- **LNG Vaporization**
- **Hybrid**

  - Some combination of two or more cooling technologies

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Turbine Inlet Cooling Technologies

- Each TIC technology has its pros and cons
- No one technology is best for all applications
- Evaporative cooling systems can not cool the inlet air to lower than the wet-bulb temperature but require least capital cost and have least parasitic power need
- Chiller systems can be designed to cool the air to any desired temperature but require more capital cost and have high parasitic power need

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Turbine Inlet Cooling Technologies

- TES systems shift chiller parasitic load to off-peak period
- Wet compression improves compression efficiency and low parasitic load
- Hybrid systems minimize the parasitic load to achieve a desired inlet air temperature
- LNG vaporization only applicable where the power plant is located at/or need an LNG vaporization facility

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Turbine Inlet Cooling Technologies are Simple and Proven

- Thousands of plants already benefiting from TIC
- TICA web site database of 100+ plants worldwide that are using TIC

www.turbineinletcooling.org/database.html

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Turbine Inlet Cooling Technology Performance Calculator

- Available on the TICA Website

  http://www.turbineinletcooling.org/calculation_nonmem.php5

- Member Version (Full Version)

- Public Version (Partial Features)

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Factors Affecting the Capacity Enhancement Potential of TIC

- TIC Technology
- CT Design Characteristics
- Weather Data (dry-bulb and coincident wet-bulb temperatures/humidity) for the Geographic Location of the CT
- Design Ambient Conditions
- Design Cooled Air Temperature (if allowed by the TIC technology)*

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* Cooling achieved by evap technologies is limited by the humidity

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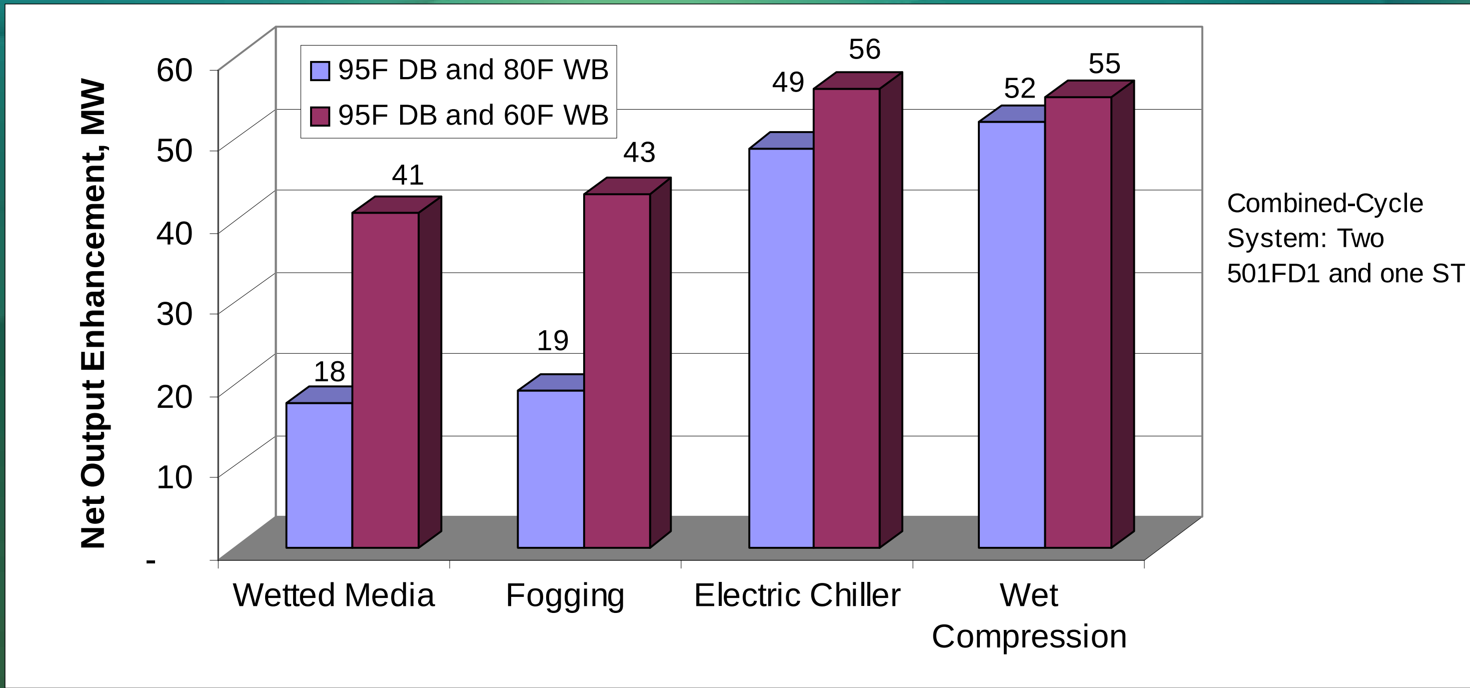
Examples of the Effect of TIC Technology and Humidity on Capacity Enhancement



Sources:

Wet Compression: Caldwell Energy, Inc.

All Others : D.V. Punwani Presentation, Electric Power 2008

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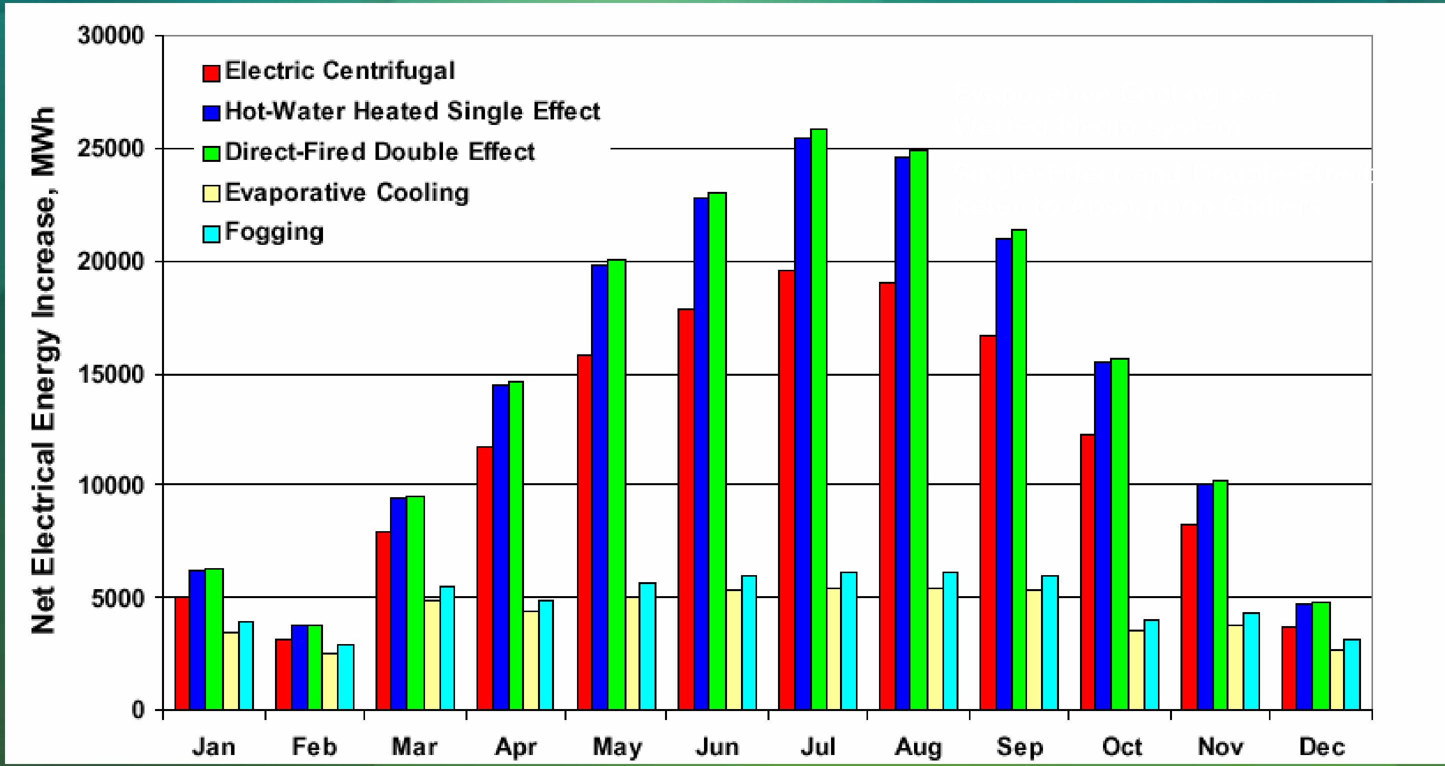
Example of Monthly Incremental Net Electric Energy Provided by Some of the TIC Technologies

(316 MW Cogeneration Plant Near Houston, TX)



Source: D.V. Punwani et. al. Presented at ASHARE 2001

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Factors Affecting the Economics of TIC

- TIC Technology
- TIC Capital & Operating Cost
- CT Characteristics
- Weather Data for the Geographic Location of the CT
- Market Value of the Additional Electric Energy Produced
- Fuel Cost

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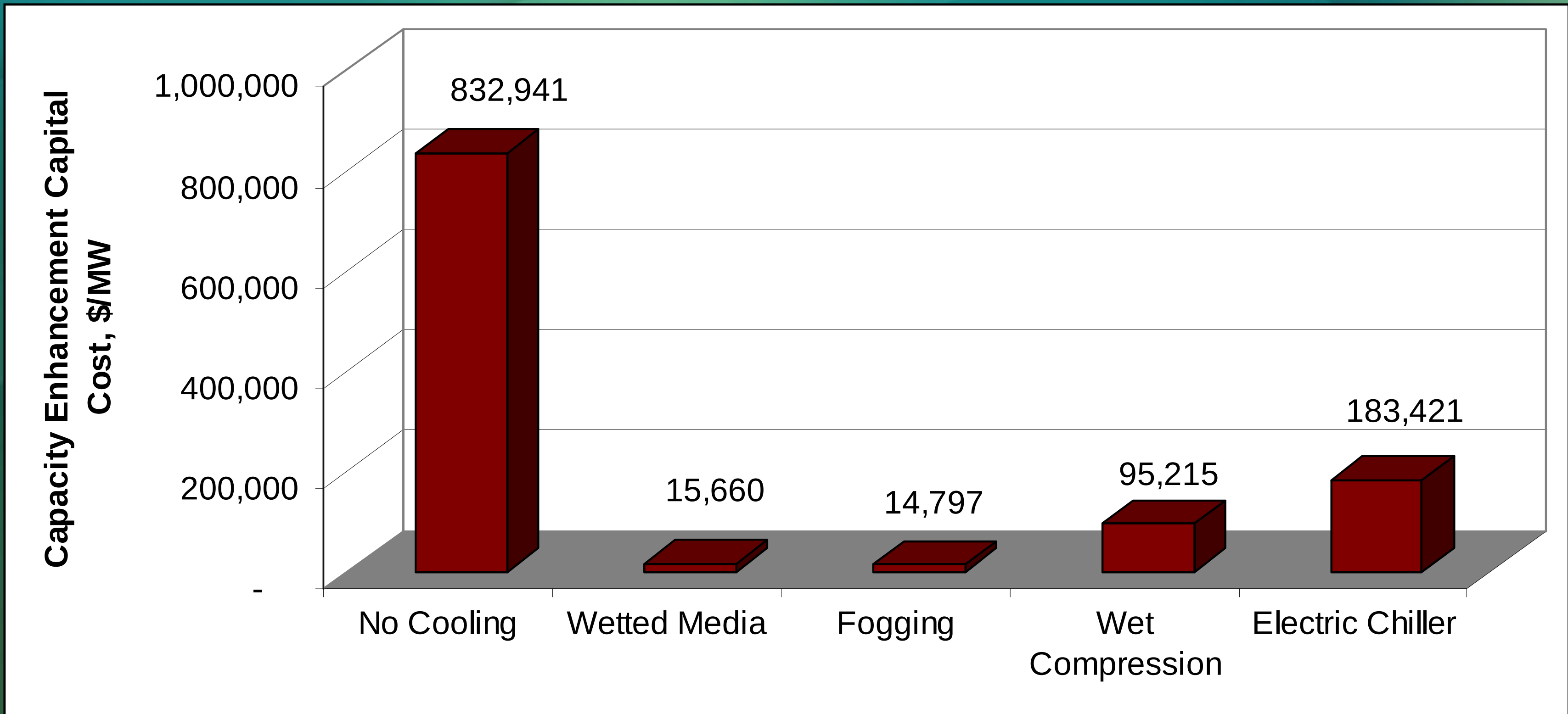
Examples of the Effect of TIC Technology on Capital Cost for Incremental Capacity



317 MW Cogeneration System Snapshot at 95°F DB and 80°F WB

Source: Punwani *et al* ASHRAE Winter Meeting, January 2001

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Turbine Inlet Cooling Economic Benefits

- Generates more MWh during peak demand periods when electric energy value is high
- Reduces capital cost per unit of the increased generation capacity compared to new power plants
- Reduces fuel cost of electric energy generation compared to the low energy efficiency “peakers”
- Reduces cost for ratepayers by potentially lower capacity payments to be provided by the independent system operators (ISOs) to power producers

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Suggested Changes To Regulatory Structure

- Realize full potential of existing combustion turbines plants
  - Require addition of TIC before allowing new plants to be built
- Exempt TIC from environmental re-permitting
  - Impact of TIC is similar to ambient temperature naturally going down during winter (i.e. TIC yields winter performance in summer)
- Calculate capacity payments for plant owners on the basis of lower cost of systems incorporating TIC
  - Consistent with the PJM affidavit made to the FERC in August 2005

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Summary

Turbine Inlet Cooling

- Significantly increases CT power output during hot weather
- Multiple options of commercially-proven technologies are available
- Generally economically attractive to the plant owners and rate payers
- Helps reduce emissions and thus, good for the environment
- Good for the environment, rate payers and the plant owners

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Upcoming TICA Webinars

- August 22, 2012: Wetted-Media Evaporative Cooling
- October 18, 2012: Fogging
- December 19, 2012: Chiller Systems
- February 13, 2012: Thermal Energy Storage
- April 17, 2012: Wet Compression
- June 19, 2012: Hybrid Systems

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Q & A

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