# Turbine Inlet Cooling: An Energy Solution That's Good for the Environment, Rate Payers and Plant Owners

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**Turbine Inlet Cooling Association**

**Presented at**
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**Orlando, FL**

**December 2, 2008**

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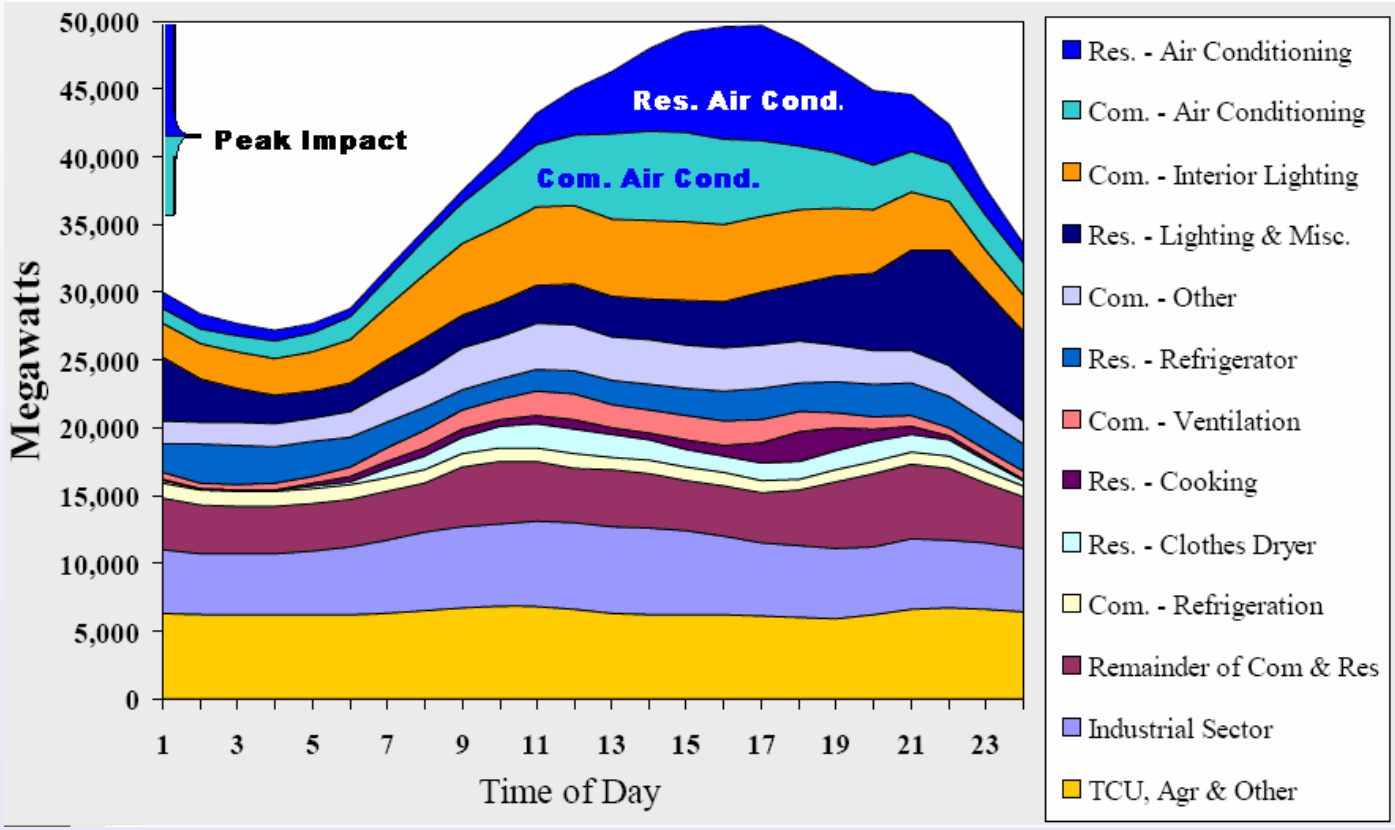
# High Summer Temperatures Lead to High Air Conditioning Loads that Become Major Contributors to the Peak Power Demand




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 4 times the value during the off-peak period**

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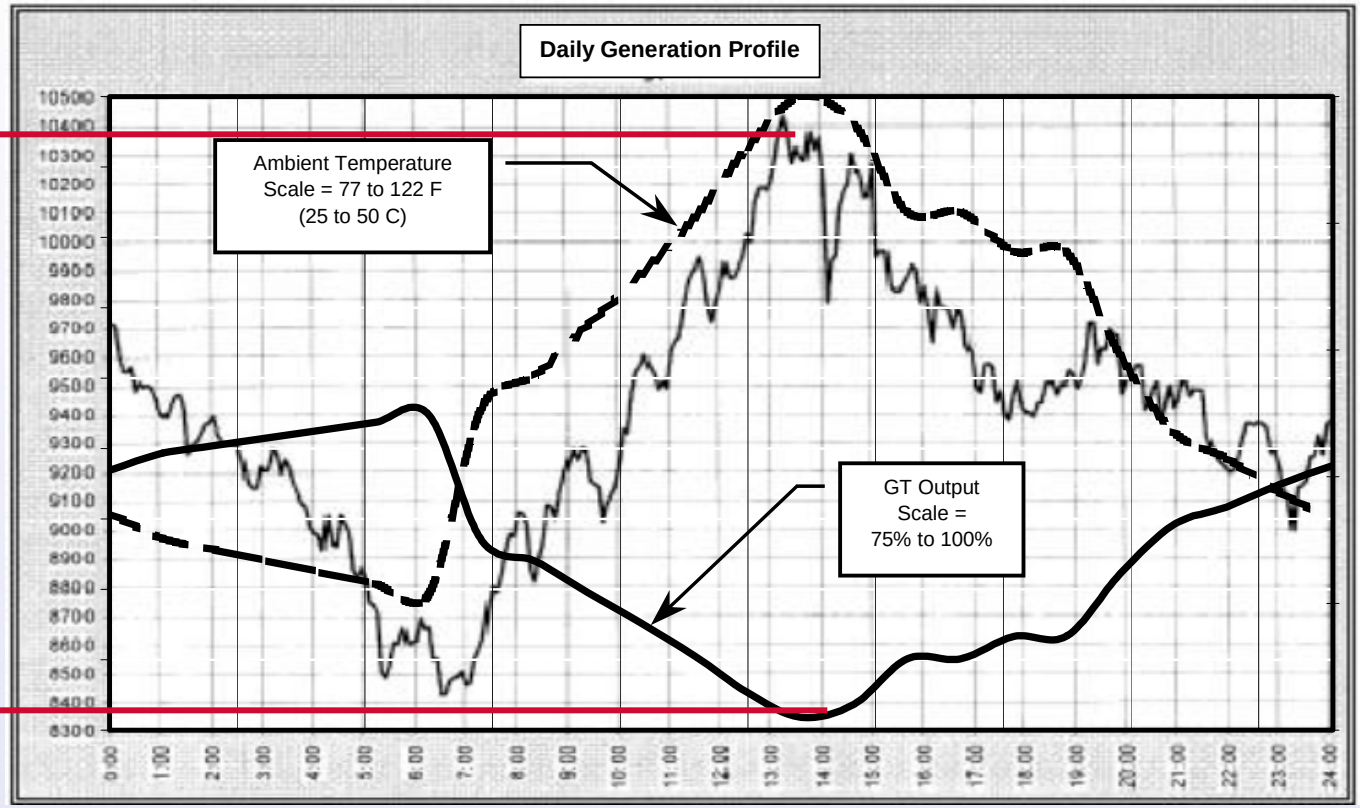
# Just When High Summer Temperatures Lead to High Air-Conditioning Loads and Power Demand, Combustion Turbine Output Decreases

Peak Power Demand

Lowest Generation Capacity

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# Reduced Summer Capacities of Combustion Turbine Power Plants is Well Recognized by the Energy Organizations

| Fuel | Winter Capacity, MW | Summer Capacity, MW | Lost Summer Capacity, % of Winter Capacity |
|---|---|---|---|
| Coal | 315,556 | 313,380 | 1 |
| Petroleum | 61,171 | 58,548 | 9 |
| Natural Gas | 412,241 | 383,061 | 9 |

Source: U.S. Department of Energy's Energy Information Agency 2005 Database

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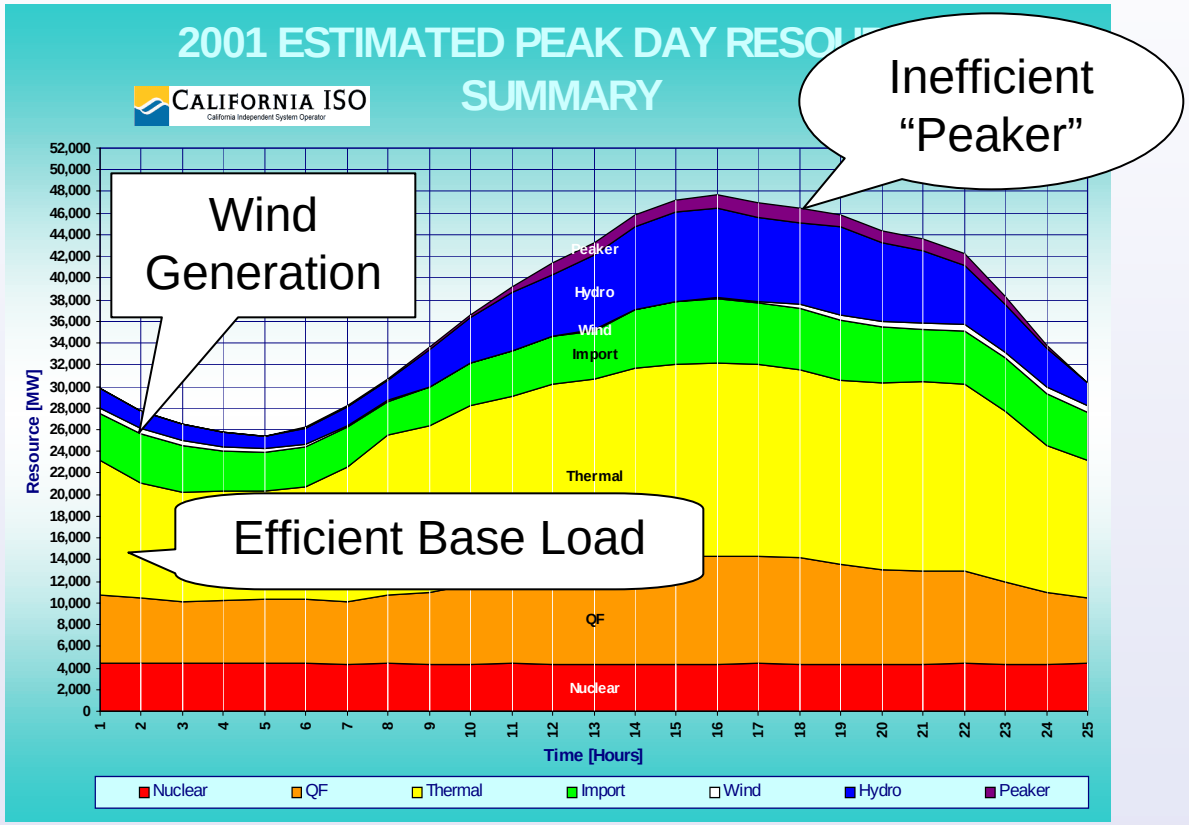
# During Peak Power Demand Period Even Inefficient “Peakers” also Have to be Operated to Meet the Power Demand




Source: Scot Duncan Presentation at ASHRAE June 2007

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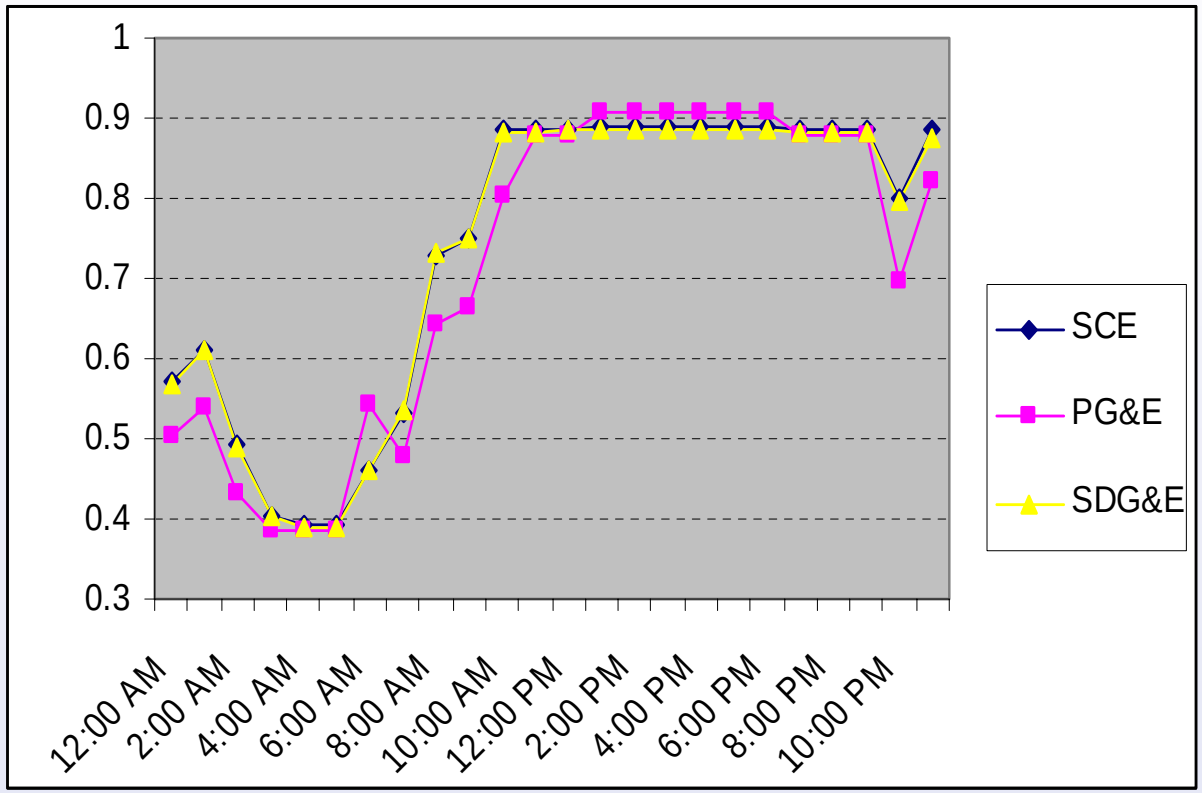
# On a Typical Summer Day in California, Operation of Inefficient Power Plants During Peak Period Doubles the Carbon Dioxide Emissions (lbs/kWh) Compared to Those During Off-Peak Period




Y-Axis Unit: $CO_2$ Emissions, Lbs/kWh

Source: Scot Duncan Presentation at ASHRAE June 2007

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# Carbon Dioxide (GHG) Emissions of Fossil Fuel Power Plants

- Power plants that burn fossil fuels (coal, oil, natural gas or synthetic gases) are significant producers of carbon dioxide and other emissions
- There are two types of fossil fuel power plants:

  1. Burn fuel to produce steam and use steam in steam turbines to produce electric power

  2. Burn oil or gas directly in combustion turbines (CTs) to produce power
- Power plants that burn coal produce the most emissions (lbs/MWh)
- Power plants that use natural gas in CTs produce the least emissions (lbs/MWh)

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# Natural Gas-Fired CTs in Combined-Cycle Systems have the Lowest Heat Rates and Least Emissions

| System | Combined-Cycle CT | Simple-Cycle CT | Steam Turbine |
|---|---|---|---|
| **Heat Rate (LHV) Range, Btu/kWh** | 6,500 – 7,000 | 8,000 – 10,000 | 12,000 – 15,000 |
| **Fuel** | Natural Gas | Natural Gas | No. 6 Fuel Oil |
| **$CO_2$ Emissions, lbs/MWh** | 814 | 1,250 | 2,236 |
| **$NO_x$ Emissions, lbs/MWh** | 0.08 | 0.36 | 3.9 |
| **$SO_x$ Emissions, lbs/MWh** | 0 | 0 | 13.25 |

Source: Pasteris Energy, Inc.

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# Power Plant Operation Priority for Reducing Emissions

**The preferred order of operating fossil power plants using natural gas should be:**

1. **CT in combined-cycle system (Lowest Heat Rate i.e. Highest Energy Efficiency)**
2. **CT in simple-cycle system**
3. **Steam turbine system (Highest Heat Rate i.e. Lowest Energy Efficiency)**

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# Two Unfortunate and Unfavorable Characteristics of Combustion Turbine Power Plants

- **During hot weather, just when power demand peaks,**
  1. Power output decreases significantly
     - *Up to 35% below rated capacity*
     - *Depends on the CT characteristics*
  2. Fuel consumption (heat rate) and emissions increase per kWh

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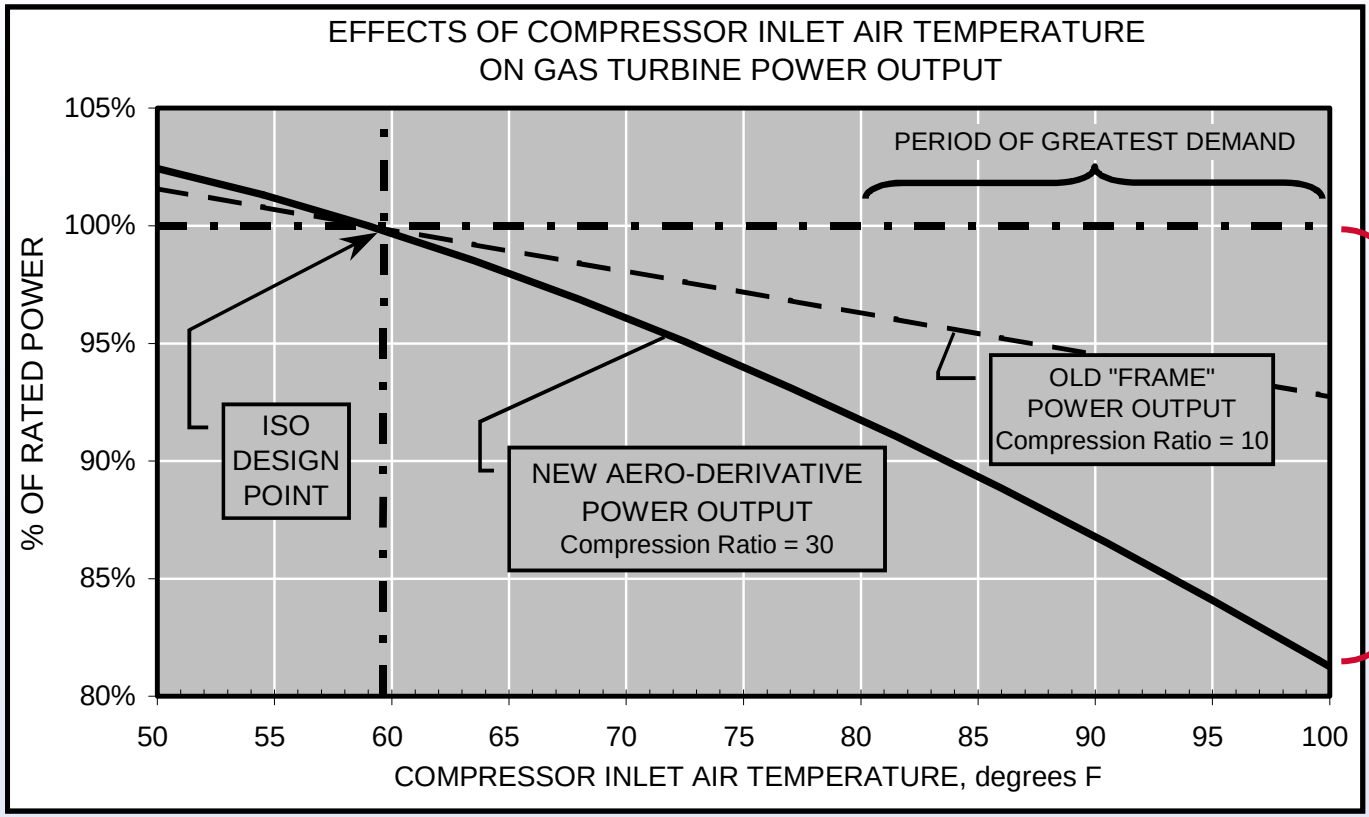
# CT Power Plants' Generation Capacity Decreases with Increase in Ambient Temperature and Depends on the CT Design




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

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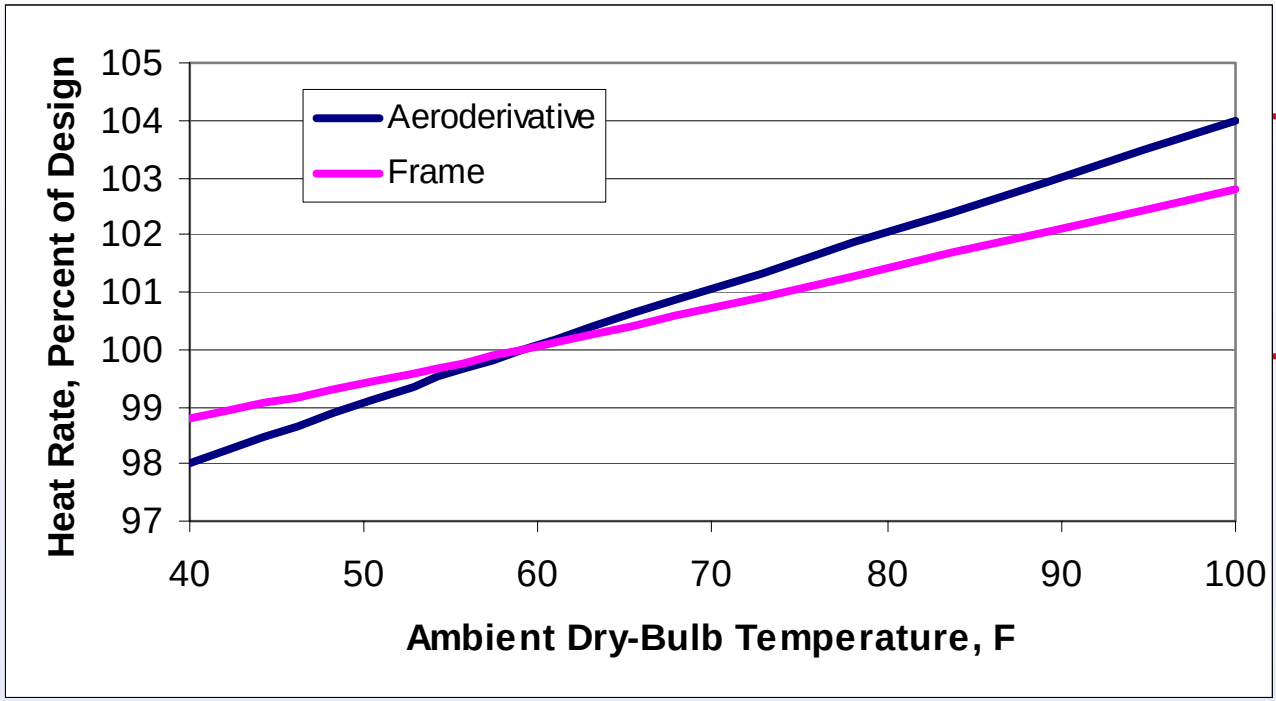
# CT Power Plants Energy Efficiency Decreases (i.e. Heat Rate Increases) with Increase in Ambient Temperature




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

Note: Heat rate is directly proportional to fuel consumption per kWh and inversely proportional to energy efficiency

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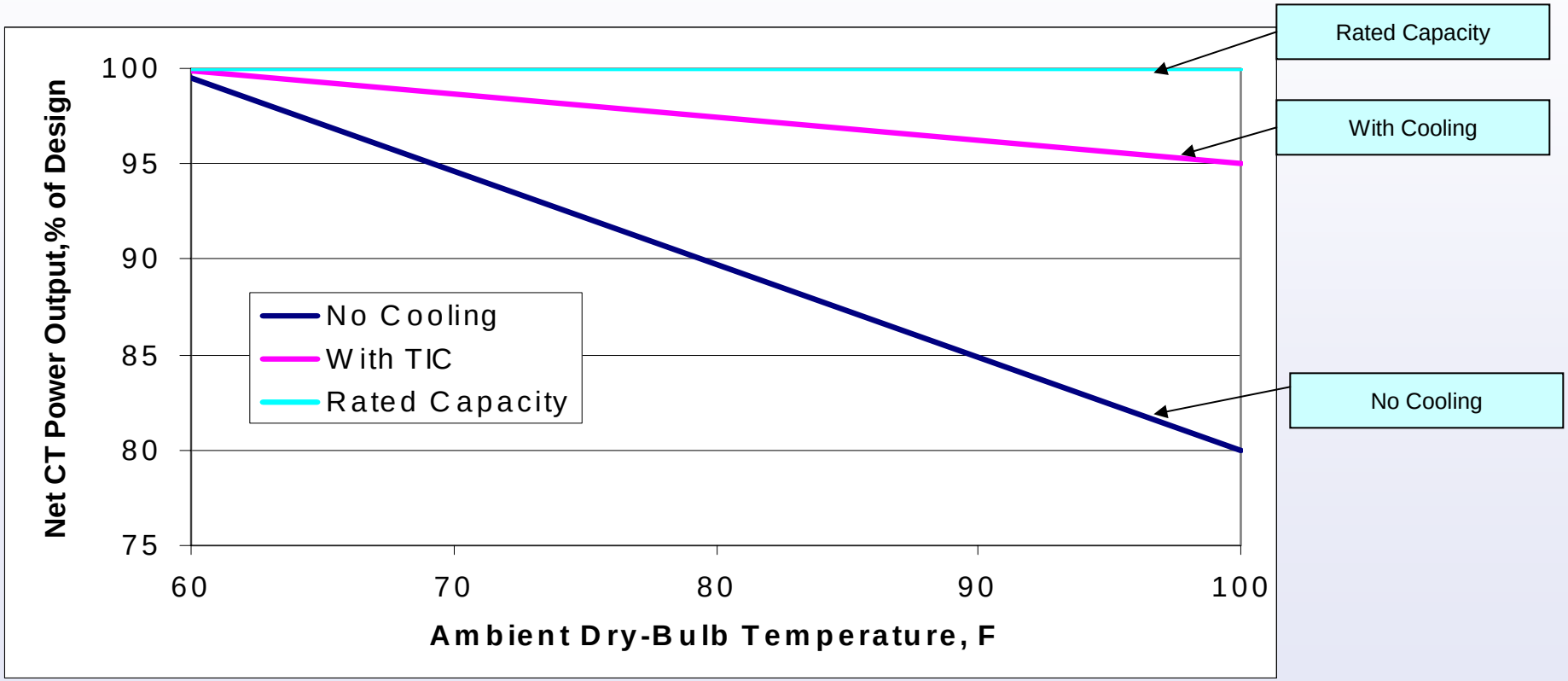
# Turbine Inlet Cooling (TIC) Overcomes the Effect of Hot Weather on the CT Capacity De-rating

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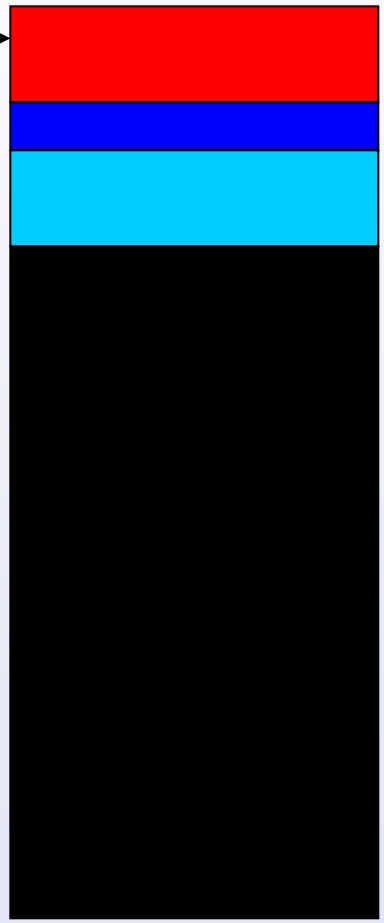
# Preferred Dispatch Order for a Typical Combined-Cycle System with TIC



73,394 kW
@ 8,440 Btu / kWh
Supplementary
Duct Firing

16,874 kW
@ 7,894 Btu / kWh
Cooling to 50°F

36,865kW
@ 6,799 Btu / kWh
Cooling to Dew Point

452,183 KW
@ 6,371 Btu / kWh
Base Case

Dispatch Order at 95°F

Basis: GTPro model at 95F DB/78F WB with inlet chilled 207FA.
Source: TAS

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

- **Implementing TIC on combustion turbines in combined-cycle (CC) systems effectively displaces/reduces operations of combustion turbines in simple-cycle (SC) systems**
- **TIC for each nominal 500 MW CC plant eliminates the need for a nominal 40-50 MW SC peaker and its associated siting, emissions, interconnection and other issues**

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# Turbine Inlet Cooling Provides Environmental Benefits

- **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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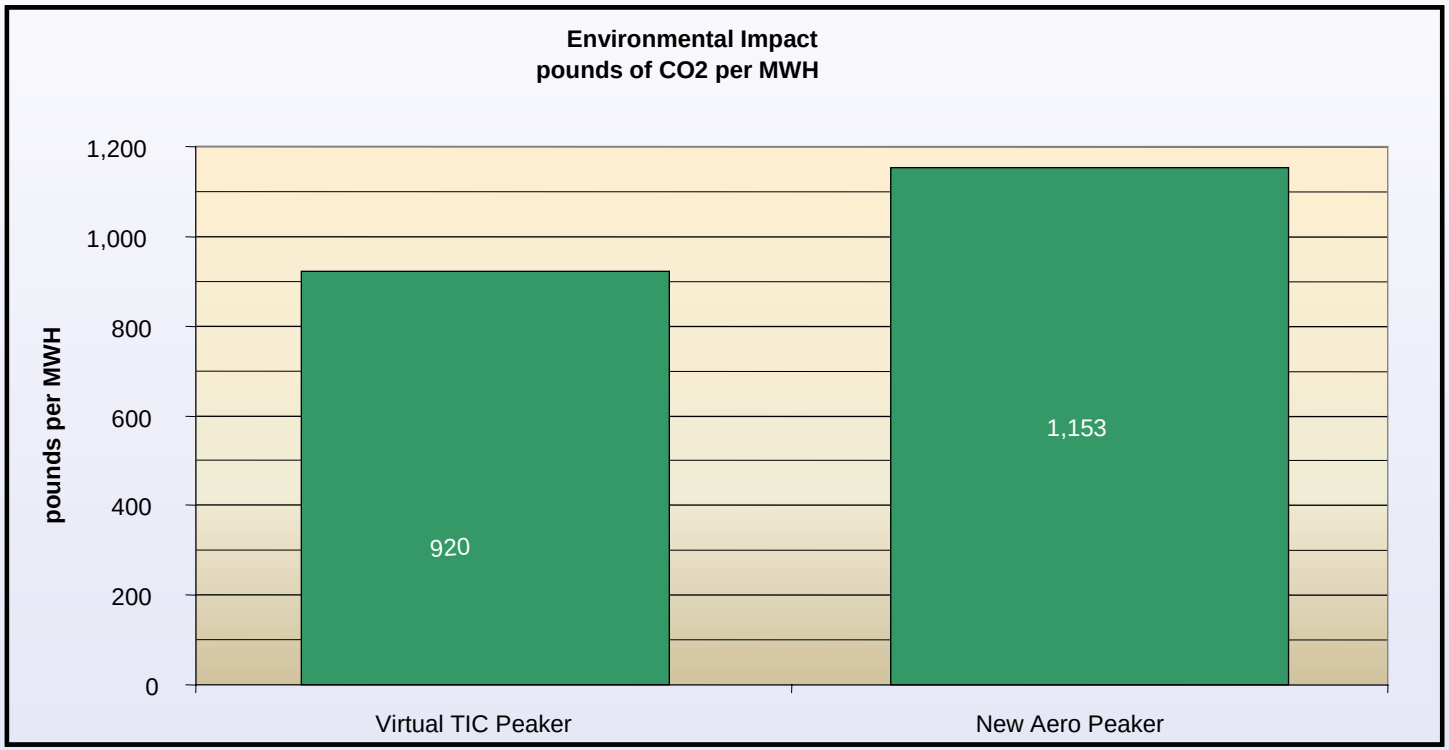
# Turbine Inlet Cooling (TIC) Reduces $CO_2$ Emissions




Basis: LM6000PC-Sprint with hot SCR & TIC vs. incremental MWH from combined cycle 207FA with TIC added

Source: TAS

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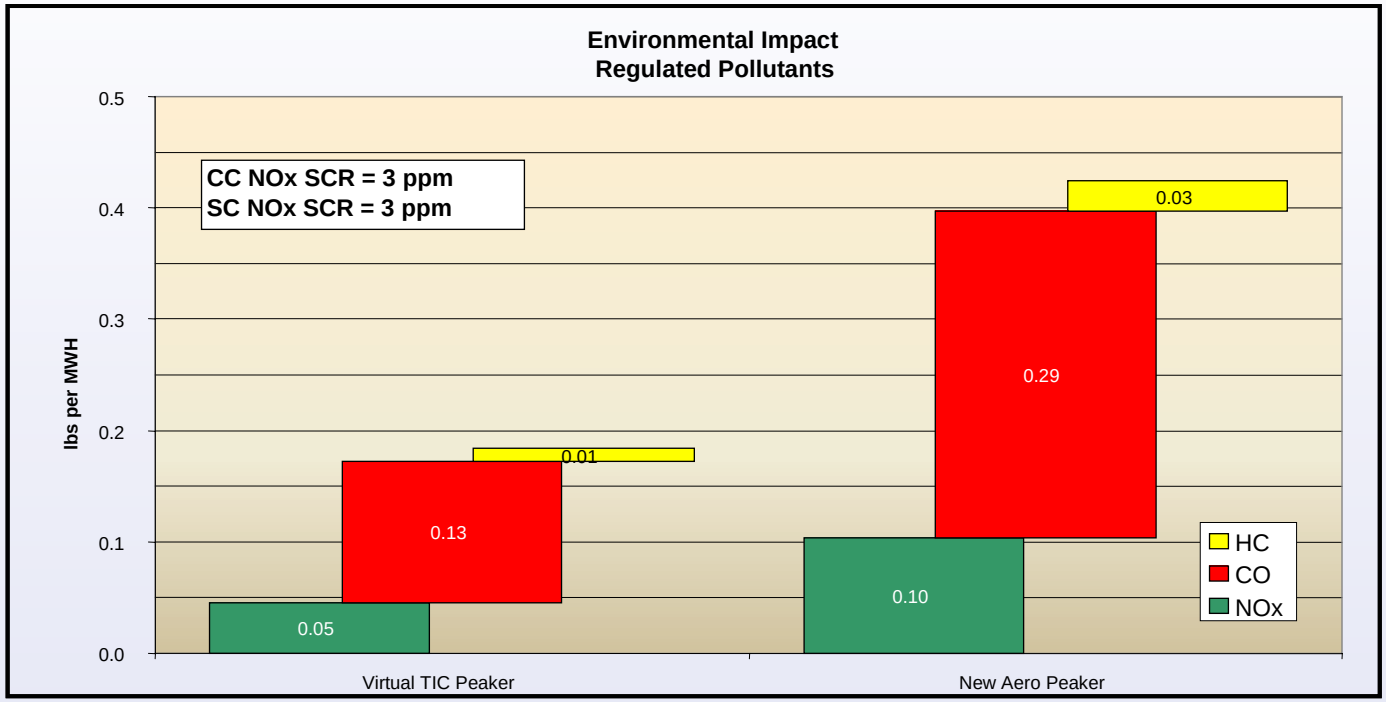
# Turbine Inlet Cooling (TIC) Reduces Emissions of Regulated Pollutants




**TIC Reduces Total Emissions (lbs/MWh) by Over 50%**

Basis: Total of all pollutants (lbs/MWh), LM6000PC-Sprint with hot SCR & TIC vs. incremental MWH from combined cycle 207FA with TIC added (Source: TAS)

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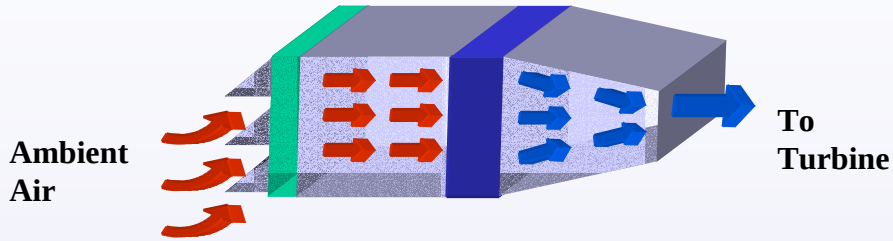
# Turbine Inlet Cooling (TIC) Technologies are Simple and Proven




- **TIC is simple**
  - Cool the ambient air before it enters the turbine
  - Just as we cool the air entering buildings
- **TIC technologies are proven**
  - Thousands of plants already benefit from TIC
  - TICA Web site database of 100+ plants worldwide

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# Many Turbine Inlet Cooling System Options are Available

- Evaporative Systems: Wetted Media or Fogging
- Chiller Systems: Mechanical  or Absorption Chillers
- Chillers with Thermal Energy Storage
- LNG Vaporization System
- Wet Compression System

* Application Limited to only where Liquefied Natural Gas (LNG) is Available

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# Factors Affecting the Capacity Enhancement Potential of TIC

- TIC Technology  Selected
- CT Design and Characteristics
- Weather Data (dry-bulb and coincident wet-bulb temperatures) for the Geographic Location of the CT
- Selected ambient design conditions
- Selected (if allowed by the TIC technology) cooled air temperature
- TIC Parasitic Load
- Pressure drop across the component inserted upstream of the compressor (insertion loss)

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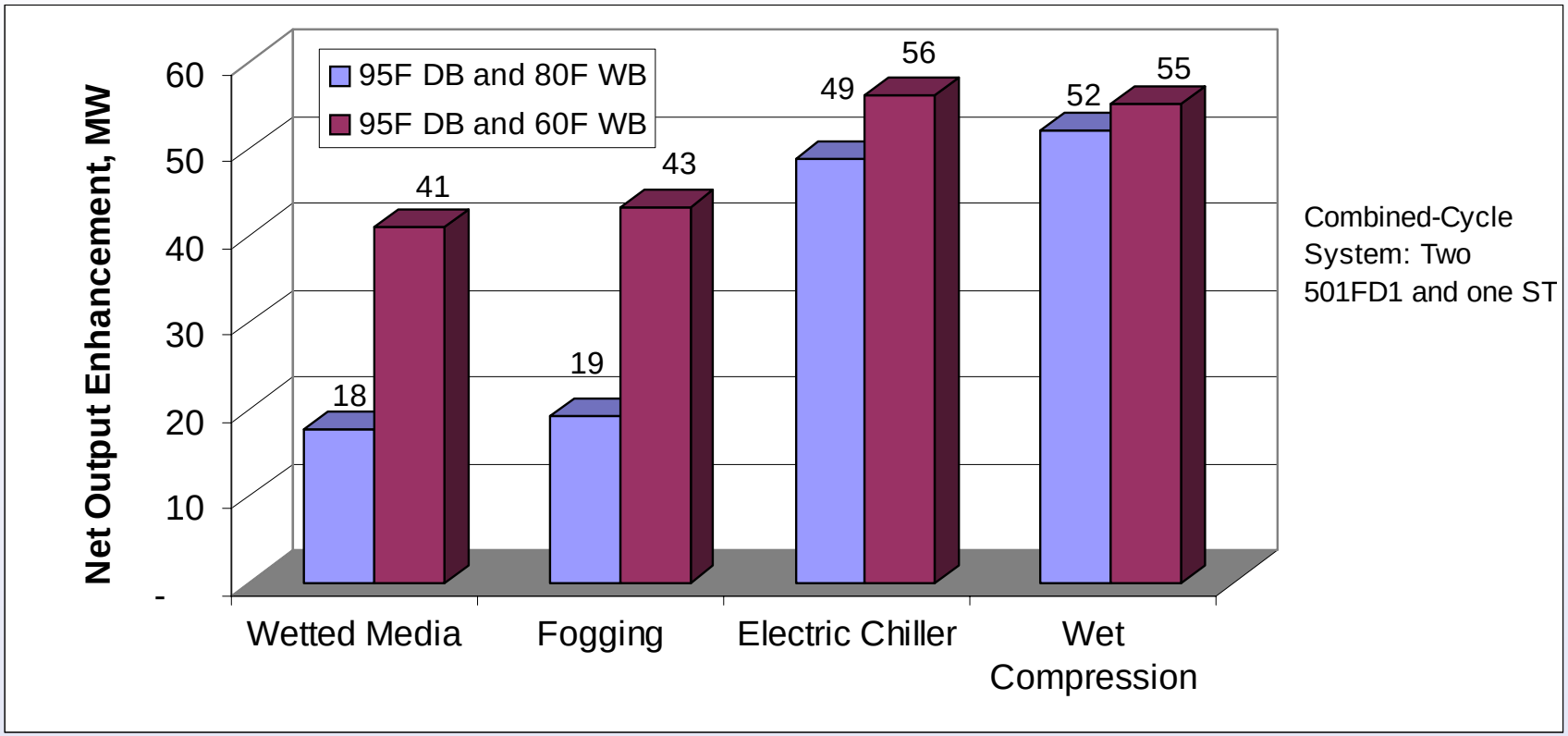
# Examples of the Effect of TIC Technology and Ambient Temperature on Capacity Enhancement




Sources:

Wet Compression: Caldwell Energy, Inc.

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

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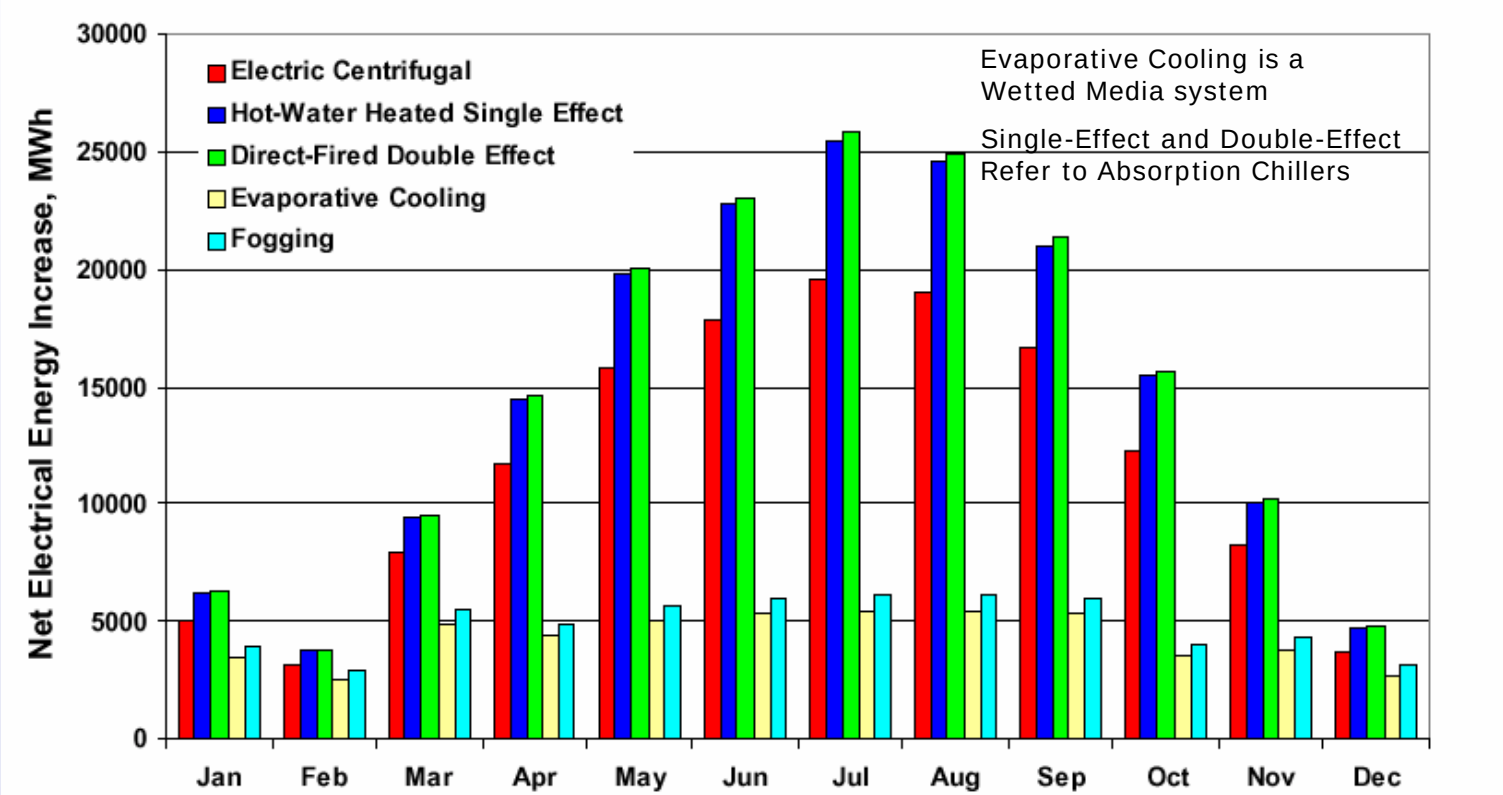
# An Example of the Monthly Incremental Electric Energy Provided by Some of the TIC Technologies
## (316 MW Cogeneration Plant Near Houston, TX)




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

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# Factors Affecting the Economics of TIC Technology

- Market Value of Increased Electric Energy Produced or the Avoided Cost of Buying the Same Energy from the Market
- Market Power Demand Profile for Selling Electric Power or Power Demand Profile for the Power User
- Market Value of Increased Plant Capacity
- Cost of Fuel
- Cost of Water

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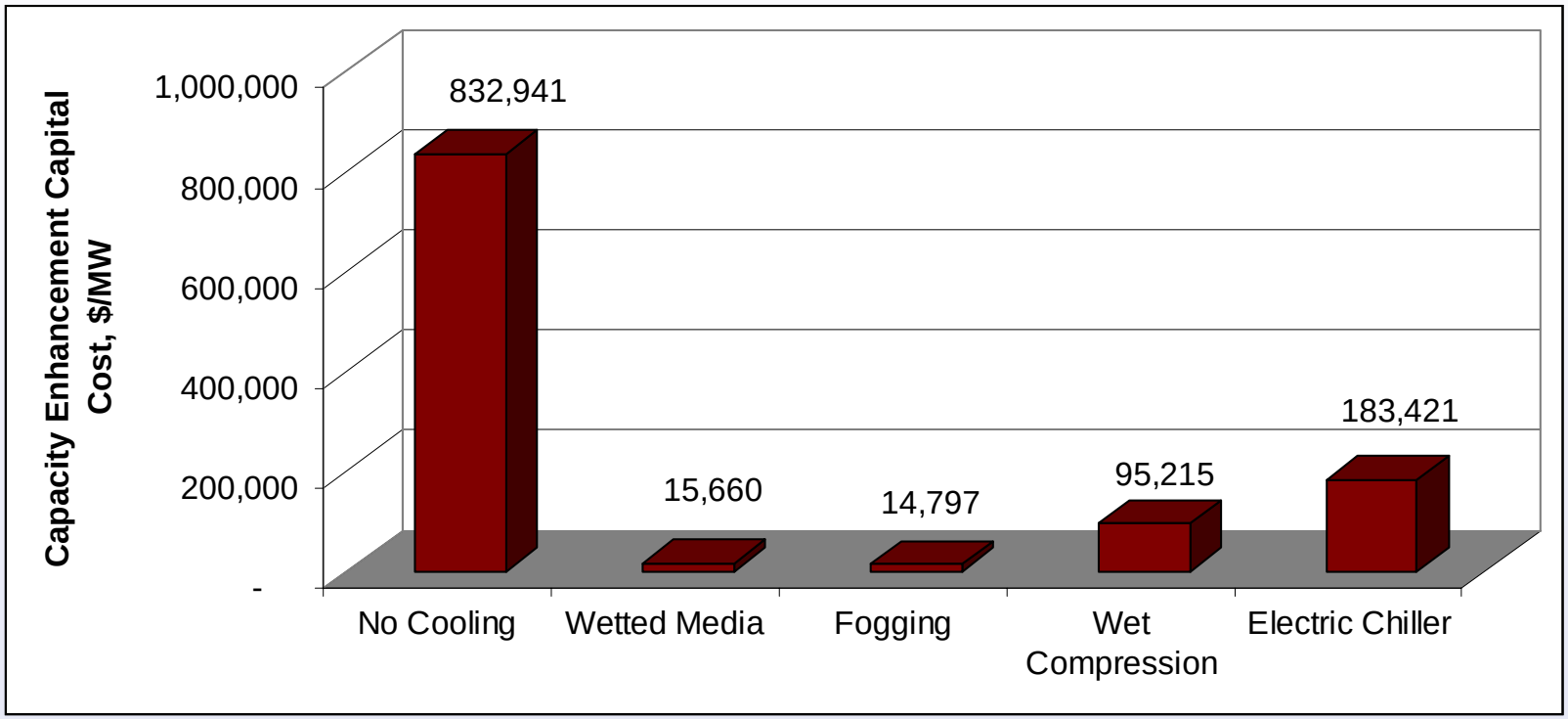
# Example of TIC Providing Capacity Enhancement at Lower Capital Costs
## (316 MW Cogeneration Plant Near Houston, TX)




Sources

Wet Compression: Caldwell Energy

Other: www.turbineinletcooling.org

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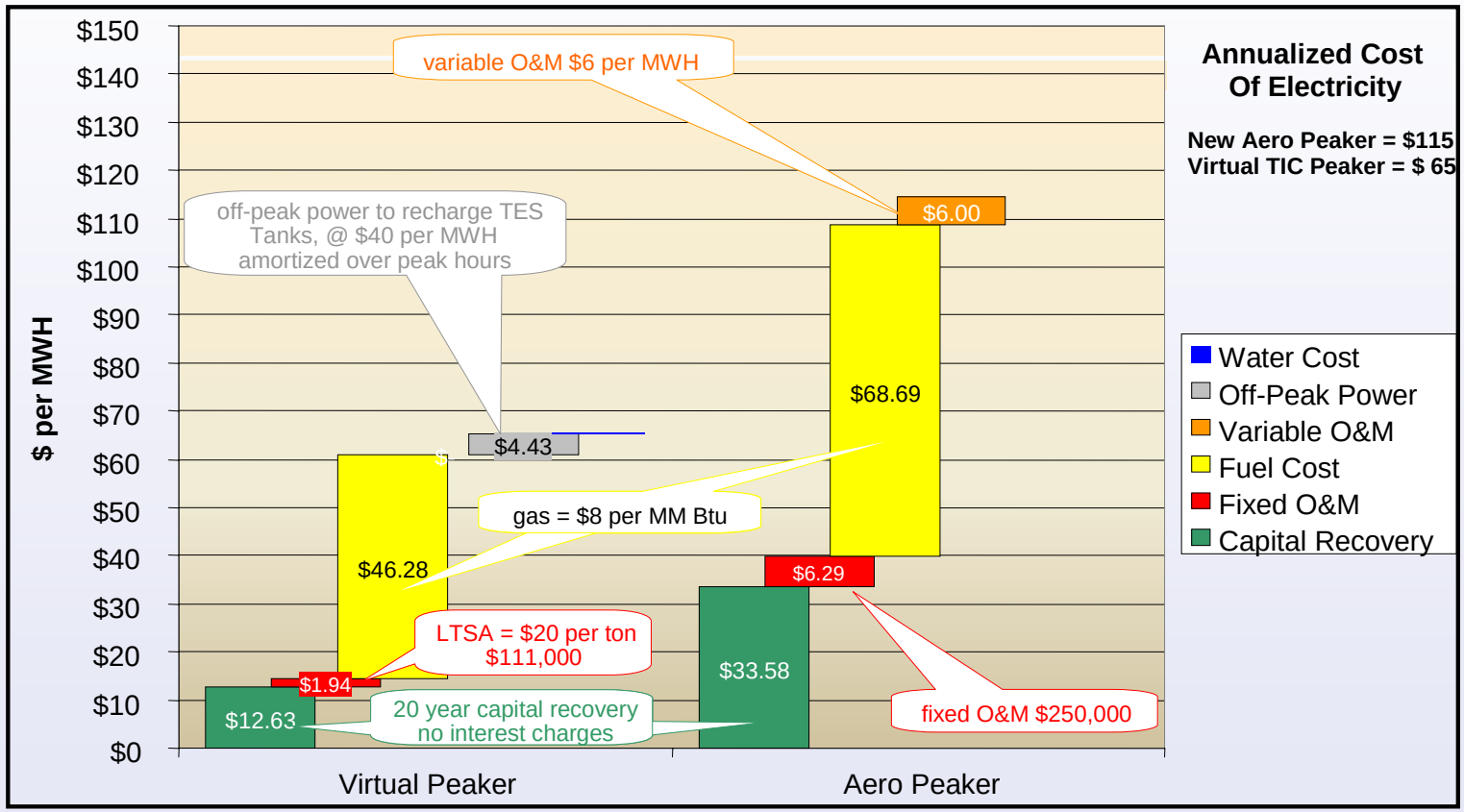
# TIC Provides Additional Electric Energy at Lower Operating Costs




Basis: LM6000PC-Sprint with hot SCR & TIC vs. incremental MWH from combined cycle 207FA with TIC added. (Source: TAS)

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# Turbine Inlet Cooling Provides Not Only Environmental but also Economic Benefits

- Generates more MWh and revenue during peak demand periods when electric energy value and price are highest
- Reduces capital cost per unit of the increased generation capacity compared to new power plants
- Reduces cost of electric energy generation compared to the low energy efficiency “peakers”
- Reduces cost for ratepayers by allowing lower capacity payments by the independent system operators (ISOs) to power producers

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# Suggested Changes To Regulatory Structure

- **Utilize full potential of existing combustion turbines plants**
  - Require addition of TIC before allowing new plants to be built
- **Exempt TIC from environmental re-permitting**
  - Use of TIC helps displace/eliminate operation of higher emission power plants
- **Calculate capacity payments for plant owners on the basis of systems incorporating TIC**
  - Consistent with the PJM affidavit made to the FERC in August 2005

Notes:

PJM: PJM Interconnection, LLC

FERC: Federal Energy Regulatory Commission

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# Conclusions

- Turbine inlet cooling can provide significant increased generation capacity during hot weather from energy efficient combined-cycle (CC) and simple-cycle (SC) power plants
- More MWh from CC and SC plants minimizes/eliminates operation of higher-emission producing thermal power plants/steam-turbine systems
- Turbine inlet cooling (TIC) of CC and SC power plants also reduces the cost of generation compared to combustion turbine without TIC and thermal power plants
- In summary, TIC is an energy solution that is good for the environment, for ratepayers, and for plant owners

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# TICA Announcement

**Annual Meeting of TICA Members**

- **Today (December 2; Tuesday) 4-6 PM**
- **Room S310F in the Orange County Convention Center**
- **Guests are Welcome to Attend**

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