Maximize Decarbonization of the Electric Grid
by Turbine Inlet Cooling of District Energy Systems

Dharam V. Punwani, Executive Director

and

John S. Andrepont, Director

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TURBINE INLET COOLING ASSOCIATION turbineinletcooling.org

INTERNATIONAL DISTRICT ENERGY ASSOCIATION

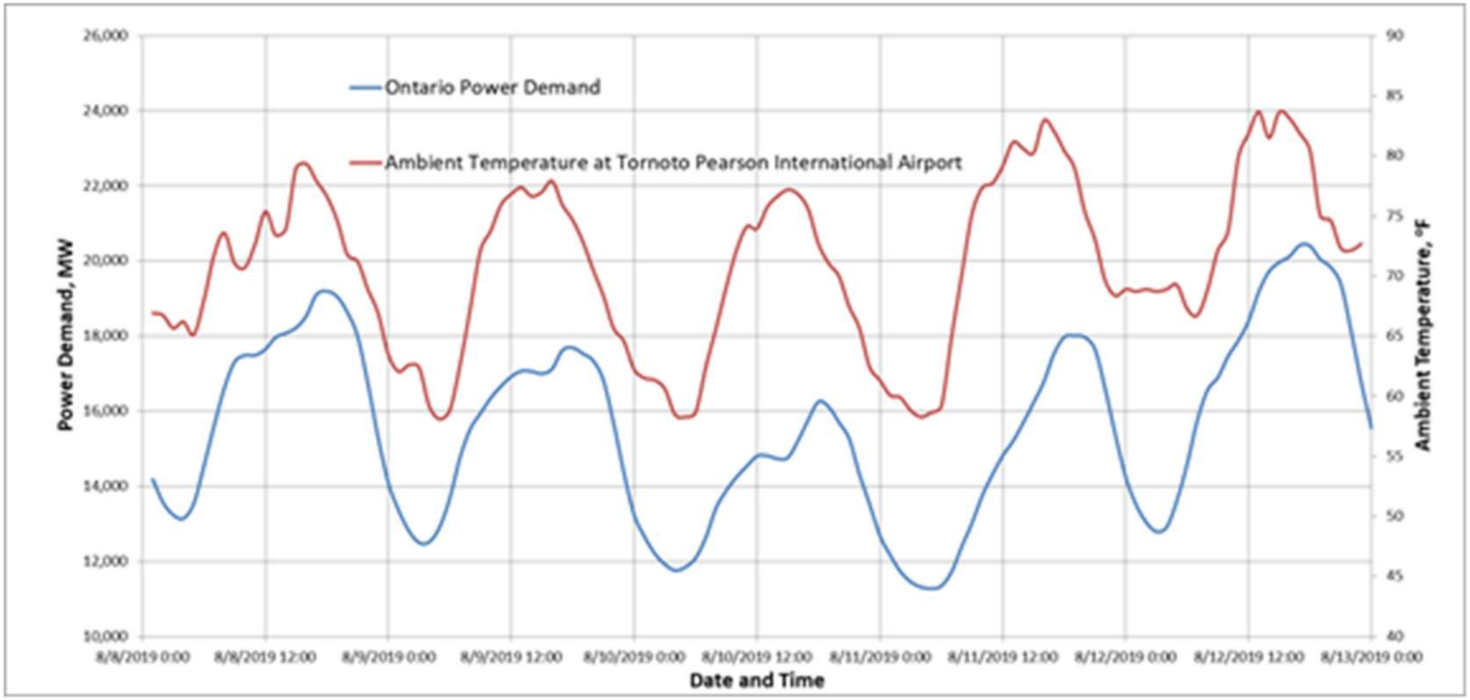
PROBLEM:

Hot Weather Reduces Electric Grid Decarbonization Potential of DE Systems Using Combustion Turbines (CTs)

Presentation Outline

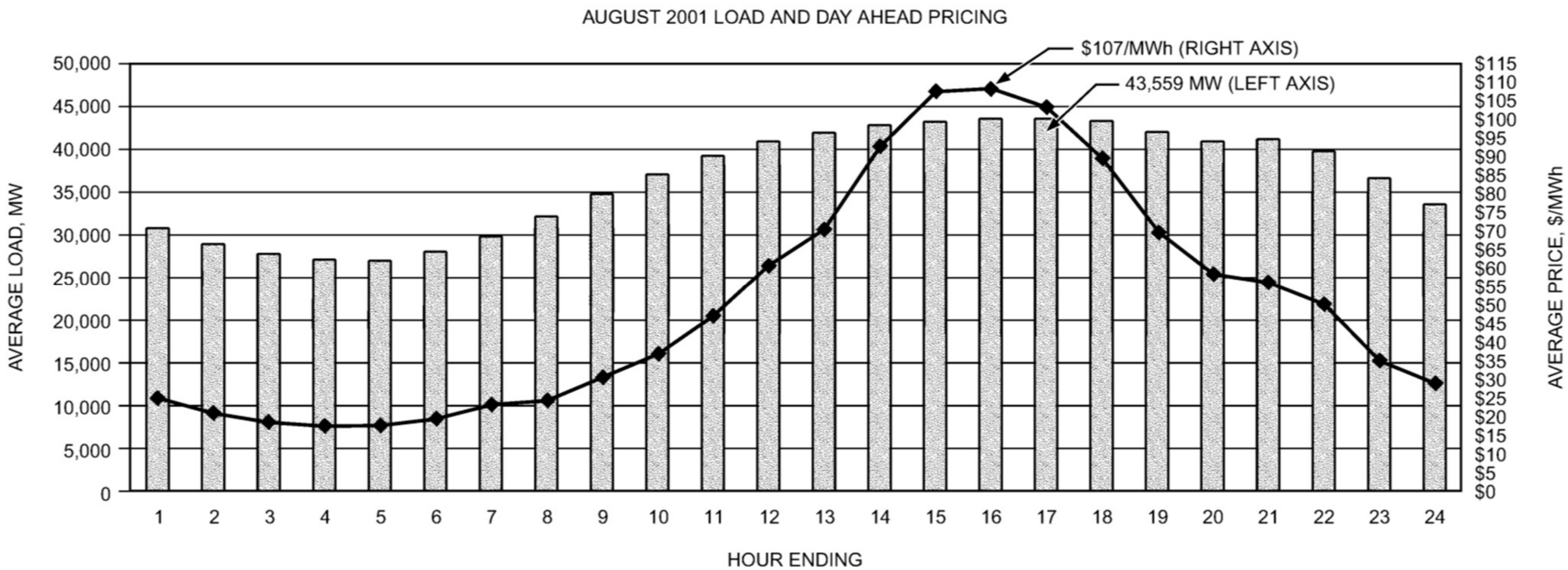
- Hot weather impacts on electricity demand, carbon emissions and price
- Why DE systems are pathways for decarbonizing electric grid
- Why use CTs?
- Why hot weather creates problems for CTs?
- Five impacts of hot weather on DE systems
- How to overcome the impacts of hot weather?
- What is turbine inlet cooling (TIC) and its pros and cons?
- What are the TIC technology options and their selection
- Four (4) success examples of DE systems using TIC
- Conclusions & Recommendations

Hot Weather Increases Demand for Electric Power



Example of Hourly Ambient Temperature and System Load Profiles in Ontario, Canada
(Punwani, D., et al, "ASHRAE Design Guide for Combustion Turbine Inlet Cooling, 2022")

Hot Weather Increases the Market Price of Electric Energy



Example of Hourly Ambient Temperature and Price of Electric Energy

(Punwani, D., et al, “ASHRAE Design Guide for Combustion Turbine Inlet Cooling, 2022”)

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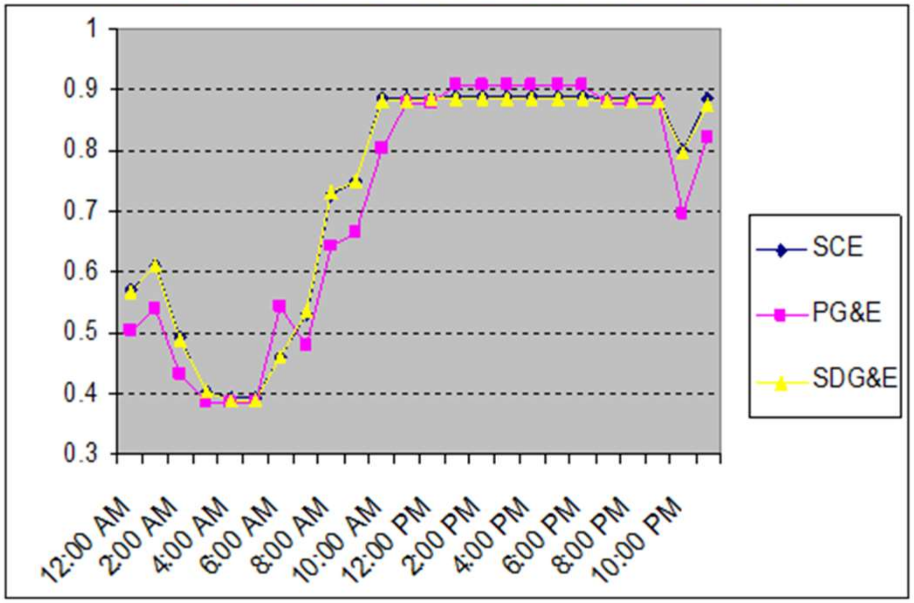
Hot Weather Leads to Increased CO_2 Emissions from the Electric Grid



Notes:

- *Y-Axis Scale Shows lb. of CO_2/kWh*
- *PG&E (Pacific Gas & Electric); SCE (Southern California Edison); SDG&E (Diego Gas & Electric)*

Emissions increase during high power demand period because less efficient systems are brought online to meet the demand.

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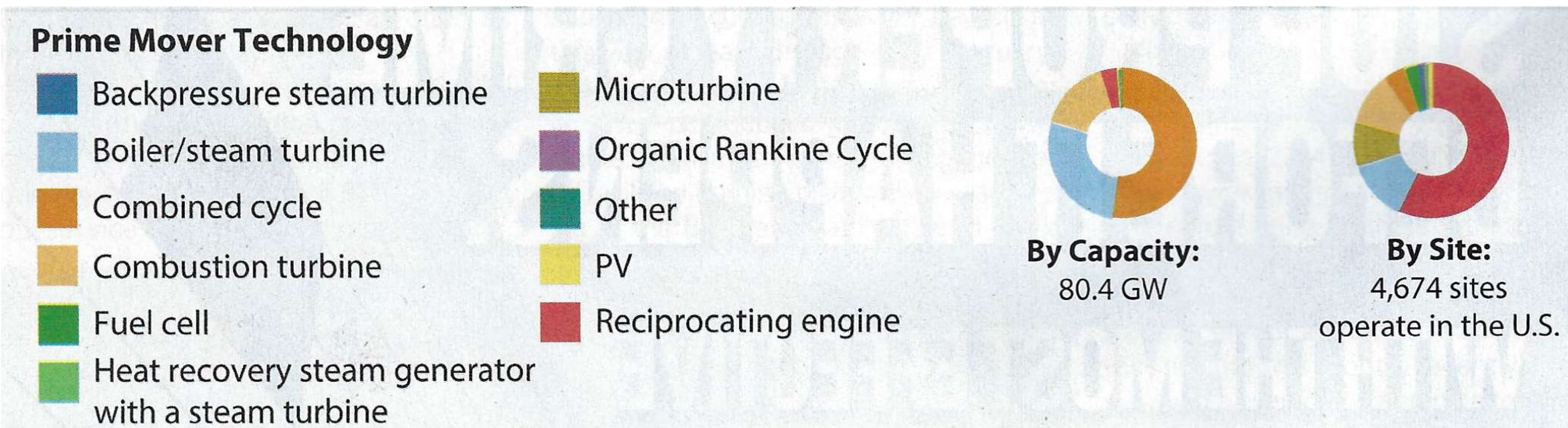
Why DE Systems are Pathways for Decarbonizing Electric Grids?

- An electric grid is supported by a number of electric power generation technologies of varying efficiencies and carbon-emission sources
- Electric power drawn from a grid suffers transmission and distribution losses
- DE systems reduce load on the grid equivalent to its own generation capacity
- Reduced DE system load on the grid leads to lower grid-wide carbon emissions by not requiring the grid to turn on low-efficiency and high-carbon emission systems

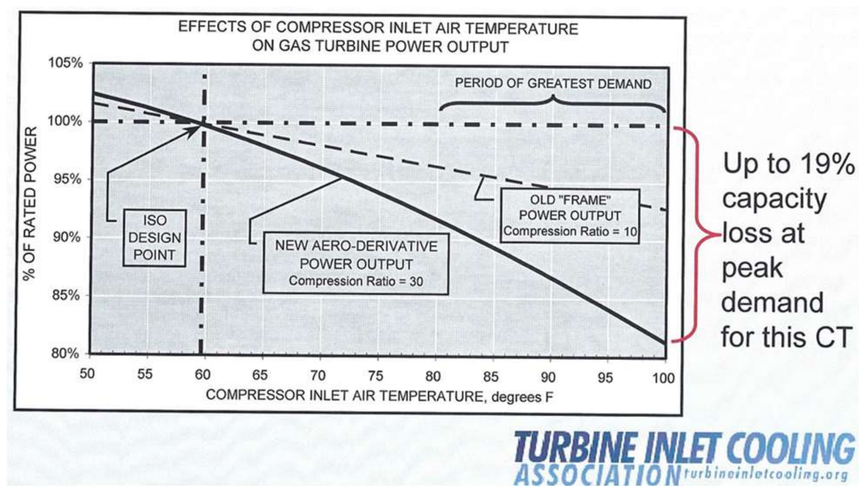
Role of CTs in Electric Power and Thermal Energy Generation

- CTs produce over two-thirds of the U.S. electric energy needs
- CTs are the prime movers of choice for large capacity DE systems
- CTs are also the prime movers of choice for a facility's thermal energy needs for high-temperature and/or high-pressure steam
- DE systems that operate in combined heat & power (CHP) mode are the most efficient for simultaneous production of heat and power
- According to the U.S. DOE database, CTs account for the maximum installed capacity as shown:



Hot Weather Decreases CT Output Capacity

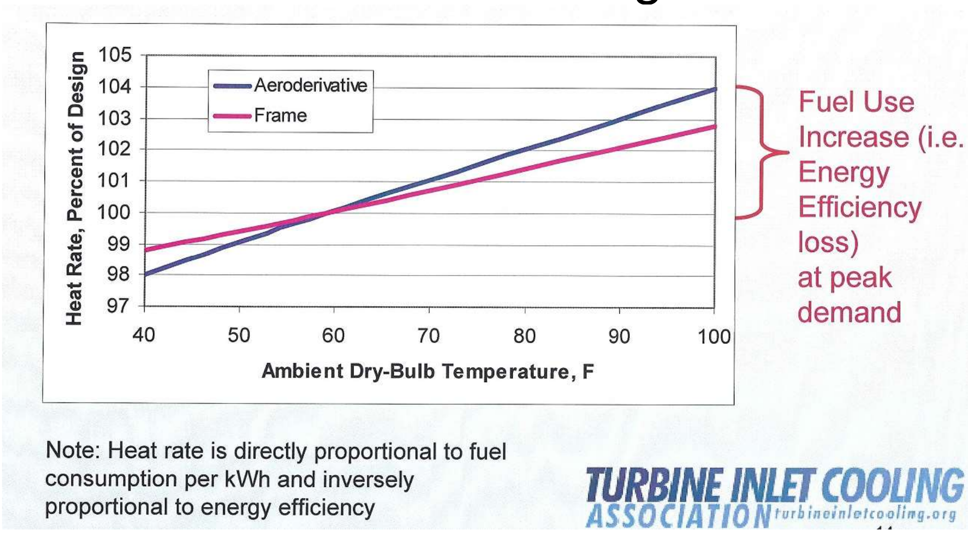
- High ambient temperatures decrease CT output capacity below its rated capacity at 59 ^{o}F.
- Quantitative impact of ambient temperature varies with CT design as shown:



  - Aeroderivative CTs are more sensitive to the ambient temperature.
  - Smaller capacity CTs are also more sensitive to the ambient temperature.

Hot Weather Also Reduces the Energy Efficiency of All CTs

- Energy efficiency decreases (heat rate increases) with increase in ambient temperature
- Quantitative impact varies with the CT Design:

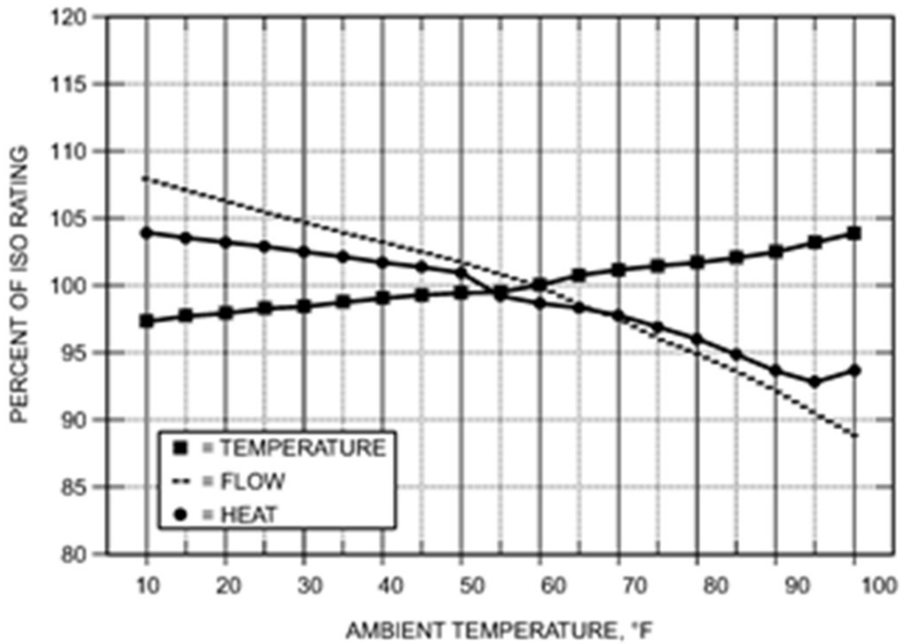


- Aeroderivative CTs are typically more efficient than the industrial ("Frame") CTs.
- But they are more sensitive to ambient temperature.

Hot Weather also Decreases Availability of Useful Thermal Energy from CHP

Effects of hot weather on CT exhaust gases:

- Temperature increases; but mass flow rate decreases significantly.
- Available overall thermal energy decreases. An example:

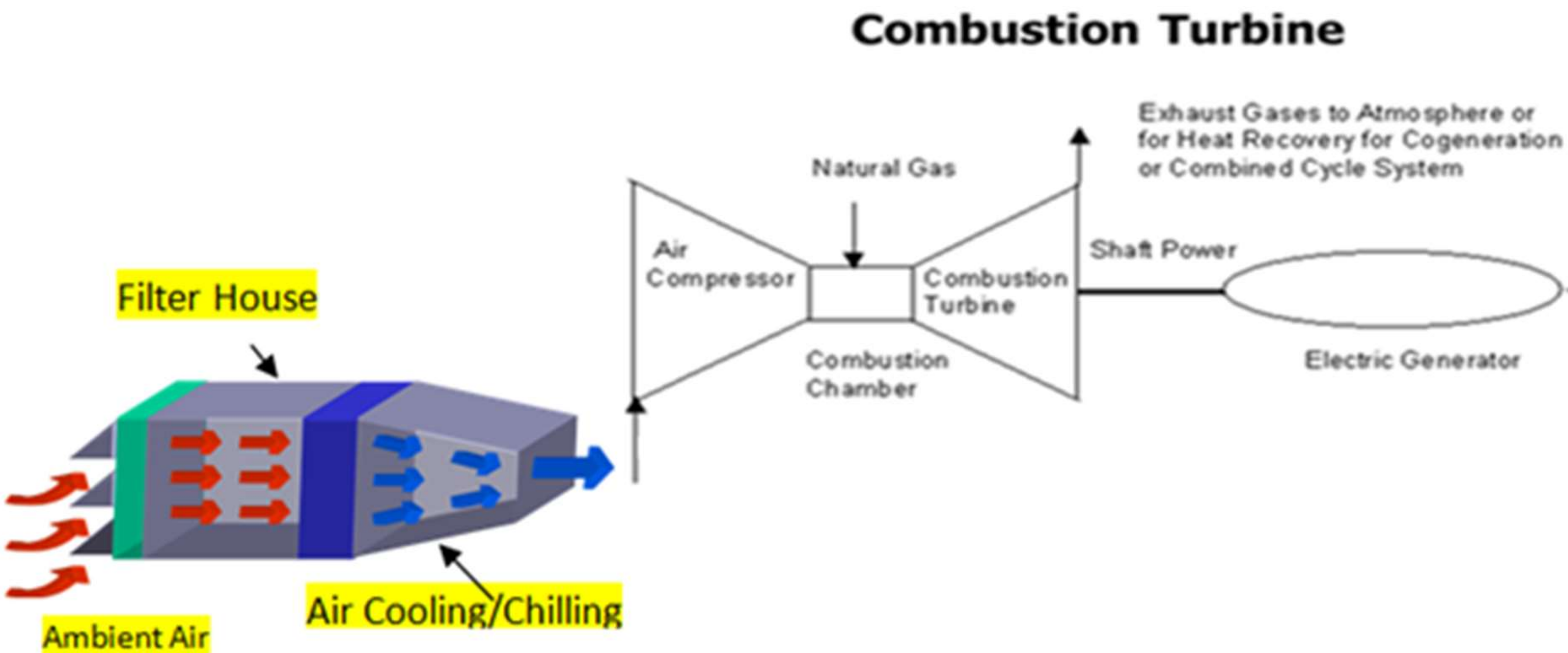


Five Adverse Impacts of Hot Weather on DE Systems using CTs

1. **Decreases power output capacity**
   - Increases the need of buying electric power from the grid
2. **Decreases electricity generation efficiency**
   - Increases the need to burn more fuel per unit of electric energy
3. **Decreases availability of useful thermal energy**
   - Increases the need to burn more fuel for meeting thermal needs
4. **Increases the annual cost of electric and thermal energy needs**
5. **Decreases potential for decarbonizing the electric grid**

Turbine Inlet Cooling (TIC)

- Cooling the inlet air to the compressor of the CT system



Turbine Inlet Cooling Technology Experience

- TIC is not new.
- It has been successfully used since as early as 1975.
- TIC has been installed on at least 1,165 CTs, 125 CT models, from 21 CT OEMs.*
- Capacities of the CT systems with TIC range from 1 MW to **3,162 MW**

Note:
*Installation database of the Turbine Inlet Cooling Association (TICA).
Actual number of installations is much more than that in that database.

Turbine Inlet Cooling Technologies

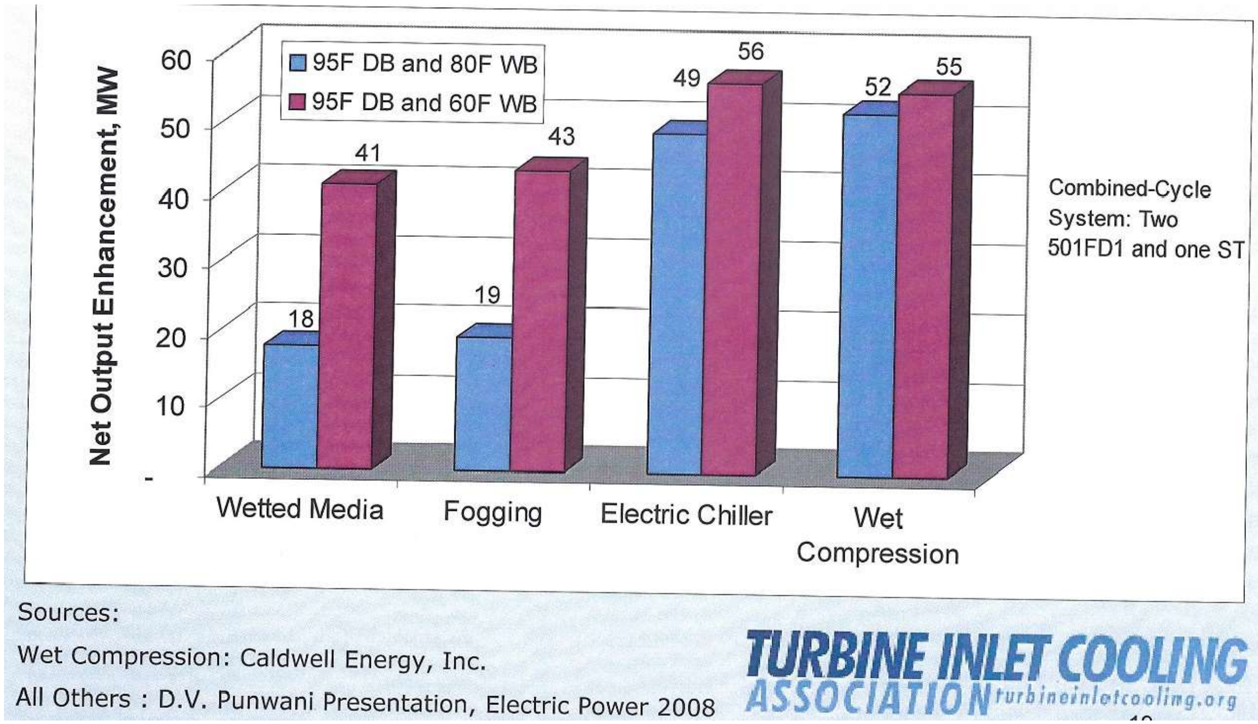
- 1. Adiabatic Wetted-Media Evaporative Cooling
- 2. Non-Adiabatic Wetted-Media Evaporative Cooling
- 3. Fogging for Evaporative Cooling
- 4. Indirect Evaporative Cooling
- 5. Wet Compression (Fog Overspray)
- 6. Indirect-Heat Exchange with Chilled Water
- 7. Thermal Energy Storage for Chilled Water Indirect-Heat Exchange
- 8. Indirect Heat Exchange with Refrigerant Evaporation
- 9. Indirect-Heat Exchange with Liquefied Natural Gas
- 10. Hybrid Cooling Systems

Note: The time limitation of this presentation does not allow for a discussion of these technologies. Use the resources coming up next.

Factors Affecting Turbine Inlet Cooling Selection

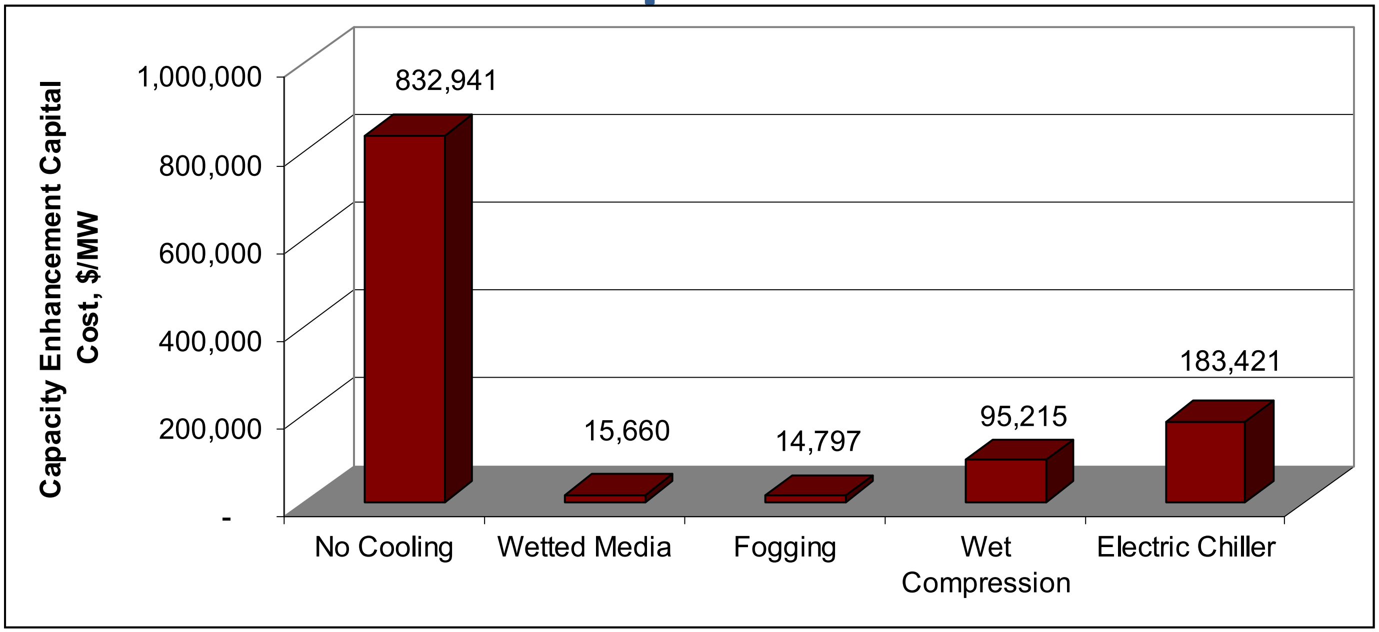
- Each technology has its pros and cons.
- No one technology is best for all power plants
- Factors affecting technology selection include:
  - * Value of the additional electricity and thermal energy produced by TIC
  - * 8,760 hours/year of weather data for the plant location
  - * Plant's annual operating schedule
  - * CT design
  - * Fuel cost
  - * Capital cost limitation
  - * Physical space limitation

Effect of TIC Technology and Humidity on Net Output Power Gain



Wetted media and fogging are more sensitive to humidity:
Less capacity gain at higher humidity.

Effect of TIC Technology on Unitized Capital Cost ($/MW) for Net Output Power Gain



Capacity gain by **all** TIC technologies costs significantly less than that for another uncooled CT.

Note: Each case study's result is only relevant for the SPECIFIC CT evaluated.

TICA Award Winning Success Story Example 1: Princeton University - Princeton, NJ

- One LM1600 gas turbine
- Using TIC since 1996
- TIC uses Low Temp Fluid cooling
- Chilled water system used for TIC and campus District Cooling incorporates Low Temp Fluid TES tank
- Cooling turbine inlet air from 98 °F to 42 °F increases power output 20% or 2.5 MW (from 12.5 to 15.0 MW)

TICA Award Winning Success Story Example 2: University of Texas at Austin - Austin, TX

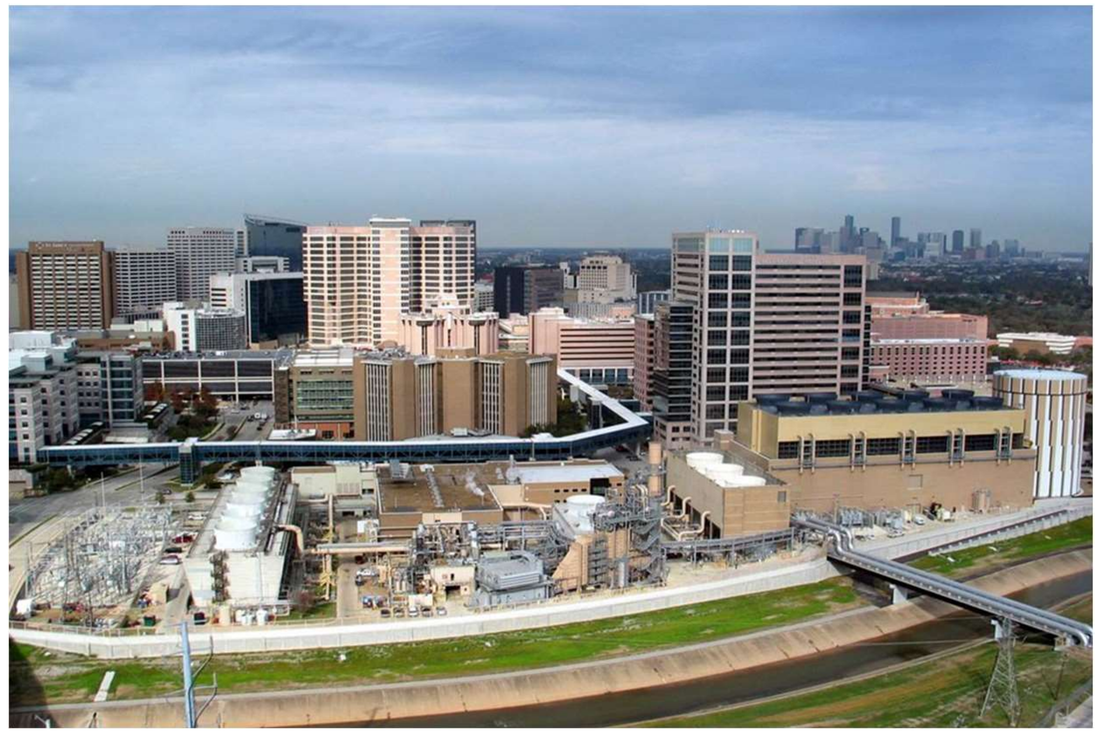
- One LM2500 gas turbine
- Using TIC since 2011
- TIC uses chilled water
- Chilled water system for TIC and campus District Cooling incorporates two CHW TES tanks
- Cooling turbine inlet air from 100 °F to 50 °F increases power output 24.5% or 6 MW (from 24.5 to 30.5 MW)

TICA Award Winning Success Story Example 3: University of Cincinnati - Cincinnati, OH

- Supplies electricity and HP steam to 100+buldings and 6 area hospitals
- Two 12.5 MW Gas Turbines with HRSG
- Using TIC since 2003
- Chilled water system for TIC and campus District Cooling incorporates two CHW TES tanks

TICA Award Winning Success Story Example 4: Thermal Energy Corporation, Houston Medical Center, TX

- Largest District Cooling system in North America
- 46 MW LM6000 CT w/ HRSG
- Using TIC since 2010
- Chilled water system for TIC and District Cooling incorporates an 8.8 Mgal CHW TES tank
- Added another 48 MW LM6000 CT with TIC in 2024



Conclusions & Recommendations

- Turbine Inlet Cooling (TIC) maximizes electric grid decarbonization potential of DE systems by maximizing power output during hot weather.
- TIC has an extensive experience base, including many DE systems.
- Some DE systems have been benefiting from TIC for over 20 years.
- It is common to provide cooling for TIC directly from the District Cooling systems, also often employing Thermal Energy Storage (TES).
- Future CTs may use NG fuel, or be dual-fuel or Hydrogen capable, etc.

More DE systems should consider evaluation and implementation of TIC.

Questions / Discussion ?

Dharam (Don) Punwani

- Email: exedir@turbineinletcooling.org
- Phone: 630-357-3960
- Website: https://www.turbineinletcooling.org
- LinkedIn: https://www.linkedin.com/company/turbine-inlet-cooling-association

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