Actual Energy Efficiency of Building Scale Cooling Systems

Robert Thornton, International District Energy Association
Robert Miller, FVB Energy Inc.
Anis Robinson, BRE Environment
Ken Gillespie, Pacific Gas & Electric

Introduction

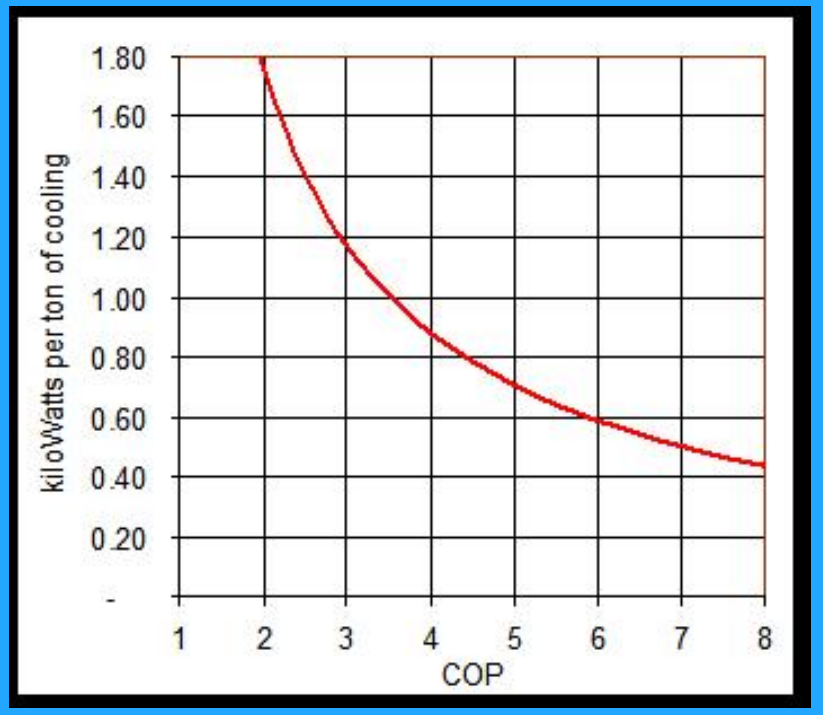
- Assumed efficiency of building-scale chillers affects marketing success of district cooling
- Often use theoretical values or equipment ratings based on static laboratory conditions
- "Real world" affected by:
  - Part load operations
  - Weather variations
  - Operating practices
  - Equipment aging
- Many variables affect actual chiller system efficiency:
  - Type of chiller equipment
  - Size of chillers and cooling towers relative to seasonal loads
  - Condenser temperature
  - Chilled water supply temperature
  - Use of variable frequency drives (VFDs)
  - Age and maintenance history of equipment

General methods for assessing efficiency

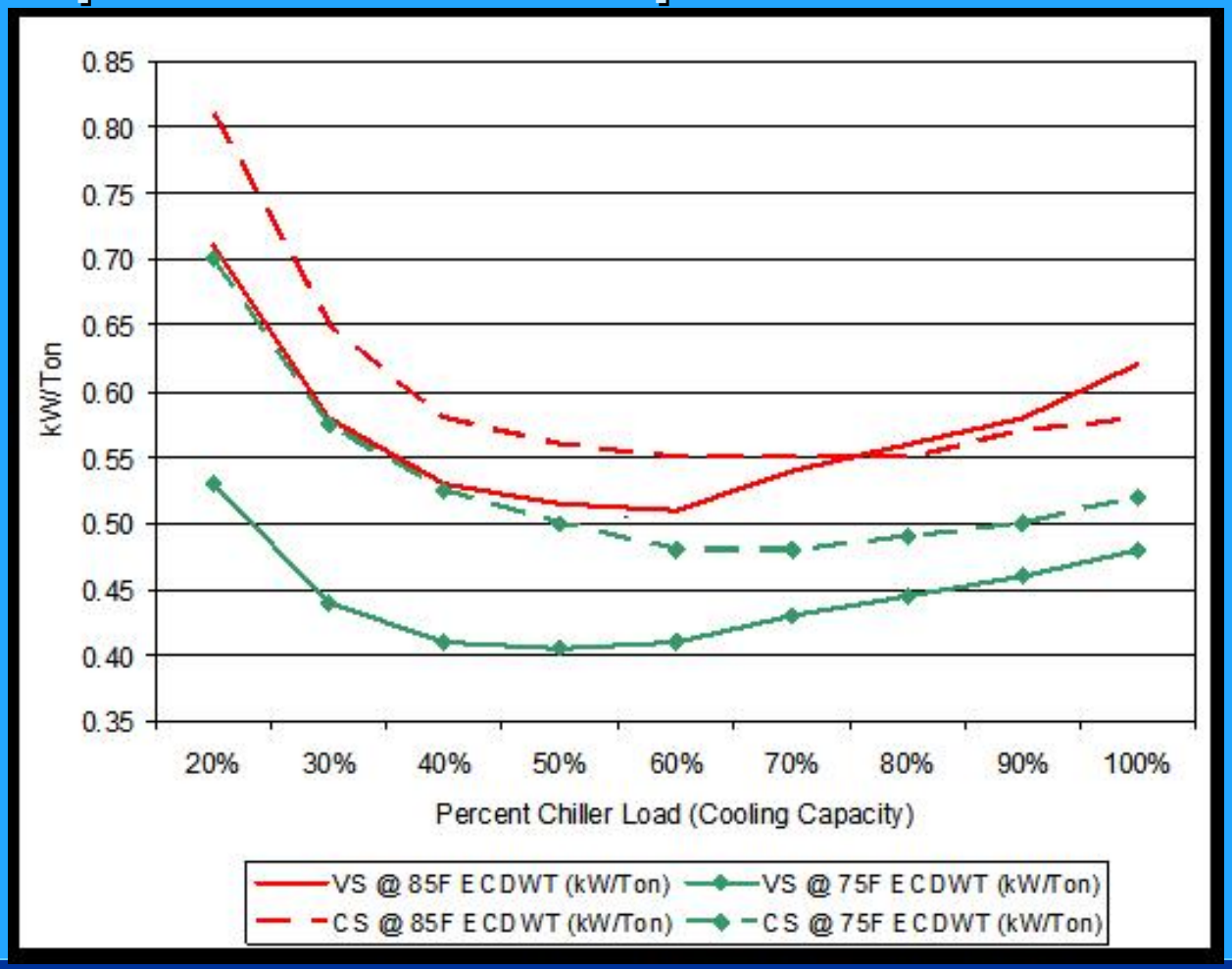
- Modelling, typically using detailed building and system simulation
- Indirect measurement
  - Monitor changes in total building electricity consumption after a building is connected to district cooling
  - Compare the reduction to the measured chilled water consumption following connection)
- Direct measurement (submetering) of chiller system components and chilled water production

Efficiency measures

- Coefficient of Performance (COP)
  - Ratio of heat removal to the rate of energy input
  - kW cooling output / kW power input
- kW/ton
  - One ton of cooling = removal of 3.516 kW (12,000 Btu per hour) of heat
  - kW electricity / ton of cooling

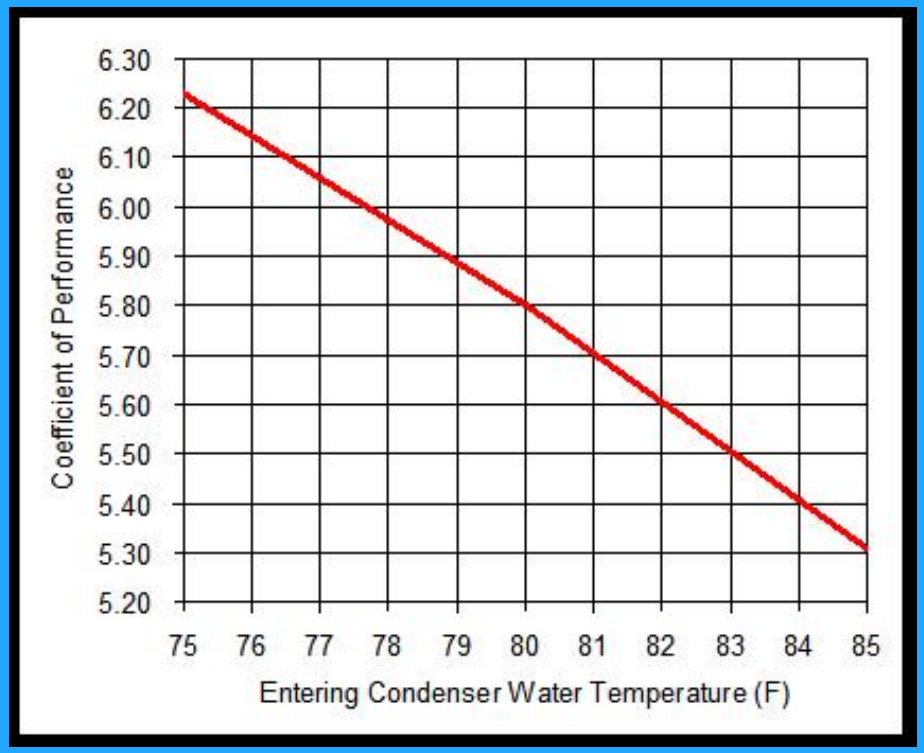


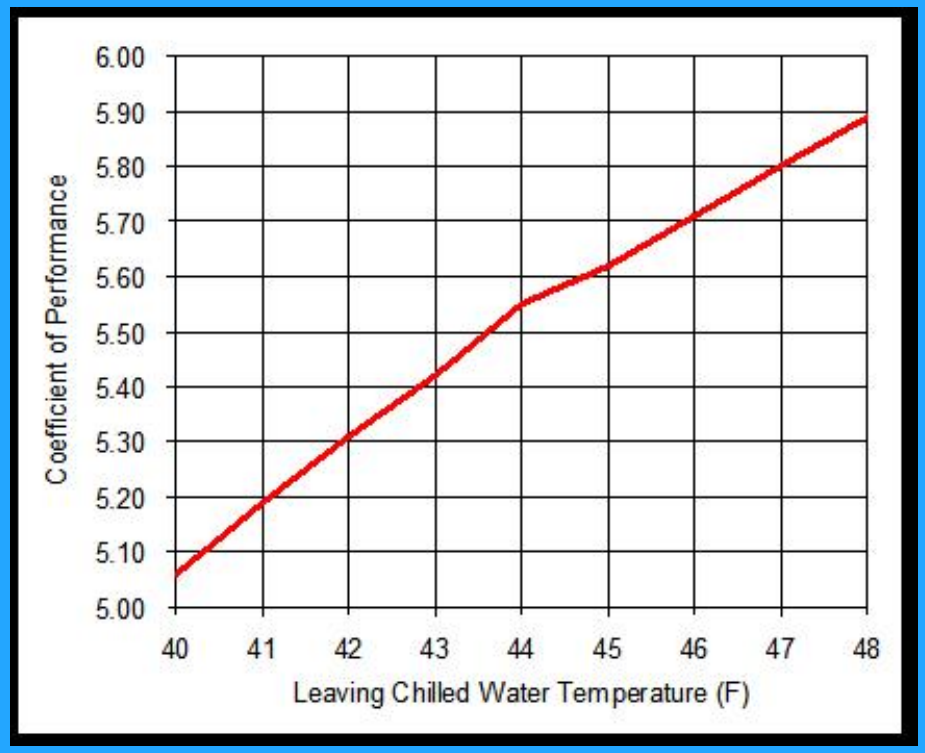
Part-load efficiency of constant-speed and variable-speed chiller compressors at fixed ECWT



Impact on COP of varying ECWT and LCWT

ECWT – Entering Condenser Water Temperature
LCWT – Leaving Chilled Water Temperature





Generalized efficiencies

Southern California USA conditions

	kW/ton		
	Low	High	Average
New all-variable-speed chiller plants	0.45	0.65	0.55
High-efficiency optimized chiller plants	0.65	0.75	0.70
Conventional code-based chiller plants	0.75	0.90	0.83
Older chiller plants	0.90	1.00	0.95
Chiller plants with design or operational problems	1.00	1.30	1.15

Annual chiller efficiency measures

- Air-conditioning and Refrigeration Institute (ARI) 550/590
  - Integrated Part Load Value (IPLV)
    - Based on specific rating parameters for ECWT, LCWT, etc.
    - Calculated weighted average efficiency at part load capacities based on an assumed “typical season”
  - Non-standard Part Load Value (NPLV)
    - For conditions other than the standard ARI conditions
    - Mix of case-specific and standard ECWT assumptions
    - NPLV does not predict actual efficiency, but is useful for comparison of chiller alternatives
- ESEER
  - European index equivalent to the ARI IPLV

Standards

- ASHRAE Standard 90.1 (American Society of Heating, Refrigerating and Air-Conditioning Engineers)
  - Chiller efficiency at specified rating conditions and with specific test procedures, for 3 chiller sizes
  - Cooling tower fan and condenser pump efficiency at design conditions
- Energy Performance of Buildings Directive (EPBD)
  - European Union (EU) directive on the energy performance of buildings (2002/91/EC)
  - Requires Member states to develop a calculation method for the energy performance of buildings
  - EU has developed a standard to be used at a Europe-wide level

Monitored chiller plant efficiencies

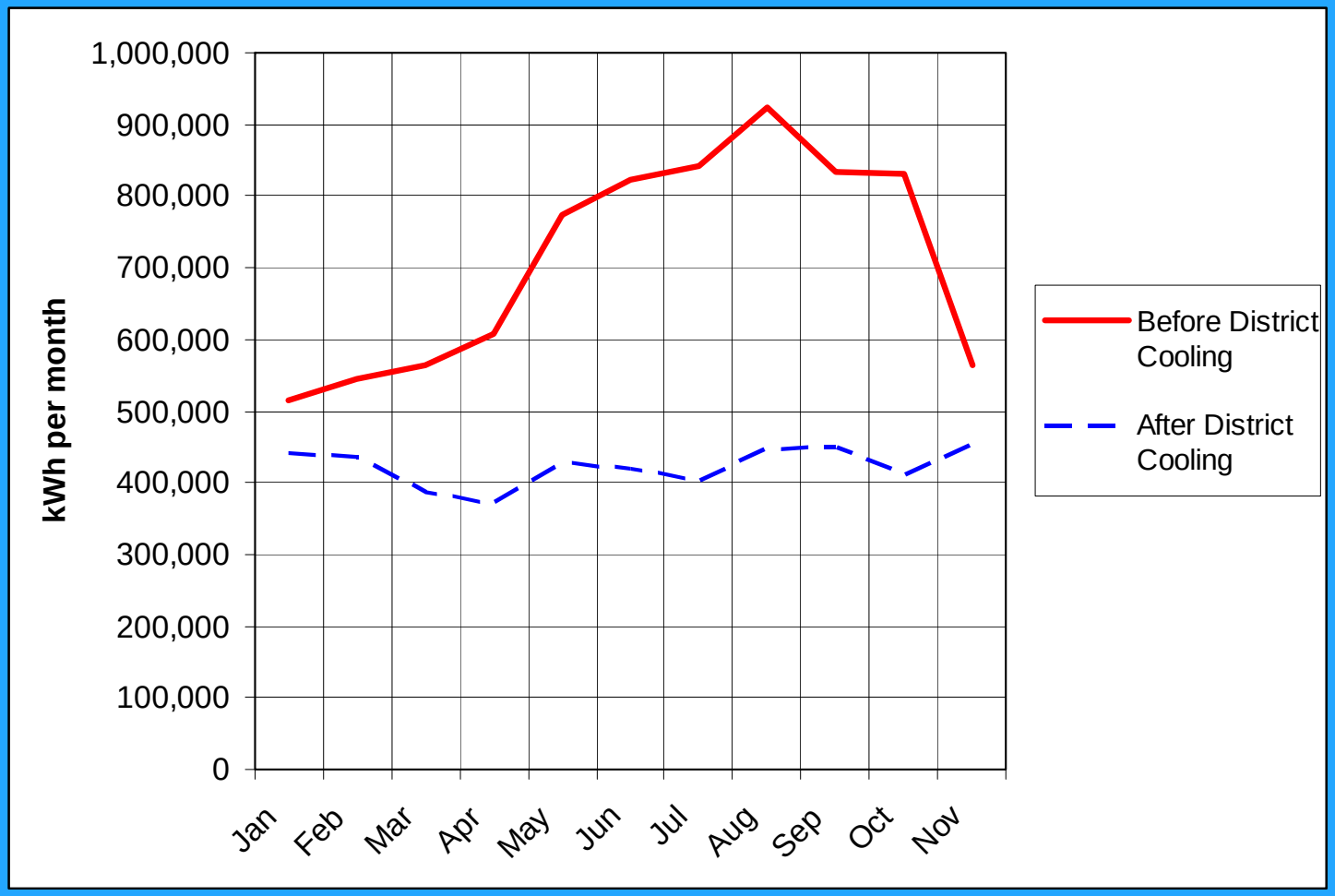
Plant type	Plant size (tons)	Annual total plant efficiency (kW/ton)
Air cooled	176	1.50
Variable speed screw	440	1.20
Ultra-efficient all variable speed with oil-less compressors	750	0.55
District cooling plant	3200	0.85

Buildings converted to district cooling

- Surveyed 11 commercial district cooling utilities and over 70 campus district cooling systems
- Sought data on “before and after” power consumption for buildings converted to district cooling
- Only 4 valid data-sets

Gross Chemistry Building, Duke University

Power consumption before and after conversion to district cooling



Summary of survey results

Building Name	Location	Chiller type	Calculation method	Average annual kW/ton
Gross Chemistry	Duke University, NC	Water-cooled	1	1.33
(Confidential)	Phoenix, AZ	Water-cooled	1	1.25
ITS Franklin	UNC Chapel Hill, NC	Air-cooled	2	1.21
Cheek Clark	UNC Chapel Hill, NC	Air-cooled	1	0.92

Calculation Methods

1. Based on electricity consumption before and after connection to district cooling, and cooling consumption following connection.
2. Submetering of chiller system.

Thanks for your attention!

Questions?