Alabama Industrial Assessment Center

DOE Best Practice Software Tools

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DOE Software Tool Use

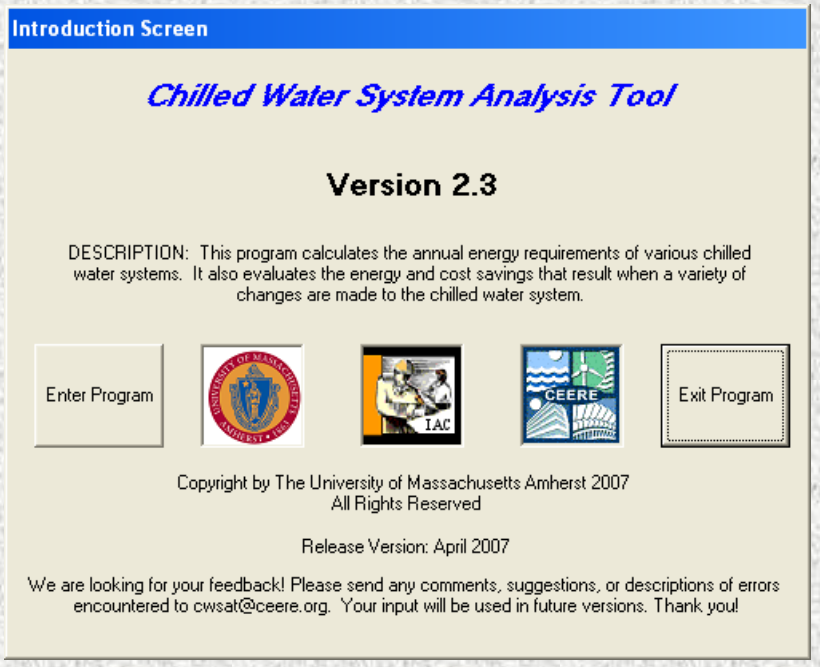
- Over the past year
  - 12 regular IAC assessments
  - 3 large energy user assessments
  - 1 SEN type assessment for a local hospital
- DOE software tools helped determine
  - System baseline operating costs
  - Assessment recommendation savings

Outline

- Software tools
  - CWSAT
  - AIRMaster
  - SSAT
  - VisualDOE
- For each tool
  - Required input
  - Output
  - Energy savings projects
  - Case study

CWSAT Software

- Designed through collaborative effort
  - The University of Massachusetts Department of Mechanical Engineering
- Determines energy and energy costs requirements for baseline operation
- Evaluates energy and costs saving opportunities
- Runs through MS Visual Basic 6
- Needs the weather folder

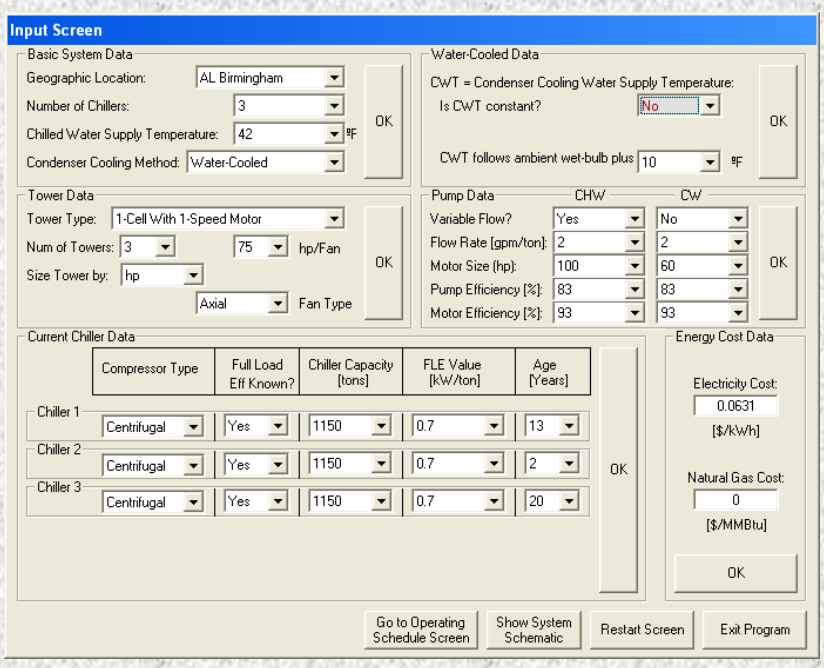


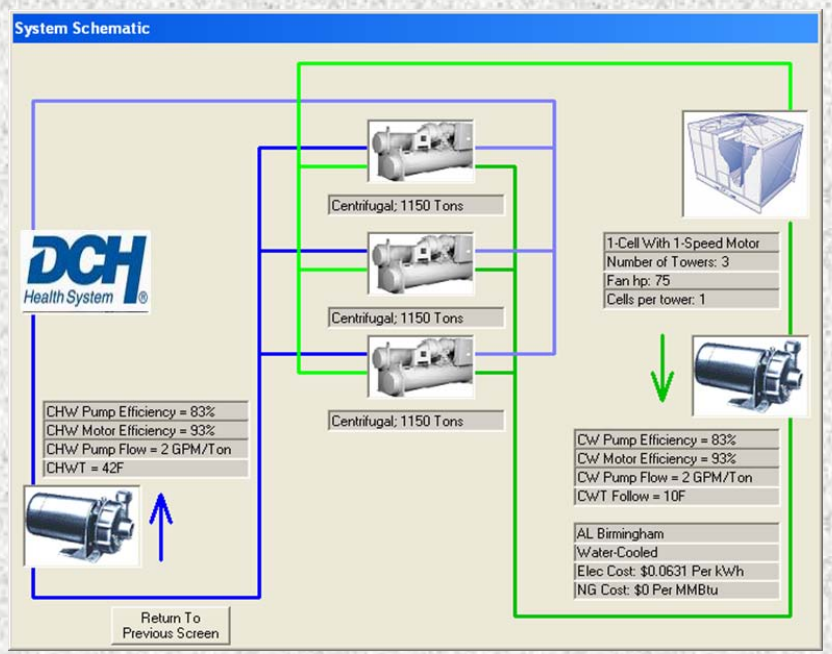
CWSAT Input Data

- Inputs
  - Weather
  - Condenser cooling method
    - Air/water
  - Pump data
  - Chiller characteristics
    - Type, capacity, efficiency, age
  - Chiller loading schedule
    - Measured flow and temperature data or amperage draws to calculate
    - Operating hours
    - Chiller loading varies according to ARI 550/590 schedule
    - Chiller loading varies from month to month and chiller to chiller
      - Load schedule screen (Time (%) at different loading capacity (%))

CWSAT Output

- Basic input screen yields
  - Chilled water system schematic
- Output screen yields
  - Baseline operation for chillers, pumps, and cooling towers
    - Energy (kWh/yr)
    - Costs ($/yr)
  - Energy breakdown for each component





CWSAT IAC Uses

- Verifies end-point energy calculations for chilled water system
- Output graphs
- Assists in assessment recommendation calculations for chilled water
  - Increase chilled water temperature set point
  - Decrease condenser cooling water supply temperature
  - Replace chillers (includes NG engine-driven models)
  - Apply variable speed control to chilled and/or condenser water pumps
  - Upgrade cooling tower fan speed control
  - Replace chiller refrigerant
  - Sequence chillers
  - Install a VSD on each compressor motor
  - Use free cooling when possible

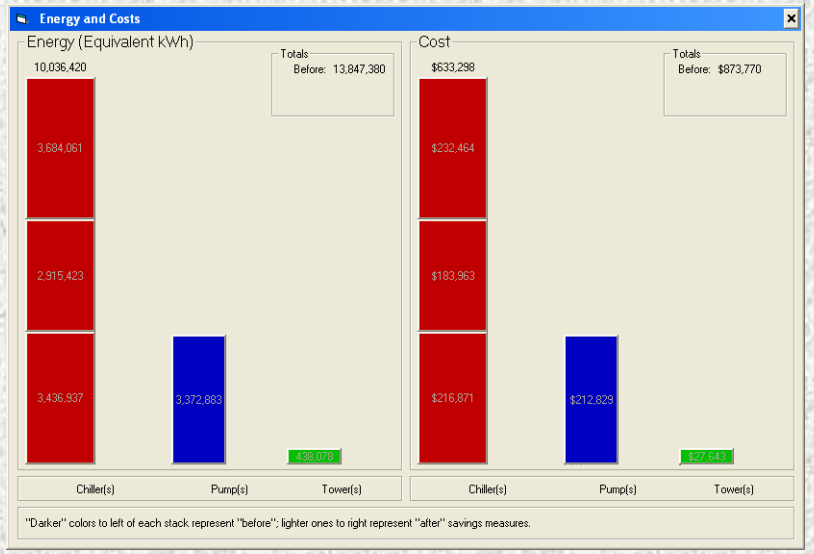
CWSAT Case Study

- Partnered with the Alabama Productivity Center(MEP), DCH hospital engineering staff, and Pinnacle Engineering
- Objective for chilled water system
  - Calculate baseline operation
  - Identify energy saving opportunities
- Limited chiller loading data for two chilled water systems
  - Main hospital
  - Medical tower hospital
- Chilled water supply and return temperatures and corresponding flow rates
  - Q_{evap} = mdot $*C_p *\Delta T$
  - Chiller loading $=Q_{evap}/Q_{totalcapacity}$

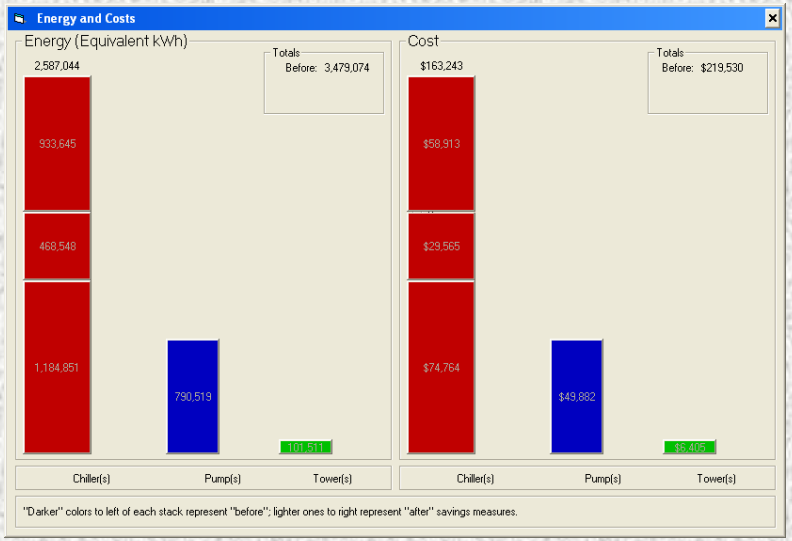
Chiller #1, on average 36%
Chiller #2, on average 22%
Chiller #3, on average 29%

Baseline Operation Results

Plant	Operating Hours Hrs	Chiller Energy kWh	Cooling Tower Energy kWh	Pump Energy kWh	Total Energy kWh	Total Cost $
Main Hospital Chiller Plant	8,760	10,036,420	438,078	3,372,883	13,847,380	873,770
Medical Tower Chiller Plant	8,760	2,587,044	101,511	790,519	3,479,074	219,530
Totals	**8,760**	**12,623,464**	**539,589**	**4,163,402**	**17,326,454**	**1,093,300**



Main Hospital



Medical Tower

Energy Savings

VSD on Chilled Water Pump Motors

Energy Savings (kWh/yr)	Energy Cost Savings ($/yr)	Imp. Cost ($)	Simple Payback (yrs)
1,294,060	81,655	54,000	0.7

VSD on Centrifugal Motors

Energy Savings (kWh/yr)	Energy Cost Savings ($/yr)	Imp. Cost ($)	Simple Payback (yrs)
3,265,795	206,075	206,000	1.0

AIRMaster+ Software

- AIRMaster+ is an auditing software tool
  - For general auditors or plant personnel
  - Evaluate compressed air system operation with basic instrumentation during a short-term assessment
- Created by IAC director from Oregon State University and his two graduate students
  - First version made available in 1997
  - Project funded by the DOE

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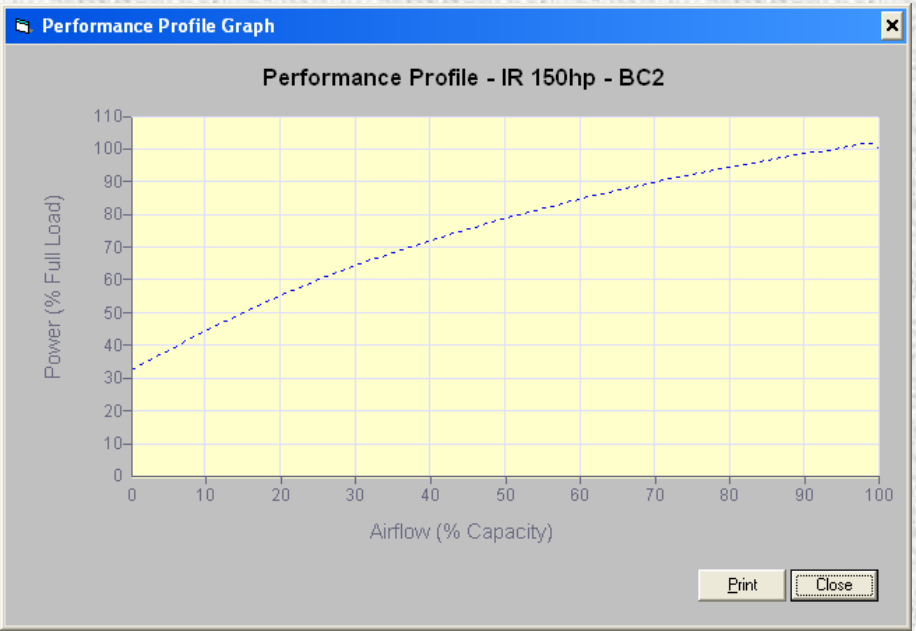
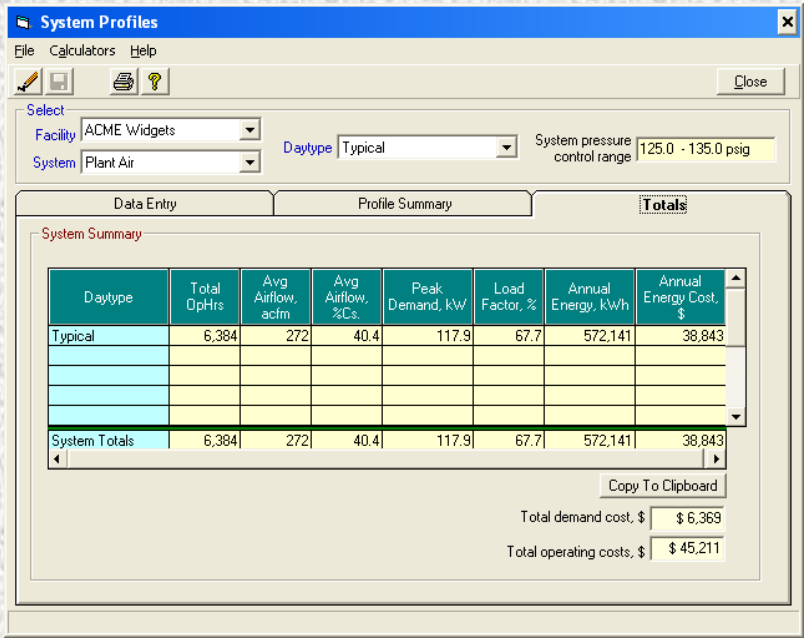
AIRMaster+ Input Data

- Type of compressor
- Nameplate information
  - Rated HP, rated flow, rated pressure, etc.
- Electrical and demand rates
- Control characteristics
  - Load/unload, modulating, modulating with unloading, etc.
- Operational pressure range
- Compressed Air Gas Institute (CAGI) data sheet helpful
  - Confirms nameplate information
  - Provides information on tested operational characteristics
- Voltage supply
  - Measured three-phase with amp meter is useful
- Logged data (24 hours)
  - Typically use logged amperage data

AIRMaster+ Output

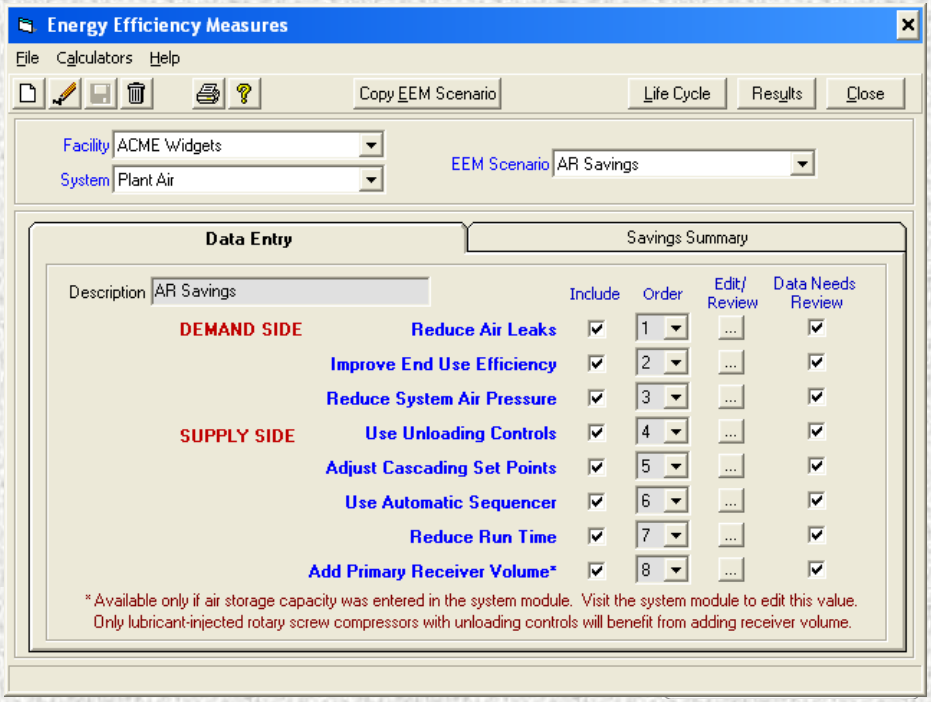
- Compressor loading data averaged through LogTool to provide power calculations for AIRMaster+
- Output yields
  - Performance profile of each compressor
  - Graphs on an hourly basis for airflow (acfm), power (kW), and capacity (%)
  - Individual compressor and system profiles





AIRMaster + IAC Uses

- Verifies end-point energy calculations for compressed air systems
- Output graphs
- Assists in assessment recommendation calculations for compressed air
  - Reduce Air Leaks
  - Improve End Use Efficiency
  - Reduce System Air Pressure
  - Use Unloading Controls
  - Adjust Cascading Set Points
  - Use Automatic Sequencer
  - Reduce Run Time
  - Add Primary Receiver Volume



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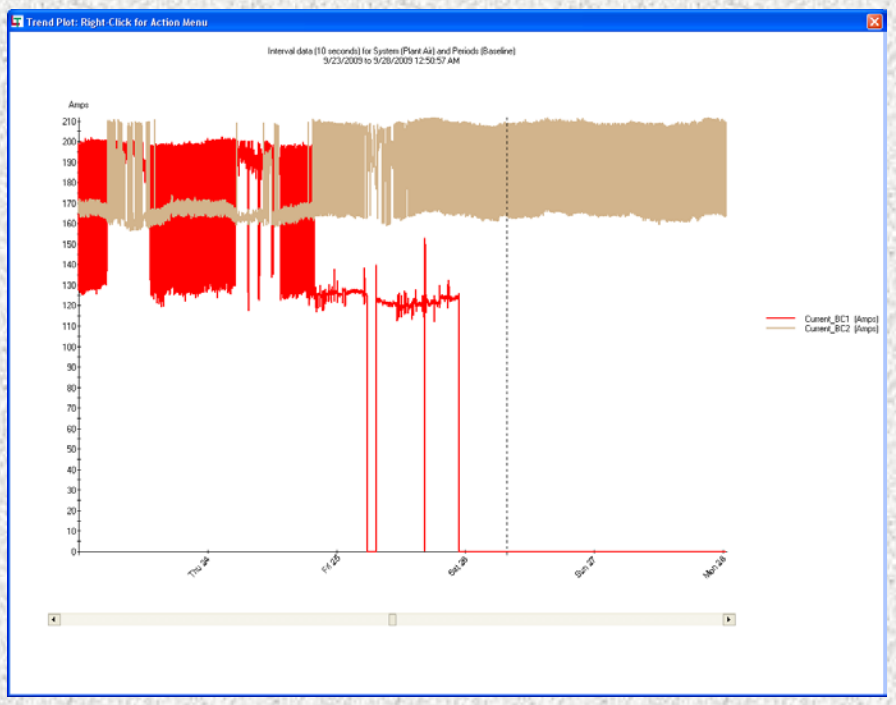
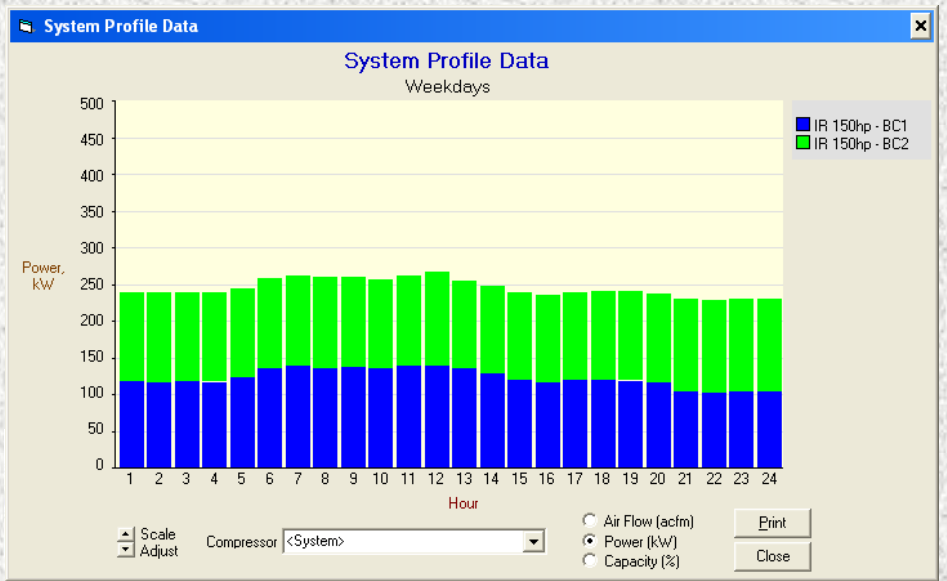
AIRMaster + Case Study

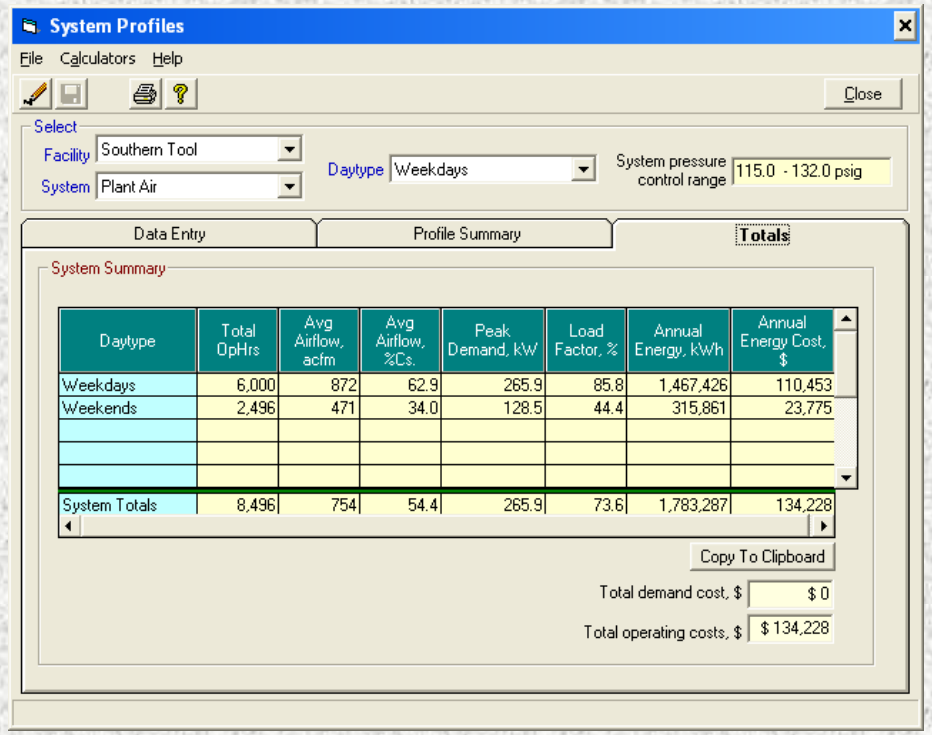
- Client with precision investment casting operation
  - Produce parts through melting and air-melt processing
- 16% of electrical energy in compressed air
  - Use compressed for pneumatic tooling and fluidized beds
  - Use two 150 hp Ingersoll Rand single stage rotary screw compressors
  - Also use three 7.5 hp Ingersoll Rand compressors for fluidized bed
- Purchased but not installed a 200 hp VSD Kaeser air compressor
- Five days of amperage data was logged



Baseline Operation Results

- Annual energy usage 1,783,000 kWh
- Annual energy costs of $134,228





Daytype	Total OpHrs	Avg Airflow, acfm	Avg Airflow, %Cs.	Peak Demand, kW	Load Factor, %	Annual Energy, kWh	Annual Energy Cost, $
Weekdays	6,000	872	62.9	265.9	85.8	1,467,426	110,453
Weekends	2,496	471	34.0	128.5	44.4	315,861	23,775
System Totals	8,496	754	54.4	265.9	73.6	1,783,287	134,228

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Energy Efficiency Measures

Assessment Recommendation	Energy Savings (kWh)	Cost Savings ($)	Imp. Cost ($)	Simple Payback Period (yrs.)
1. Install VSD Compressor	422,660	31,810	25,000	0.75
2. Reduce Air Pressure	358,030	29,110	0	0.0
3. Reduce Runtime on Compressors	312,000	25,370	0	0.0
4. Repair Air Leaks	63,810	5,300	5,500	1.1
5. Use Outside Air for Compressor Intake*	34,400	2,860	1,000	0.4
6. Add Primary Receiver Volume**	18,820	1,420	9,300	6.5
Totals	**1,209,720**	**95,870**	**40,800**	**0.4**

*AIRMaster+ not used

**Other recommendation

Steam System Analysis Tool (SSAT)

- Runs as an add-in within Microsoft® Excel
- Develops approximate models of real steam systems
- Quantifies energy, cost, and emission savings of implementing potential improvement opportunities

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What data do you need for SSAT?

- Requires answering 23-46 questions in four main categories:
  - General Site Data
  - Generation
  - Distribution
  - Recovery

What data do you need for SSAT?

- General Site Data:
  - Power demand and cost
  - Makeup water temperature and cost
  - Type of boiler fuel and cost
- Steam Generation:
  - Boiler efficiency
  - Steam generation conditions
  - Boiler blow-down rate
  - Deaerator
- Steam Distribution:
  - Header pressure
  - Steam demand
  - Steam turbines
  - Steam traps
  - Insulation heat loss
- Steam Recovery:
  - Condensate recovery
  - Heat recovery

SSAT Outputs

Energy Savings Projects

- General Site Data:
  - Use alternative boiler fuel
- Generation:
  - Increase boiler efficiency
  - Reduce boiler blow-down rate
  - Change steam generation conditions
- Recovery:
  - Condensate recovery
  - Recover waste heat
- Distribution:
  - Install turbines
  - Repair steam traps and steam leaks
  - Reduce steam demand
  - Improve insulation

Case Study

- Gypsum paper manufacturer in Oxford, AL
- Steam created between 210 and 215 psi by two 1,200 hp water tube boilers
- Pressure is reduced to 75 psi by a turbine that powers a shaft used to drive processes along the production line for three months of the year
- Steam pressure reduced by throttling other nine months
- Steam at 75 psi is used for production purposes
- Steam is further reduced to 25 psi for comfort heating

Case Study

- Average Steam Demand: 30,000 lbm/hr per boiler
- 10.3%-12.5% excess O_2 present in exhaust gas
- 460°F – 510°F exhaust temperature
- 73%-74% efficiency

SSAT Model

- Considered one large boiler
- Created model in SSAT
  - Three header model
    - 210 psi, 75 psi and 25 psi
  - Boiler efficiency: 74%
  - Steam demand:
    - 70% demand at 75 psi
    - 30% demand at 25 psi

2008 Baseline Operation

- Fuel Usage:

  660,000 MMBtu

- Fuel Cost:

  $5,790,000

- Power Usage

  32 GWh

- Power Cost

  $2,240,000

- Makeup Water Cost

  $3,000

Cost Summary ($ '000s/yr)	Current Operation
Power Cost	2,224
Fuel Cost	5,790
Make-Up Water Cost	3
Total Cost (in $ '000s/yr)	**8,017**

On-Site Emissions	Current Operation
CO2 Emissions	76638 klb/yr
SOx Emissions	0 klb/yr
NOx Emissions	152 klb/yr

Power Station Emissions
CO2 Emissions
SOx Emissions
NOx Emissions

Note - Calculates the impact of the change in site pow er import on emissions from a

Utility Balance	Current Operation
Power Generation	627 kW
Power Import	4000 kW
Total Site Electrical Demand	4627 kW
Boiler Duty	82.5 MMBtu/h
Fuel Type	Natural Gas
Fuel Consumption	82430.1 s cu.ft/h
Boiler Steam Flow	61.0 klb/h
Fuel Cost (in $/MMBtu)	8.78
Power Cost (as $/MMBtu)	20.37
Make-Up Water Flow	3735 gal/h

Energy Savings Projects

- Install economizers on boiler units
  - High exhaust temperatures
- Reduce tramp air
  - High levels of O_2 present in exhaust gas
- Insulate steam pipes
  - Approximately 600 feet of un-insulated pipe
  - Average surface temperature ranging from 200°F to 425°F
- Use Steam Turbine to Convert High Pressure Steam to Low Pressure Steam
  - Currently reduce steam pressure from 210psi to 25 psi through throttling

Energy Savings Results

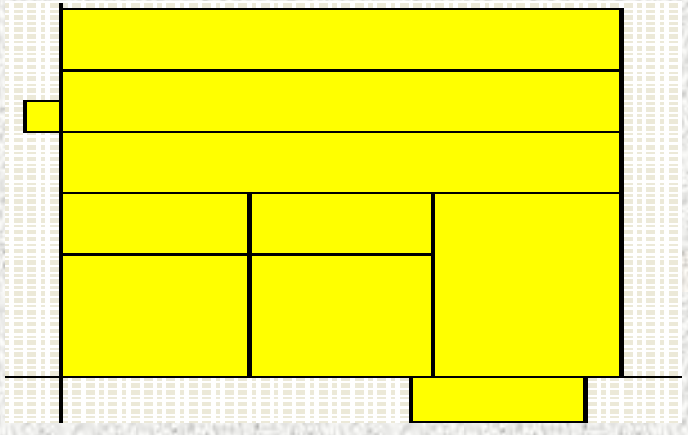
	Energy Savings	Cost Savings	Estimated Implementation Cost	Simple Payback Period
	(MMBtu/yr)	($/yr)	($)	yrs
Recover Waste Heat with Economizer	72,600	637,000	220,000	0.3
Reduce Tramp Air in Stack Gas	32,400	284,000	10,000	0.04
Insulate Bare Piping	677	6,000	4,500	0.8
Use Steam Turbine to Reduce Steam Pressure	2,400	10,000	0	0.0
	108,000	937,000	235,000	0.25

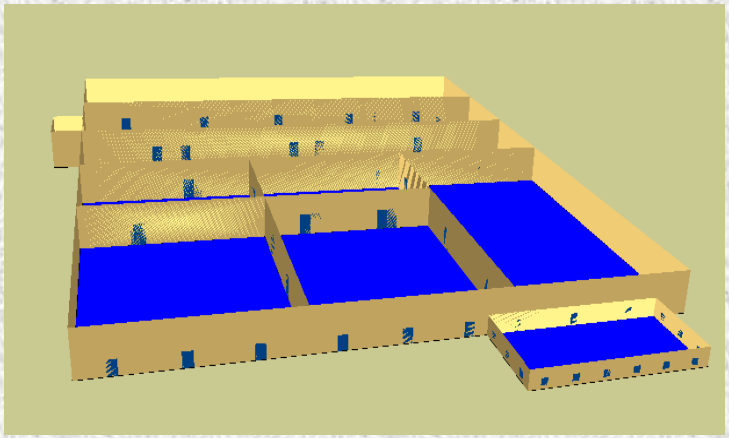
VisualDOE

- Created by the Architectural Energy Corporation in 1999
- Design software tool developed to allow engineers and architects the opportunity to evaluate the performance of an HVAC system under given conditions
- A "front end" to DOE2, a building energy analysis program developed by the Lawrence Berkeley National Laboratory through funding by the Department of Energy
- Covers all major building systems including lighting, day lighting, HVAC, water heating, and the building envelope

What data is needed for VisualDOE?

- Requires an architectural model be made of the facility
- Bin weather data for the area
- An estimated light , power, and occupational density and schedule
- Data regarding the HVAC system (cooling and heating capacity, fan data, thermostat settings, outdoor air usage and infiltration)
- Bill data





VisualDOE Outputs

- Estimated monthly energy usage and cost of lighting system, equipment, and HVAC system
- Estimated monthly power demand
- Hourly temperature profile of the facility
- Maximum heating and cooling demand

VisualDOE 4.1 - Results January 22, 2010

Monthly Electrical Usage (kWh)

Alternative	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Base Case	1,737,444	1,561,928	1,815,484	2,003,336	2,213,298	2,316,661	2,290,068	2,402,274	2,137,460	1,720,855	1,627,766	1,704,883

Monthly Electrical Power Demand (kW)

Alternative	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Base Case	2,925	2,882	2,824	4,096	4,166	4,293	4,332	4,319	4,141	2,802	2,832	2,880

Monthly Fuel Usage

Alternative	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Base Case - Natural Gas (Therm)	136,740	123,510	136,747	-65,723	-68,442	-62,981	-45,861	-66,786	-74,823	136,724	132,317	136,732

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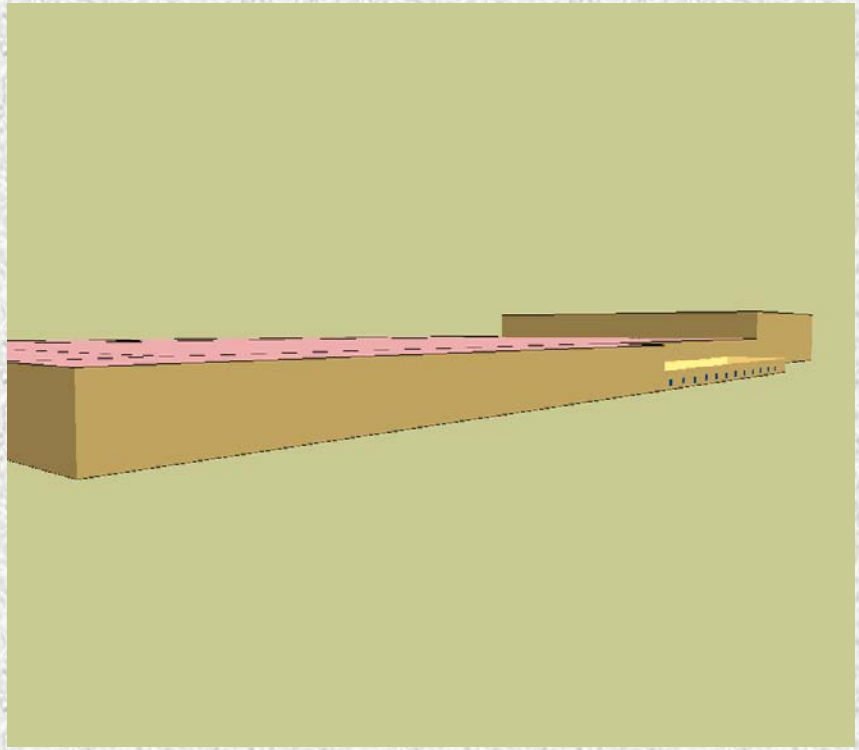
Energy Savings Projects

- Improve building insulation
- Reduce outdoor air infiltration
- Change thermostat set points
- Reduce the amount of conditioned space
- Consider new equipment
  - Improve efficiency

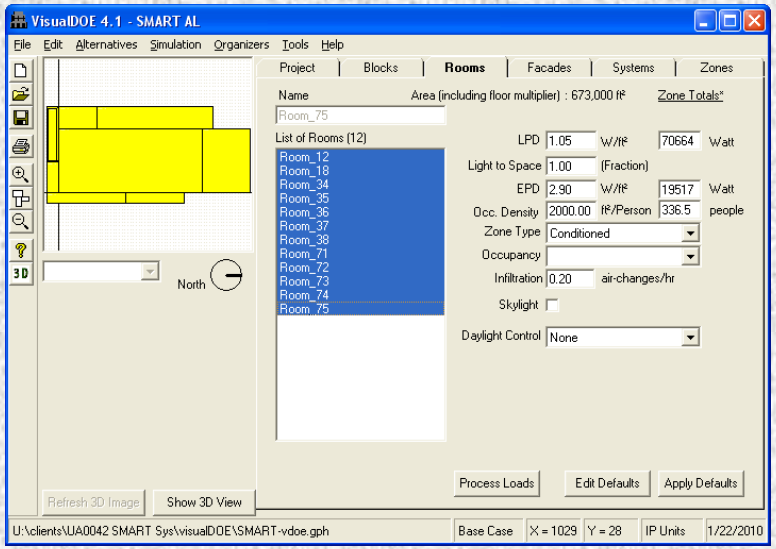
Case Study

- Automotive components manufacturer in Luverne, AL
- Entire plant conditioned throughout the year
- Large heat load generated by welding operation
- Exhaust fans used to improve indoor air quality
- Unoccupied warehouse also conditioned



VisualDOE Model

- Created building model
- Input LPD, EPD, occupational density, and infiltration
- Created one large zone with lumped HVAC system
  - 22,284 kBtu/hr cooling capacity
  - 13,520 kBtu/hr heating capacity
  - 570,600 cfm airflow from unit fans
- Input outdoor air infiltration rate
  - 1,203,000 cfm exhaust flow rate



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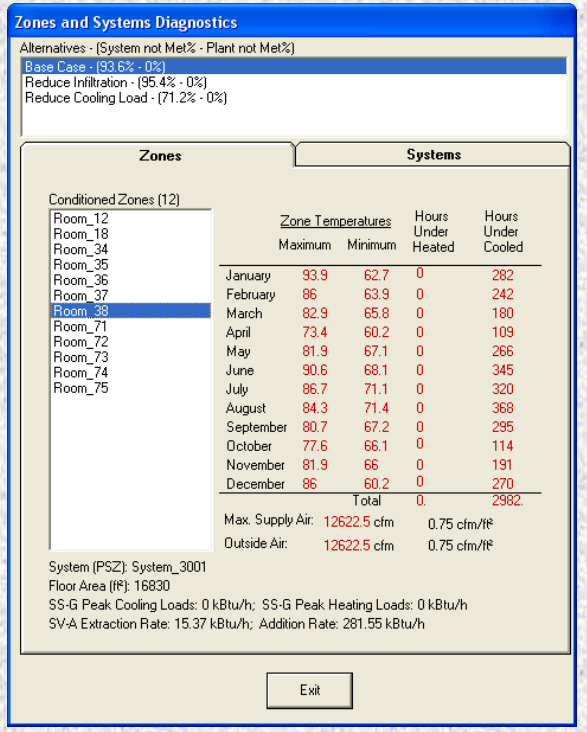
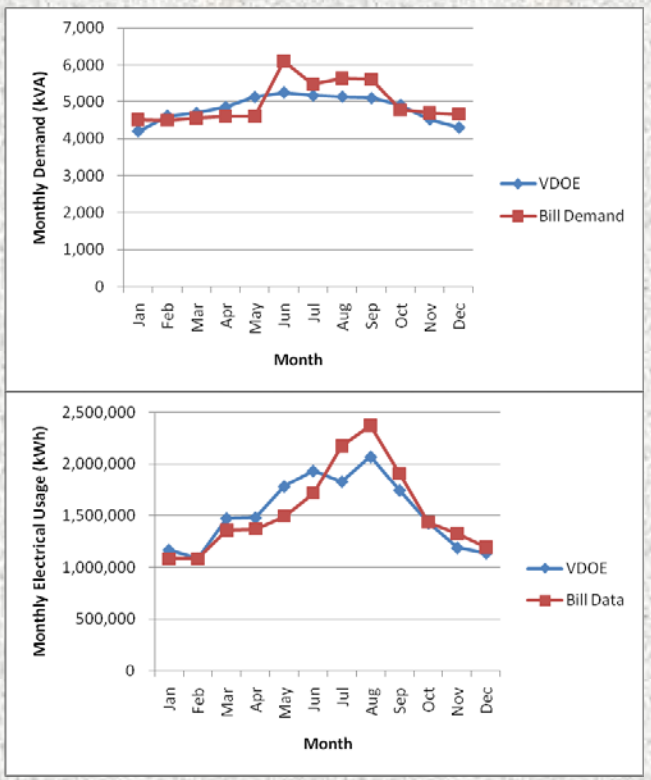
Case Study Baseline

Lighting Energy Usage (kWh/yr)	Equipment Energy Usage (kWh/yr)	Cooling Energy Usage (kWh/yr)	Heating Fuel Usage (MMBtu/yr)	Fan Energy Usage (kWh/yr)	Annual Electric Usage (kWh/yr)	Annual Heating Fuel Usage (MMBtu/yr)
4,191,118	7,725,082	5,060,947	4,700	1,718,704	18,695,850	4,700





Energy Savings Projects

- Main issue: exhaust fans
  - Exhausting conditioned air to improve air quality
  - Loosely used ASHRAE standards and determined air turnover should be decreased by half
  - Recommended cutting off half of exhaust fans and installing filtration system
  - Estimated energy savings: 1.61 MWh/yr
- Secondary issue: conditioned warehouse
  - Recommended zoning off warehouse with vinyl curtains
  - Estimated energy savings: 407,000 kWh/yr

Pros/Cons

SSAT

- Pros:
  - Ability to model real steam systems
  - User friendly
- Cons:
  - Can't have model with variable loading
  - No economizer option

VisualDOE

- Pros:
  - Provides accurate estimation of HVAC system energy usage
  - Provides accurate estimation of plant energy usage
  - Provides temperature profile of the plant
- Cons:
  - Requires a lot of time
  - EPD

Pros/Cons

CWSAT

- Pros
  - Graph generation
  - Many efficiency measure options
- Cons
  - Cannot save input data
  - Limited input variability
  - Needs some debugging

AIRMaster+

- Pros
  - Graph generation
  - Many efficiency measure options
- Cons
  - Complications from logged data
  - Importing data to AIRMaster is cumbersome
  - Hard to measure value of air leaks in plant

Questions/Comments

- Pros/cons of these tools?
- Which tools do you use?