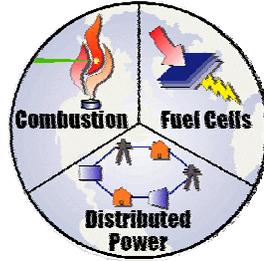


# Installation, Operation, and Monitoring Experiences with SCAQMD Sponsored Microturbine Deployment Program



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**Advanced Power & Energy Program**  
**University of California, Irvine**

**DOE/CETC Workshop On Microturbine Applications**  
**January 20, 2004**  
**Marina Del Rey, CA**

**Supported by SCAQMD, SC Gas, California Energy Commission,  
SC Edison, LADWP, US Department of Defense**

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# Background

- **SCAQMD Program Inception 4/2001: Distribution of Capstone MTGs in the AES and LADWP service Area offered to interested public service parties.**
  - **Approx 150 Capstone microturbines for distribution:**
    - 30 kW units without heat recovery in LADWP region
    - 60 kW units with heat recovery in AES region
    - 30 kW “digester gas” units at 3 water treatment plants
    - Does not include installation at Lopez Canyon or Calabasas Land Fills
  - **Government offices, schools, prisons, hospitals, utilities (water treatment and local electrical utilities).**
- **Approximately 50 sites were selected based on description**
  - **Peak Shave and Grid Parallel Operation Dominant**
  - **Financial assistance offered to help with installation costs**



# Background

- **UCI Role**
  - **Provide preliminary site survey assistance, review of site viability.**
  - **Long term monitoring of MTG performance**
    - **Goal: Record CRMS data on all installed units**
    - **Goal: For some selected sites (~ 4), CRMS data + instrument for gas consumption, hot water recovery, and net electric power output.**



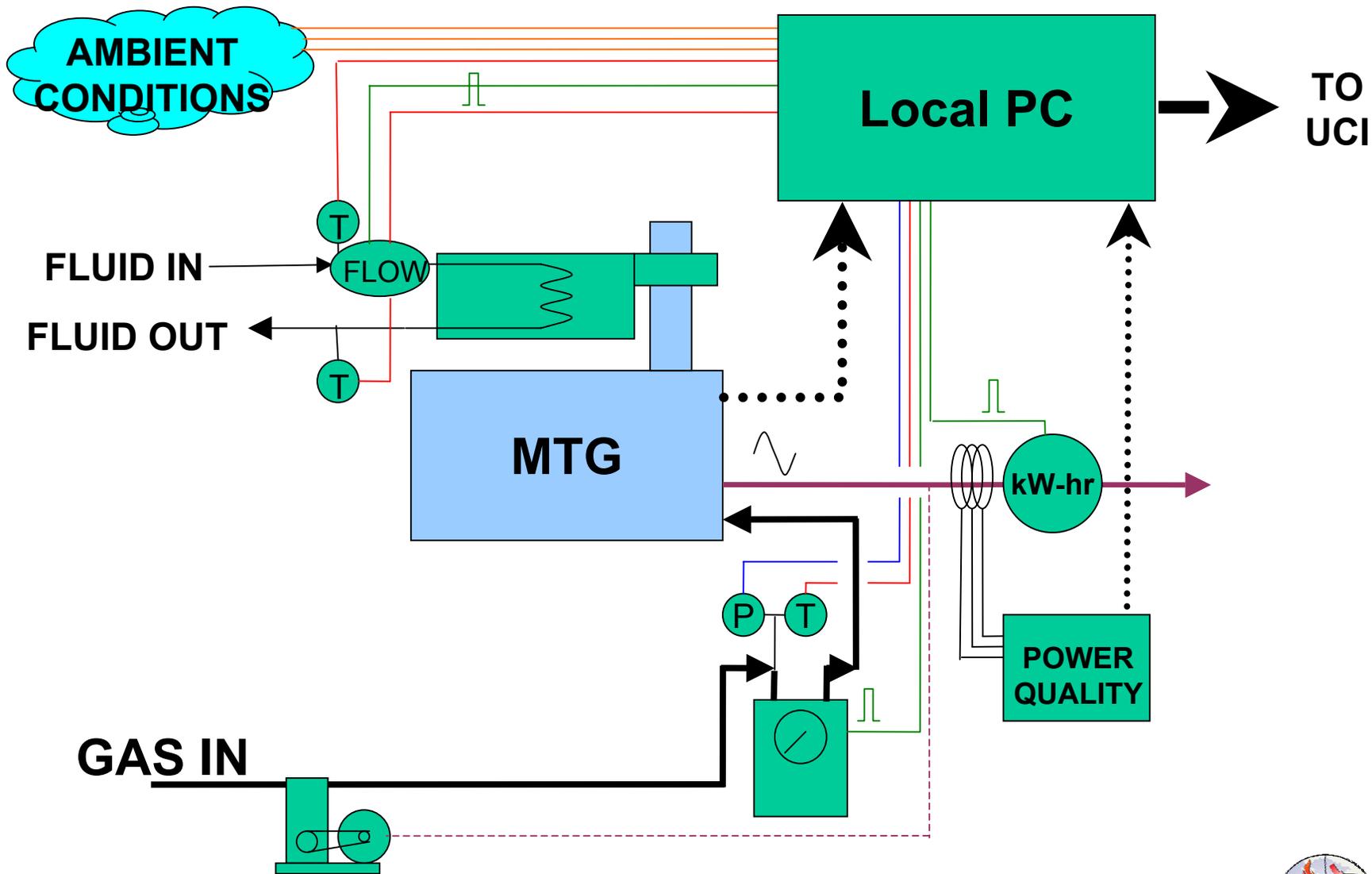
# Site Characteristics/Selection Criteria

- **Site Needs/Desires**
  - **Electric Power**
    - 3 Phase tie in to power; 480 VAC preferred
    - Proximity of service to proposed location
  - **Fuel:**
    - Natural gas
    - Digester gas (at selected sites)
    - Proximity of service to proposed location
  - **Telecommunications**
    - Telephone or internet connection for data acquisition
  - **Space**
    - Service space
  - **Noise**
    - Understanding/Consideration of Noise Issues
  - **CHP operation**
    - Ability to make use of waste heat

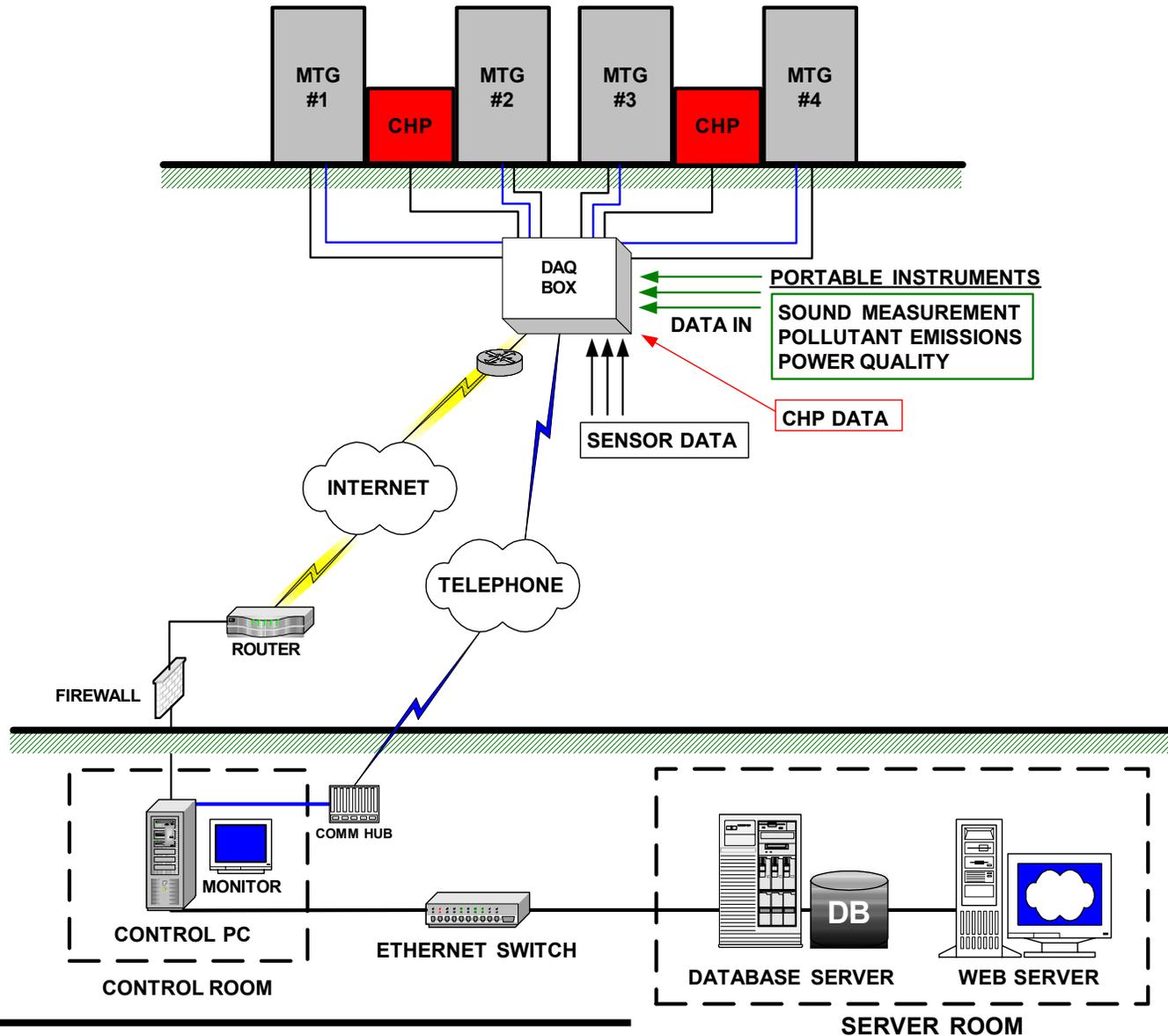




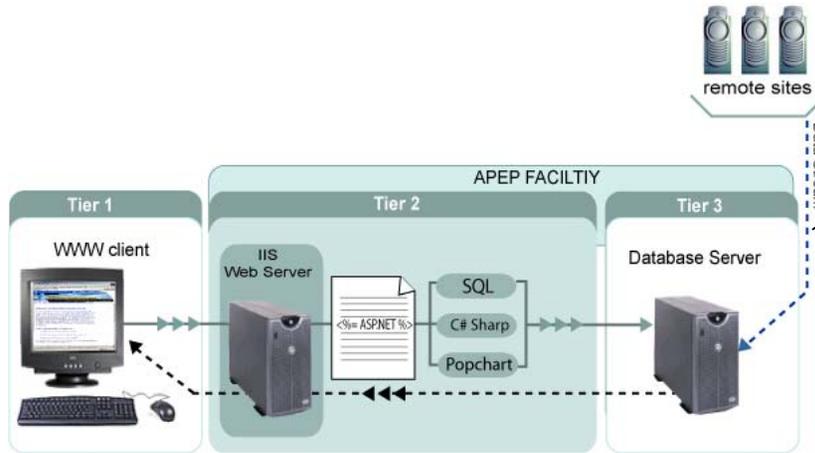
# Data Acquisition and Storage



# Data Acquisition and Storage



# Data Acquisition and Storage



## Three Levels of Information

### 1. Operational Data

Goal: All 200+ Units, 35 Sites—33 SCAQMD

Reality: ~40 units, 15-20 sites

### 2. Real Time Efficiency/Heat Rate (“Super” sites)

(support from LADWP, SoCal Gas, SCE)

Goal: 4-6 sites

Reality: 3 sites: UCI, AQMD, CSUN

| OperationalData        | FieldPointData          |
|------------------------|-------------------------|
| MachineCode            | MachineCode             |
| AcquisitionTime        | AcquisitionTime         |
| EngineSpeed            | NatGasMeterTime         |
| TurbineExitTemp        | NatGasMeter             |
| CompressorInTemp       | ElectricMeter           |
| AmbientPressure        | WaterMeter              |
| IncidentRecord         | NatGasTemp              |
| NumOfStarts            | MTGExhaustTemp          |
| ServiceHours           | MTGInletTemp            |
| SystemSeverityLevel    | WaterColdTemp           |
| SystemState            | WaterHotTemp            |
| PowerEnable            | EmissionsTemp           |
| PowerDemand            | NatGasPressure          |
| PowerSupplyVoltage     | AmbientTemp             |
| StartCommand           | AmbientRelHumidity      |
| FuelInletPLP           | EmissionsO2             |
| FuelOutletPLP          | EmissionsCO             |
| FuelInletPHP           | EmissionsNO             |
| SPVFuelExP             | EmissionsNO2            |
| BatteryTemp            | EmissionsSampleValvePos |
| BatterySOC             |                         |
| BatteryVolts           |                         |
| BCDCBus                |                         |
| InvDCBusVoltage        |                         |
| OutputFrequency        |                         |
| OutputCurrentPhaseA    |                         |
| OutputCurrentPhaseB    |                         |
| OutputCurrentPhaseC    |                         |
| OutputCurrentPhaseNeut |                         |
| OutputVoltagePhaseA    |                         |
| OutputVoltagePhaseB    |                         |
| OutputVoltagePhaseC    |                         |
| OutputPowerPhaseA      |                         |
| OutputPowerPhaseB      |                         |
| OutputPowerPhaseC      |                         |
| OutputPower            |                         |
| BatNoEqCharges         |                         |
| MeterPowerIn           |                         |
| MeterPowerOut          |                         |
| MeterVarIn             |                         |
| MeterVarOut            |                         |
| LFCInjectorState       |                         |
| TurbineNumber          |                         |
| MultiPackEnable        |                         |

| SiteMaster    |
|---------------|
| SiteID        |
| AgencyID      |
| SiteCode      |
| SiteName      |
| ShortSiteName |
| Address1      |
| Address2      |
| City          |
| State         |
| ZipCode1      |
| ZipCode2      |
| SitePhotoURL  |
| SiteText      |



# Data Access/Retrieval

South Coast Air Quality Management District
APEP    NFCRC    UCICL



## MICROTURBINE GENERATOR PROGRAM

Tuesday, January 28, 2003 11:07:46 PM PST University of California, Irvine

[Home](#)
[Map of Monitored Sites \(flash required\)](#)
[\(Download Flash Player\)](#)
[View Site Summary](#)
[Glossary](#)

**DATA CHARTS**

To view data charts for one day, week, month or quarter select the site #, machine # and data period

**DATA GRID: Overview of Site summary**

Click on the Site below to view additional information about the Site.

Show summary data for month of

| Site No.      | Status   | As Of          | Latest Readings      |                          | Summary Data          |                              |                    |                    |            |                 |                    |            |
|---------------|----------|----------------|----------------------|--------------------------|-----------------------|------------------------------|--------------------|--------------------|------------|-----------------|--------------------|------------|
|               |          |                | Current Output<br>kw | Start Of Data Collection | Total Operating Hours | Total Output Power*<br>(kWh) | Totals for 12/2002 |                    |            | ON Peak 12/2002 |                    |            |
|               |          |                |                      |                          |                       |                              | Operating Hours    | Power Output (kWh) | % Capacity | Operating Hours | Power Output (kWh) | % Capacity |
| <b>Site 1</b> |          |                |                      |                          |                       |                              |                    |                    |            |                 |                    |            |
| Machine #1    | Load     | 01/28/03 08:55 | 59.93                | 05/08/2002               | 10,257                | 239,246                      | 744                | 44,188             | 99         | 132             | 7,734              | 98         |
| Machine #2    | Load     | 01/28/03 08:40 | 59.90                | 07/09/2002               | 9,017                 | 81,284                       | N/A                | 0                  | 0          | 0               | 0                  | 0          |
| Machine #3    | Load     | 01/28/03 09:50 | 57.89                | 07/09/2002               | 10,892                | 211,834                      | 744                | 43,891             | 98         | 132             | 7,625              | 96         |
| <b>Site 2</b> |          |                |                      |                          |                       |                              |                    |                    |            |                 |                    |            |
| Machine #1    | Stand By | 01/28/03 11:50 | 0.00                 | 06/07/2002               | 1,552                 | 16,263                       | 96                 | 2,266              | 10         | 59              | 1,428              | 36         |
| Machine #2    | Stand By | 01/28/03 12:00 | 0.00                 | 06/07/2002               | 1,800                 | 19,508                       | 139                | 3,509              | 16         | 87              | 2,112              | 53         |
| Machine #3    | Stand By | 01/28/03 11:50 | 0.00                 | 06/07/2002               | 1,827                 | 14,600                       | 147                | 3,459              | 15         | 87              | 2,093              | 53         |
| Machine #4    | Stand By | 01/28/03 11:50 | 0.00                 | 06/07/2002               | 1,682                 | 16,451                       | 122                | 2,947              | 13         | 72              | 1,794              | 45         |
| Machine #5    | Load     | 01/28/03 11:50 | 25.15                | 05/03/2002               | 2,102                 | 19,074                       | 149                | 3,761              | 17         | 89              | 2,271              | 57         |
| Machine #6    | Load     | 01/28/03 11:50 | 24.99                | 05/03/2002               | 1,328                 | 24,507                       | 149                | 3,740              | 17         | 89              | 2,254              | 57         |
| <b>Site 3</b> |          |                |                      |                          |                       |                              |                    |                    |            |                 |                    |            |
| Machine #1    | Load     | 01/28/03 20:50 | 29.26                | 05/24/2002               | 8,634                 | 139,277                      | 457                | 13,135             | 59         | 77              | 2,220              | 56         |
| Machine #2    | Load     | 01/28/03 20:50 | 28.99                | 05/24/2002               | 8,756                 | 104,199                      | 280                | 7,942              | 36         | 50              | 1,383              | 35         |
| <b>Site 4</b> |          |                |                      |                          |                       |                              |                    |                    |            |                 |                    |            |
| Machine #1    | Load     | 01/28/03 08:45 | 29.02                | 08/06/2002               | 6,414                 | 73,248                       | 690                | 19,620             | 88         | 118             | 3,402              | 86         |

[www.apep.uci.edu/aqmd](http://www.apep.uci.edu/aqmd)



# General Status: SCAQMD (12/2003)

- **First site operational 8/7/01 (UC Irvine)**
  - limited by MTG availability for delivery
- **30% of originally selected sites “backed out”:**
  - installation costs realities (majority)
  - other installation issues
- **33 Sites currently “active”**
- **Approximately 20 sites are operational (at some level)**
- **11 are operating reliably and consistently.**
- **What were some of the issues encountered?**



# General Issues: SCAQMD

- **Utility Permitting (3+ month process)**
  - **Electric Interconnect**
    - **Adds Delay and Cost (Despite Improvements)**
  - **Gas**
    - **Confirmation of Service Capacity**
- **Local Building Authority**
  - **City “education” relative to technology**
  - **Noise Considerations**
- **Air Quality Authority**
  - **SCAQMD—No permit required with <2MMBTU/hr firing rate**
    - **SB1298 may come into play (1/1/03, CA)**
  - **Exception: Operation on Landfill or Digester Gas**



# General Issues: SCAQMD

- **Other Authorities**
  - **Public Schools/Institutions**
    - **Office of State Architect – apparently not consistent.**
  - **Hospitals (9 month+ delay)**
    - **OSHPD – Some still awaiting approval since May 2001**
- **Installation Cost Issues**
  - **Although some \$ were provided for installation, many sites were not prepared to provide additional funds**
  - **Lack of an integrated package**
  - **Single unit installations on per kW basis appear unattractive**
- **Operation Cost Issues**
  - **Some sites postponed commissioning due to uncertainty in electric rates**



# Example Installation--CSUN

- **6 Capstone 330 MTGs w/2 Micogen HX provided by AQMD**
- **Open, indoor location in Central plant (noise not issue)**
  - Nominal 10 psig gas service
  - “On-board” gas compressor used
  - Electrical Tie-In convenient (3 ph 480V)
  - Telephone and Ethernet communications available
- **CHP used to augment space heating and DHW needs.**
  - Preheat of return feedwater to boilers
  - Good size match on heat loads
  - Heat exchangers ganged;  
one 4 MTG unit and one 2 MTG unit
- **Multi-pak operation (4 units + 2 units)**
- **~\$80,000 installation cost (\$450/kw)**
  - Pad, gas plumbing, electrical,  
water interconnection
- **Commissioned in Dec 2001**



# Example Installation--CSUN

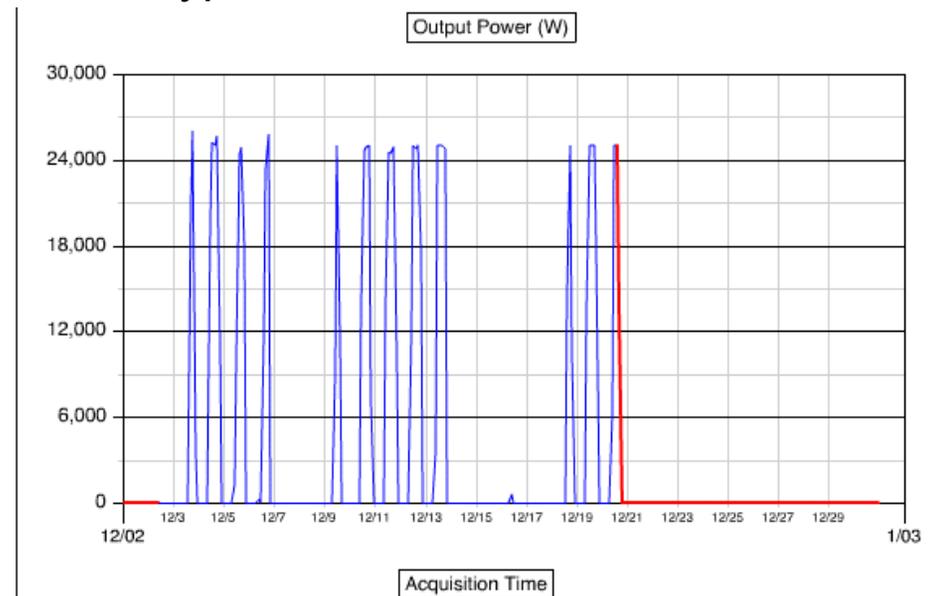
- **Commissioning Issues**
  - Natural Gas Service sizing; required upgrade in piping size.
  - Exhaust leaks from heat exchangers
  - Multi-pack control issues
- **Operational Experiences**
  - Total kw-hr/Possible kw-hr
    - 43% 10/02 to 5/03
  - Down time associated more with communications and software control rather than mechanical component failure.
  - CHP integration: Significant heat/energy loss of “preheated feedwater” entering cold boiler.



# Example Installation--CSUN

- **Time of day use:**
  - approx 10 am to 8 pm (“mid-peak” and “peak” time table)
  - units operated at “base load” (i.e., full power) when running
  - Units have 1,900 to 2,400 hrs each (through 5/03)
- **Economics difficult to assess**
  - **Natural Gas: “core” rates from Southern California Gas**
  - **Electric Power Rate structure still not finalized**
    - Originally on LADWP S-3 rate structure
    - LADWP announced review of S-3 at approximately same time units were commissioned.
    - Still not finalized

Typical Load Profile—Machine #1



# Example Installation—Allergan

- **Pharmaceutical R&D location (Irvine, CA)**
  - Large electrical demand
  - Substantial hot water/space heating
  - Displace planned diesel recip (reduce emissions)
  - Mitigate need to replace failing existing boiler (reduce emissions)
- **2 Capstone C-60 MTGs with Micogen HX for one**
- **Contained within existing equipment room**
  - Tight arrangement makes equipment movement difficult
  - Noise not an issue
  - Electric tie-in, 480V
  - Gas nearby
  - Phone installation needed



# Example Installation—Allergan

- **Timeline**

- Mar 02—requested 4 60 kW MTGs
- Jun 02—granted 2 60 kW MTGs w/dual mode operation
- Oct 02—Dec 02—Initial Installation
- Jan 03—UL certification required by City
- Feb 03--Installation dismantled and UL certified version installed and approved by City
- Feb 03 – May 03 Commissioning issues

- **Interconnection Experience**

- SCE required meters to be installed for each unit (\$7,000) which will never be read (Allergan prohibited from selling power to SCE)
- SCE failed two applications based on measured protective relay settings being outside of requirements
- Third application was approved after SCE provided Capstone with the required settings



# Example Installation—Allergan

- **Operational Experience: General**
  - Exhaust dampers installed have been unreliable
    - One seized closed-may have resulted in engine failure
  - Temperature Issues
    - Ducting insulation insufficient—room temps over 115 F
    - Allergan added insulation and had to increase room ventilation to mitigate
    - More system heat was generated than suggested by specs
- **Operational Experience: MTGs**
  - Unit 1 (w/heat recovery)—major startup/operational issues
    - Multiple Cooling Fans, Controller boards failed/replaced
    - Still not truly operation (5/03)
    - Backup boiler installed
  - Unit 2
    - Also problems with cooling fans
    - Has operated ~1500 hrs out of 3000 desired since Feb 03



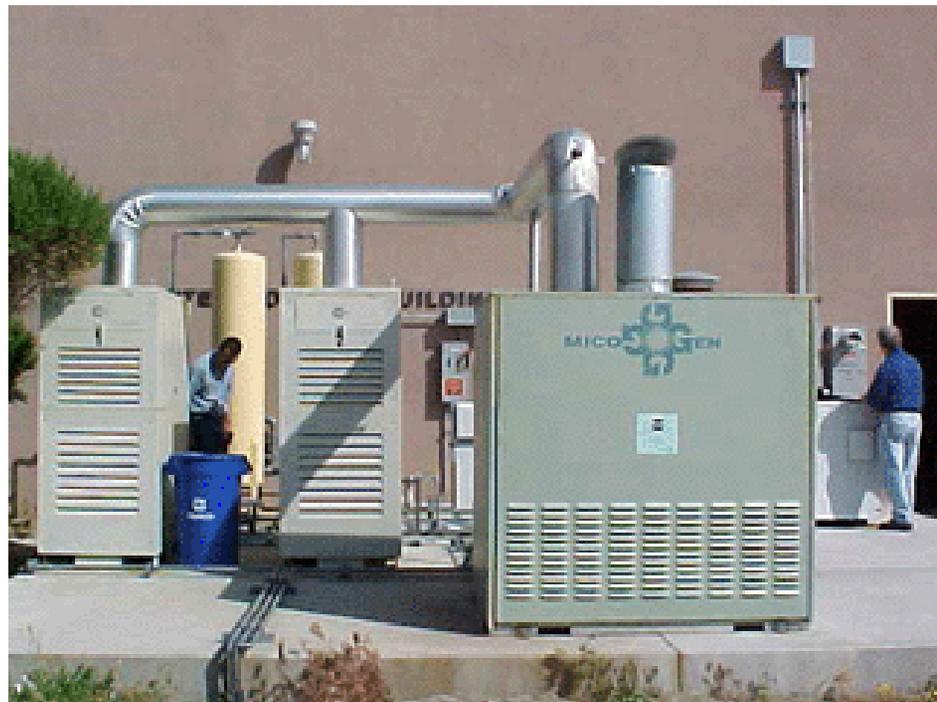
# Example Installation—Allergan

- **Self Gen Incentive Experience**
  - Applied for \$36,000 CEC rebate through SCE in Oct 2002
  - Continuing/repeated requests by SCE for additional information; information repeatedly provided.
  - Final application submitted in May 2003
    - Delays due to operational issues
    - Must be finalized by Dec 2003
- **Costs**
  - Project Cost was budgeted at \$190,000
    - Removal of existing boiler, ducting, prepping room
    - Heat Exchanger for the MTGs (~\$12,000 for HX)
    - Installation of new equipment, ducting
    - \$1,483/kW for installation
  - Actual Costs (through 5/03)
    - \$260,000 which includes removal/reinstall of MTG equipment, ducting, adding/reinstalling additional insulation, increased room ventilation



# Example Installation--SMWD

- **Chiquita Water Reclamation Plant (2 Capstone 330 MTGs w/ 1 Micogen Heat Exchanger provided by AQMD)**
- **Open, outdoor space (noise not an issue)**
  - Convenient electric tie-in, 480V 3ph
  - Phone installation needed
- **SMWD has ordered (and is paying for) 2 more units**  
**Installation to begin 6/23/03**
- **Operation on digester gas**
- **Multipak Operation**
- **Installation Cost: \$83,666**
  - Gas cleanup, connections, site prep, interconnect (\$1,400), air permit (\$1,611), source test (\$8,815)



# Example Installation--SMWD

- **Current CHP provides all necessary heating for digesters.**
  - 2 boilers on-site – 1 is off and the other on stand-by
  - Heat from 2 new MTGs will heat 3<sup>rd</sup> (future) digester and/or dry sludge for transport



# Example Installation--SMWD

- **Operational Experience**
  - **Commissioned end of December, 2001**
  - **10,800 hours operation on each machine (5/03)**  
**>530,000 kW-hr generated**
  - **Pleased with technology – first 2 units operating reliably**  
**90% strict reliability (operating/calendar time) as of May 2003**
  - **Service**
    - **Typically slow responding**
    - **Typically slow resolving**
  - **Typical operating cost savings: ~\$4,000-\$5,000 per month**
  - **Several delays in finding contractor to install 3<sup>rd</sup> and 4<sup>th</sup> turbines**



# Example Installation—UC Irvine

- **3 Capstone C-60's, No CHP utilization**
- **Gas pressure variable from few inches to 150 psig**
- **Adjacent to Laboratory Facility**
  - **Sound concerns to residences 0.25-0.5 miles from site**
  - **\$7,500 study to approve**
- **Additional 480 V 600 A Tie-in**
  - **Existing interconnect OK**
- **Ethernet and Phone available**
- **Campus Authorities required 4 months and \$21,850 to develop and review plans**
- **Installation Cost: \$71,500**
  - **Electrical, gas meter, conduit, protections, gauges, labor, campus plans/management**
- **Commissioned Aug 2001**



# Example Installation—UC Irvine

- **Commissioning Issues**
  - **Software Versions were initially incorrect, resolved in 10 days**
- **Operational Experience**
  - **Strict Availability (83, 87, 88%) 8/01 to 8/02**
  - **Availability Accounting for Non-MTG Downtime (94.5, 99.4, 100%) (8/01 to 8/02)**
  - **In Oct 02, Smart Proportional Valve failed on two units, replaced within 2 days by on-site Authorized Service Provider**
  - **April 03, gas compressor serviced**
  - **Strict Availability (84, 76, 88%) 8/01 to 5/03**
    - **“Low” Units undergoing research tests and procedures**
    - **13,300, 12,117, 14,006 hours on each unit (through 5/03)**
  - **5/03 Operating Software Upgraded**



# Example Installation—EMWD

- **5 Capstone C-60's, CHP (hot water) utilization on one pair**
  - 4 clustered in one area
  - One at separate location
  - Pair on CHP are Multi-packed
- **Gas pressure at 25 psig**
- **Outside Installation**
- **Self Installed and Serviced**
- **Installation Cost: \$132,500**
- **Separate gas meter installed**
- **No net-electric meter**
- **Ethernet and Phone available**
- **Commissioned May 2003**



# Example Installation—EMWD

- **Commissioning Issues**
  - Experience with other MTG installation by ASP prompted desire to install in-house.
  - Several staff received ASP training at Capstone
- **Operational Experience**
  - Very reliable; 24/7 operation
  - CHP of hot water adequate to off-set operation of hot water heater for
  - Net savings about \$12,000 per month



# Example Installation—City of Banning

- **Municipal Water Reclamation Plant (2 Capstone 330 MTGs w/ 1 Micogen Heat Exchanger provided by AQMD)**
- **Open, outdoor space (noise not an issue)**
  - Convenient electric tie-in, 480V 3ph
  - Phone installation needed
- **Operation on digester gas**
- **Multipak Operation**
- **Installation Cost: \$50,000**
  - Gas cleanup, connections, site prep.
- **Municipal Utility**
  - Minimal Interconnect issues



# Example Installation—City of Banning

- **Commissioning Issues**
  - Poor opinion of installation
  - Gas supply not consistent
  - Competition with boiler needs
- **Operational Experience**
  - Disappointing operation
  - Engine Failure
    - One engine @ 600 hrs
    - Other engine questionable
    - No backflow dampers
  - Minimal benefit from CHP
    - Unreliable operation



# Example Installations: Summary

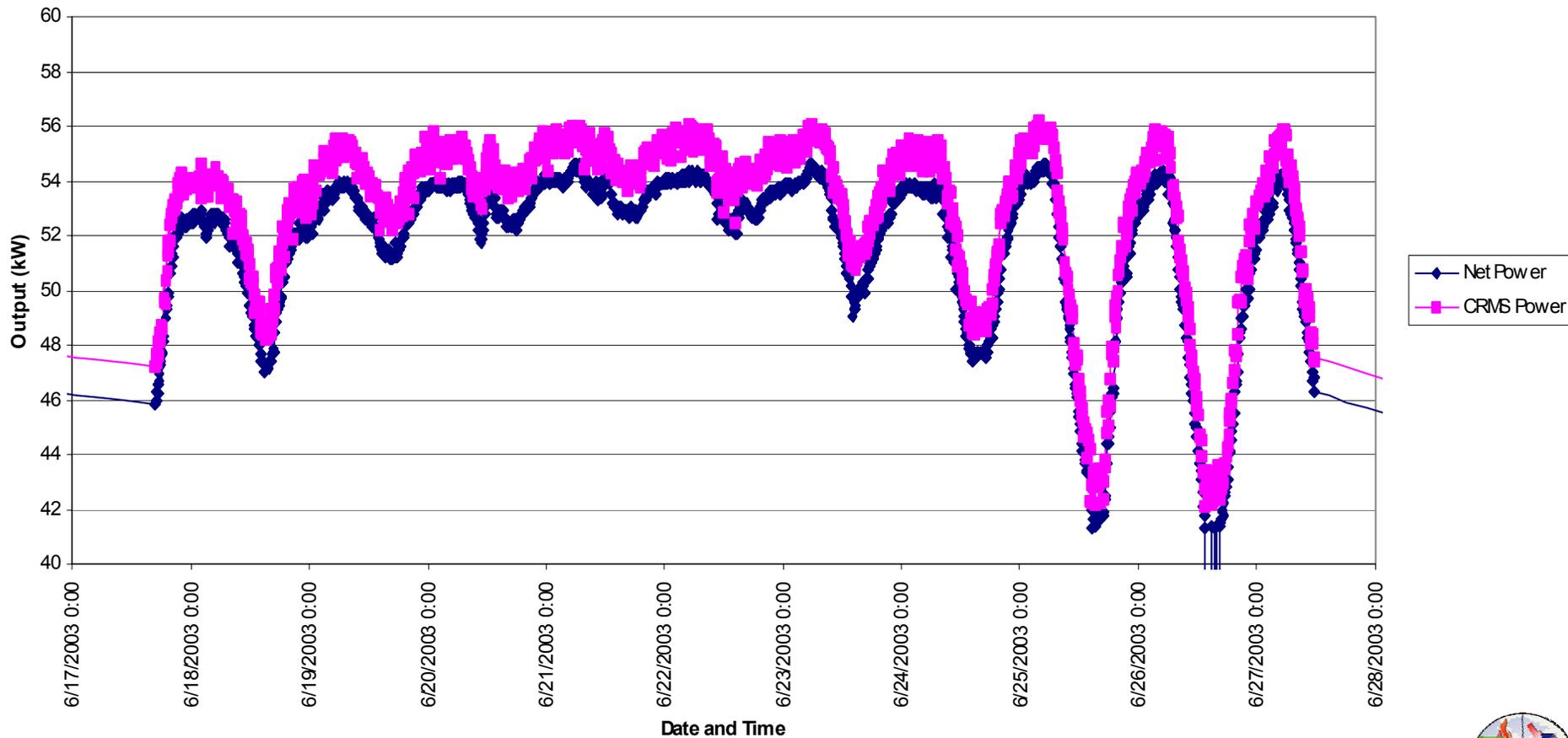
| Site            | Units | Total kw | CHP? | Dual Mode? | Fuel     |
|-----------------|-------|----------|------|------------|----------|
| CSUN            | 6     | 180      | Y    | N          | Nat Gas  |
| RSM             | 2     | 60       | Y    | N          | Digester |
| UCI             | 3     | 180      | N    | N          | Nat Gas  |
| Allergan        | 2     | 120      | Y    | Y          | Nat Gas  |
| EMWD            | 4     | 240      | Y    | N          | Nat Gas  |
| City of Banning | 2     | 60       | Y    | N          | Digester |

| Site            | Installation Experience | Installation |          |         | Reliability |
|-----------------|-------------------------|--------------|----------|---------|-------------|
|                 |                         | Total        | per Unit | per kW  |             |
| CSUN            | minor problems          | \$80,000     | \$13,333 | \$444   | fair        |
| RSM             | minor problems          | \$83,666     | \$41,833 | \$1,394 | good        |
| UCI             | sound, campus           | \$71,500     | \$23,833 | \$397   | excellent   |
| Allergan        | equip probs, utility    | \$178,000    | \$89,000 | \$1,483 | poor        |
| EMWD            | Self Installation; few  | \$132,000    | \$33,000 | \$550   | excellent   |
| City of Banning | Highly problematic      | \$50,000     | \$25,000 | \$833   | poor        |



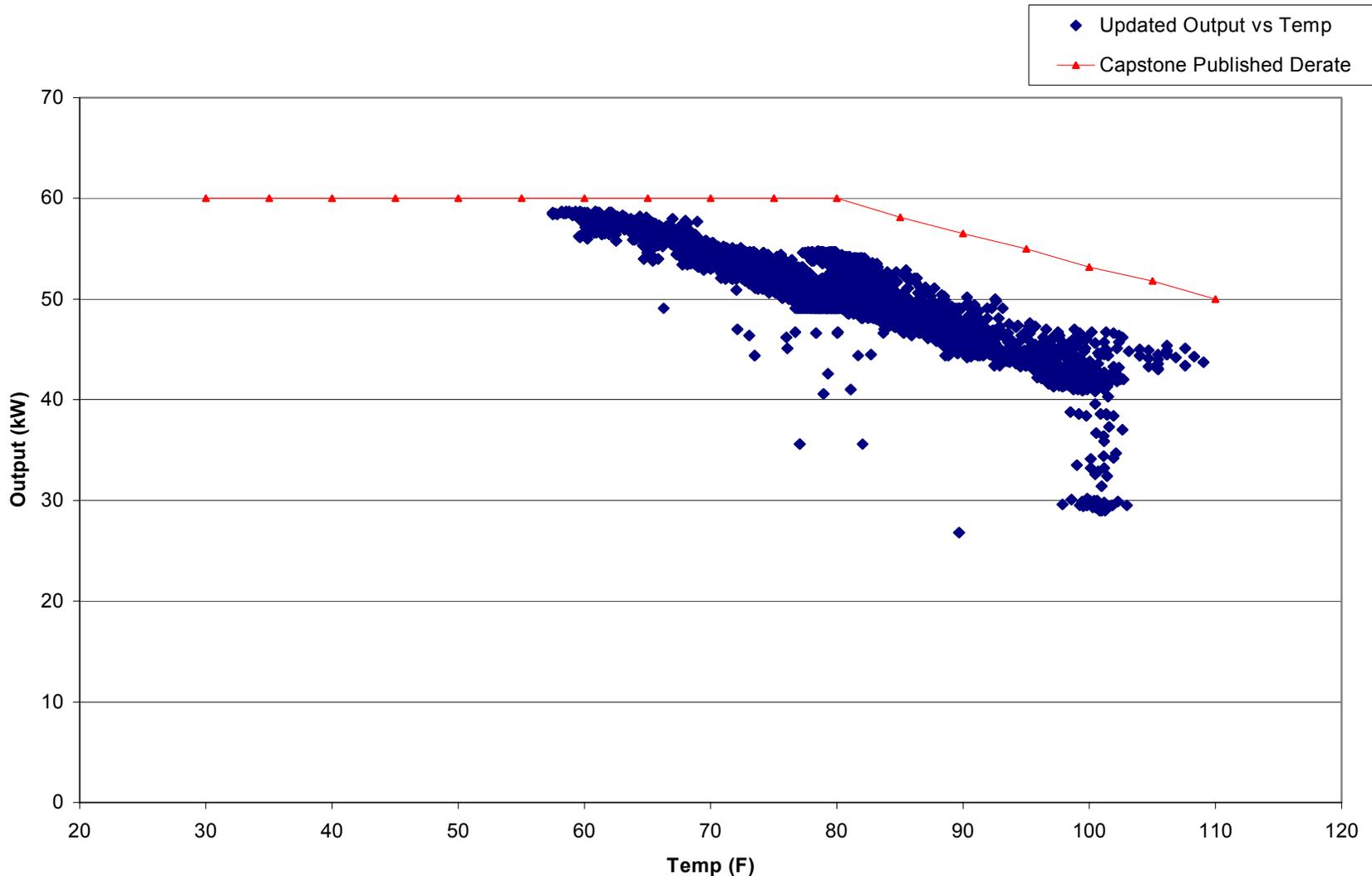
# Long Term Performance Monitoring

- Typical results from long term performance monitoring



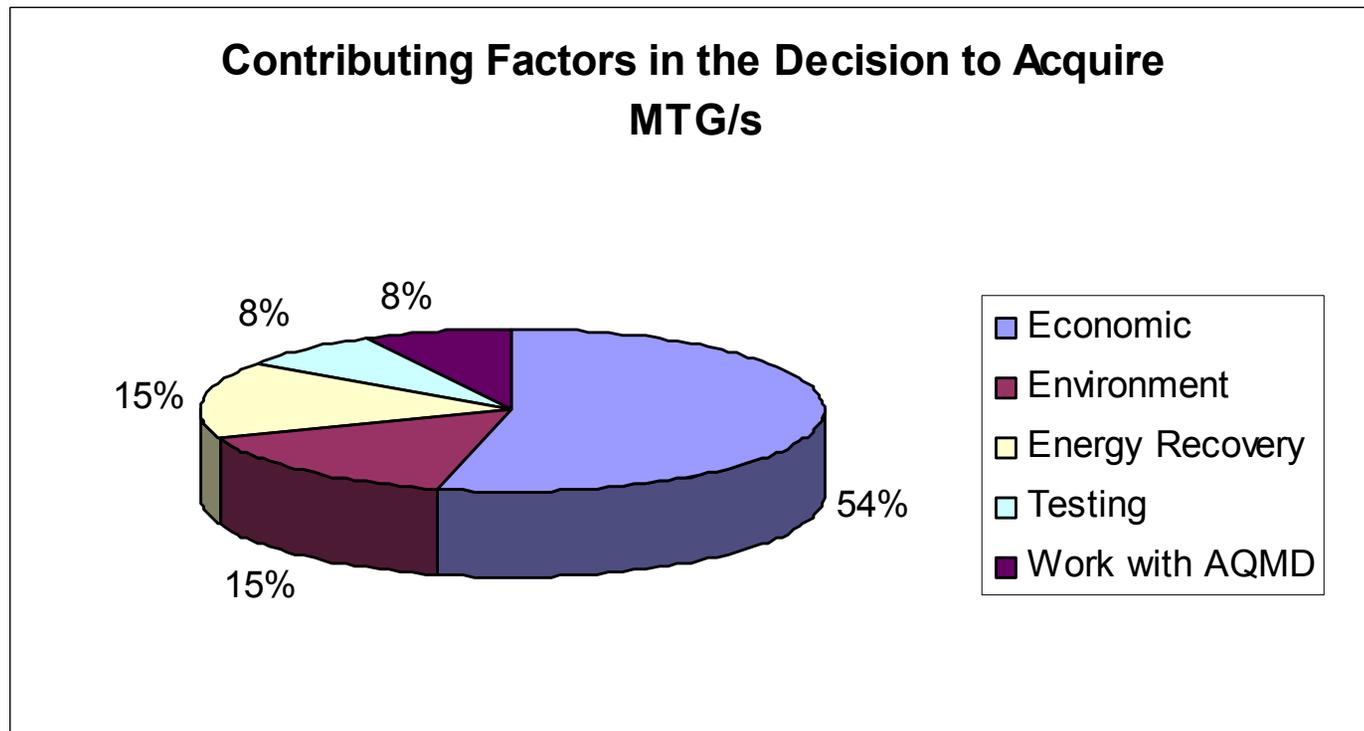
# Long Term Performance Monitoring

- Typical results from long term performance monitoring



# Post Installation Site Survey

- **Survey Sent to Program Participants**
  - 30 sent, 13 responses received.
- **Reason for Participation:**



# Post Installation Site Survey

- **Survey Sent to Program Participants**
  - 30 sent, 13 responses received.
- **Satisfaction with Installation (1=bad, 10 = excellent)**
  - Average: 6.0 (nine responses excluding self install)
  - Range: 1 - 10
- **Satisfaction with Commissioning (1=bad, 10 = excellent)**
  - Average: 6.4 (nine responses excluding self install)
  - Range: 1 - 9
- **Satisfaction with Service (1=bad, 10 = excellent)**
  - Average: 7.4 (nine responses excluding self install)
  - Range: 4 - 9



# Concluding Remarks

- **Uncertain market is creating decision challenges**
  - Fuel price vs. electricity cost—California is attractive for now
  - “Free fuel” applications appear to work well economically
  - Using waste heat helps ensure payback
- **Installation Costs are a Major Hurdle**
  - Single/Few Unit Installation are relatively expensive
  - Integrated/Packaged units should help reduce costs
    - Each Installation has minimum fixed costs
  - More options needed
    - Integrated maintenance package needed to help service provider recognize consistent cash flow
- **Reliability/Availability**
  - Facility design, construction quality, installation quality are key to reliability/availability
    - Capstone C-60 and 330 products individually are high quality

