TEXAS LoanSTAR
MONITORING AND ANALYSIS PROGRAM

Report to

THE MONITORING AND ADVISORY REVIEW COMMITTEE

Presentations

June 2–3, 1993
Austin, TX

ENERGY SYSTEMS LABORATORY
Department of Mechanical Engineering
Texas Engineering Experiment Station
Texas A&M University System
PRESENTATIONS
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Current Status of the LoanSTAR Program - W. Dan Turner

Task 1 - LoanSTAR Energy Auditing: Update and Changes - Warren M. Heffington

Task 6 - Improved Energy Audit Process: Accomplishments - Jeff S. Haberl, John K. Houcek, and Mingsheng Liu

Task A - Building Monitoring on the LoanSTAR Project: Agency Update - Dennis L. O'Neal, Chuck Bohmer, John Bryant, and Curtis Boecker

Task B - Calibration Laboratory - W. Dan Turner, Dennis L. O'Neal, Jeff S. Haberl, Chuck Bohmer, John Bryant, Kelly Milligan, and Jay Robinson

Task C - Data Handling and Retrieval: Accomplishments - Jeff S. Haberl, Robert Sparks, Dean Willis, and Ron Chambers

Task D - Analysis of Data and Software Development: Accomplishments - David E. Claridge and Jeff S. Haberl


Task D - Analysis and Software Development: Savings Measurement Accomplishments - David E. Claridge, Jeff S. Haberl, J. Kelly Kissock, and Jinrong Wang

Task E - Reporting and Technology Transfer: Accomplishments - David E. Claridge and Jeff S. Haberl

Task E - O&M Identification and Implementation - David E. Claridge, Jeff S. Haberl, John K. Houcek, Mingsheng Liu, and Aamer Athar

Task E - Reporting the Savings - David E. Claridge, Jeff S. Haberl, Aamer Athar, Ron Chambers, Srinivas Katipamula, Kelly Kissock, and Robert Sparks

Future Directions - W. Dan Turner
Wednesday, June 2, 1993

7:30 - 8:30 a.m. Continental Breakfast

8:00 - 8:30 a.m. Opening Comments, Introductions, Energy Office

8:30 - 10:15 a.m. LoanSTAR Overview, Economic Impact Comments

Task 1: Energy Audits, Training, Audit Procedures in 1992-93 (Warren M. Heffington)

Task 6: Improved Energy Audits (Jeff S. Haberl)

Task A: Metering Hardware and Oversight of Data Acquisition Subcontractors (Dennis L. O'Neal)

Task B: Calibration Laboratory (W. D. Turner)

Feedback on Tasks 1, A, B

10:15 - 10:30 a.m. Coffee Break

10:30 - 12:15 p.m. Task C: Data Handling and Retrieval (Jeff Haberl, Robert Sparks)

Task D: Analysis of Data and Software Development (Jeff Haberl, Robert Sparks)

Feedback on Tasks C, D

12:15 - 1:30 p.m. Sit-down Lunch

1:30 - 3:30 p.m. Task D: Analysis of Data and Software Development (David Claridge and Kelly Kissock)

Task E: LoanSTAR Technology Transfer (David Claridge, Jeff Haberl, Dan Turner)

Feedback on Tasks D, E

3:30 - 3:45 p.m. Coffee Break
3:45 - 4:00 p.m.  Ernie Freeman, U.S. Department of Energy - "Existing Buildings Research"

4:00 - 4:15 p.m.  Bill Mixon, Oak Ridge National Lab - "ORNL Commercial Retrofit Update"

4:15 - 4:30 p.m.  Margaret Fels, Princeton University - "A Study of the Effect of Humidity on PRISM Results"

4:30 - 4:45 p.m.  Todd Taylor, Battelle Pacific Northwest Laboratories - "Dip-Stick Audits"

4:45 - 5:00 p.m.  Vijay Reddy, Houston Lighting & Power - "HL&P DSM Programs"

5:00 - 5:15 p.m.  Grant Brohard, Pacific Gas & Electric - "Results of Date ACT^2"

5:15 - 5:30 p.m.  Hashem Akbari, Lawrence Berkeley Laboratory - "Use of Energy Management Systems for Building Energy Monitoring"

5:30 - 5:45 p.m.  Ren Anderson, NREL - "TBA"

5:45 - 6:00 p.m.  Bruce Hunn, University of Texas at Austin - "TBA"

6:00 - 6:30 p.m.  Break

6:30  Dinner

**Thursday, June 3, 1993**

7:30 - 8:30 a.m.  Sit-down Breakfast

8:30 - 10:15 a.m.  Future Directions

Tasks 1, 6
Task A
Task B
Task C
Task D
Task E

10:15 - 10:30 a.m.  Coffee Break

10:30 - 12:30 p.m.  Wrap-up, Open Discussion

12:30 - 1:30 p.m.  Buffet Lunch in the Restaurant
Current Status

LoanSTAR Program

for

MARC Meeting

by

W. D. Turner

June 1993
GOVERNOR'S ENERGY OFFICE

MARC
- GEO
- LBL
- MIT
- UT
- ORNL
- NREL

ENERGY SYSTEMS LAB
- Monitoring & Analysis
  - W. D. Turner, Program Manager

Task 1
- Desktop Audit, Review, & Training
  - Warren Heffington, P.I.

Task 6
- Improved Energy Audit
  - Jeff Haberl, P.I.

Task B
- Calibration Laboratory
  - Dan Turner, P.I.

Task A
- Metering Installation
  - Dennis O'Neal, P.I.

Task C
- Computer and Technical Support
  - Jeff Haberl, P.I.

Task D
- Analysis
  - Software Development
    - David Claridge, P.I.

Task E
- Reporting and Technology Transfer
  - Jeff Haberl, P.I.

MAR
- Subcontracts
  - MIT Wash. U.
  - Princeton LBL
LoanSTAR Personnel
May 1993

Faculty:  W. D. Turner, D. O'Neal, D. Claridge, W. Heffington, J. Haberl, T. A. Reddy, N. Saman

Administrative:  D. Greer, D. Rosenkranz, S. Swanson, D. Wallace


Undergraduate Students:  M. Castillo, B. Broyles, J. Steele, J. Rife, S. Gregorcyk
Marketing (GEO, Contractors, Auditors)

Audit Request (Owners)

Audit Assignment (GEO)

Audit (Auditing Firms)

Audit Report Review (GEO / A&M)

Loan Approved (GEO)

Metering (A&M)

Design / Bid (Engineering Firms)

Implementation (Contractors / Inhouse)

Repayment (Owners)

Site Map (A&M)

Monitoring Plan Approved (GEO)

Monitoring (A&M)

Reporting (MECR, Voyager, etc.)

Savings (A&M)

Audit Report Submission (Auditor)

Review (GEO & A&M)

Report Approved (A&M & GEO)

Loan Application (Owner)

Review Application (GEO)

Optimal Revisions (Owner)

Loan Approved (GEO)
Percent Area by Functional Use
Buildings Monitored as of April, 1993

Total Area Monitored Under LoanSTAR Program: 18.27 Million sq.ft.

- Medical Institutions: (33.7%)
- Offices: (14.7%)
- Offices/Computer Facilities: (7.3%)
- School Districts: (12.1%)
- Classrooms/offices: (10.1%)
- Classrooms/Offices/Labs: (14.4%)
- Classrooms/Offices/Theaters: (4.1%)
- Libraries: (1.8%)
Estimated Cost of Retrofits
As of May, 1993

Number Reporting Savings: 24 Sites/36 Buildings
Number Completed Retrofits: 35 Sites/65 Buildings
Number being Monitored: 69 Sites/199 Buildings
Number Monitored & Under Future Contract: 70 Sites/200 Buildings

Cost of Retrofits ($)
(Millions)
SITES MONITORED UNDER LOANSTAR PROGRAM AS OF MAY 1993
Audit Estimated Retrofit Cost

69 Sites/199 Buildings Monitored as of May 1993
Total Estimated Retrofit Cost: $32.5 Million

Audit Estimated Cost Savings

69 Sites/199 Buildings Monitored as of May 1993
Annual Cost Savings: $9.6 Million
Summary of ECRM's for Buildings Being Monitored as of May 1993

<table>
<thead>
<tr>
<th>ECRM Recommendations</th>
<th>Impl. Cost $</th>
<th>% of Total Impl. Cost</th>
<th>Cost Savings $</th>
<th>% of Total Cost Savings</th>
<th>Simple Payback Yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC System Retrofits</td>
<td>$10,504,625</td>
<td>32.3</td>
<td>$3,256,227</td>
<td>34.0</td>
<td>3.2</td>
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<tr>
<td>Boiler &amp; Steam Retrofits</td>
<td>$1,439,646</td>
<td>4.4</td>
<td>$1,116,516</td>
<td>11.7</td>
<td>1.3</td>
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<tr>
<td>Motor/VSD/VSP Conversion</td>
<td>$4,679,163</td>
<td>14.4</td>
<td>$1,172,166</td>
<td>12.3</td>
<td>4.0</td>
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<tr>
<td>Chiller &amp; CHW Retrofits</td>
<td>$1,936,886</td>
<td>6.0</td>
<td>$362,643</td>
<td>3.8</td>
<td>5.3</td>
</tr>
<tr>
<td>Lighting Retrofits</td>
<td>$4,841,987</td>
<td>14.9</td>
<td>$1,605,062</td>
<td>16.8</td>
<td>3.0</td>
</tr>
<tr>
<td>EMC Systems</td>
<td>$3,368,158</td>
<td>10.4</td>
<td>$736,918</td>
<td>7.7</td>
<td>4.6</td>
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<tr>
<td>Pumping Sys Retrofits</td>
<td>$1,752,647</td>
<td>5.4</td>
<td>$655,057</td>
<td>6.8</td>
<td>2.7</td>
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<tr>
<td>Others</td>
<td>$3,997,383</td>
<td>12.3</td>
<td>$662,291</td>
<td>6.9</td>
<td>6.0</td>
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<tr>
<td>Totals</td>
<td>$32,520,495</td>
<td>100</td>
<td>$9,566,880</td>
<td>100</td>
<td>3.4</td>
</tr>
</tbody>
</table>
Energy Conservation Identified in Buildings Monitored Under LoanSTAR
Program as of May 1993

<table>
<thead>
<tr>
<th>Purchased Utility Category</th>
<th>Site Energy</th>
<th>Site Energy** (million Btu/yr)</th>
<th>Source Energy* (million Btu/yr)</th>
<th>Fractional Site Energy Savings (%)</th>
<th>Fractional Source Energy Savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity</td>
<td>113,282,528 kWh/yr</td>
<td>386,520</td>
<td>1,314,077</td>
<td>26.6</td>
<td>52.9</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>305,274 MCF/yr</td>
<td>314,432</td>
<td>314,432</td>
<td>21.7</td>
<td>12.7</td>
</tr>
<tr>
<td>Steam/Hot Water</td>
<td>318,237 (million Btu/yr)</td>
<td>318,237</td>
<td>424,316</td>
<td>21.9</td>
<td>17.1</td>
</tr>
<tr>
<td>Chilled Water</td>
<td>35,986,682 (Ton-hr/yr)</td>
<td>431,840</td>
<td>431,840</td>
<td>29.8</td>
<td>17.4</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>1,451,029</td>
<td>2,484,666</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

** Btu savings calculated on the basis of site Btus (i.e. 3,412 Btu/kWh, 1,030,000 Btu/MCF and 12,000 Btu/ton-hr)
* Btu savings calculated on the basis of source Btus (i.e. 11,600 Btu/kWh, 1,030,000 Btu/MCF, boiler efficiency of 75% and 12,000 Btu/ton-hr)
AUDIT ESTIMATED ENERGY SAVINGS
69 Sites/199 Buildings Monitored as of May 1993
Site Energy Savings: 1.45 Trillion Btu/yr

- Chilled Water (29.8%)
- Electricity (26.6%)
- Natural Gas (21.7%)
- Steam/Hot Water (21.9%)

Btu savings calculated on the basis of site Btus (i.e. 3,412 Btu/kWh, 1,030,000 Btu/MCF & 12,000 Btu/ton-hr)
Total Cumulative Repayments of Loans as of April, 1993

The graph shows the total cumulative repayments of loans as of April 1993. The x-axis represents months from February 1992 to March 1993, while the y-axis represents the amount in $, ranging from $500,000 to $5,000,000. The graph indicates that the number of sites is 15 as of April 1993.
LOANS EXECUTED AS OF MAY, 1993
Total Loan Amount: $49,738,000

- School Districts (13.2%)
- Local Govt. & County Buildings (9.2%)
- State Agencies (77.5%)
LOANS IN PROCESS AS OF MAY, 1993
Total Loan Amount: $11,840,000

- School Districts (14.0%)
- Local Govt. & County Buildings (20.9%)
- State Agencies (65.1%)
LOANS EXECUTED & IN PROCESS
Total as of May, 1993: $61,578,000

- School Districts (13.4%)
- Local Govt. & County Buildings (11.5%)
- State Agencies (75.1%)
LoanSTAR ENERGY AUDITING:
UPDATE AND CHANGES
(TASK 1)

Presented By:
Warren M. Heffington

Energy Systems Laboratory
and
Mechanical Engineering Dept.
Texas A&M University
College Station, Texas

June 2, 1993
• **Role of Energy Systems Laboratory (Task 1)**

  - Provide thorough review of detailed energy analysis reports
  - Provide auditor training
  - Streamline and update audit process

• **Review Personnel**

  - Three staff engineers
    (Saman, Nutter, Britton - two are P.E.s)
  - One cost estimator (Tiner - P.E.)
  - One water/wastewater specialist (Stallard)
  - Several graduate students (3/8 FTE)
• Reports are reviewed for:

  • Suitability of engineering recommendations

  • Compliance with audit agreements (screening report)

  • Compliance with audit guidelines

  • Compliance with audit format

  • Correctness of numbers
• Basis for LoanSTAR loans

• Energy audits by private consultant engineering firms

• Presently 27 firms under contract to EO for audits

• About 14 are active

• Each energy audit report shows:
  • Implementation costs - basis for amount of loan
  • Calculated annual savings - basis for payback of loan

• Following are data and observations

• From completed audit reports

• By report reviewers (also with independent audit experience)
• LoanSTAR Audit Results

• 1/89 - 5/93

• Dependent results for capital-intensive projects known as ECRMs

• Reviewed by ESL

  • $73.1 million investment costs
  
  • $20.5 million annual savings
  
  • 3.6 year simple payback
  
  • 70.0 million sq. ft.
  
  • 111 audit reports
  
  • 63% of the investment cost is for state agencies
  
  • 37% is for local governments and school districts
• Two Types of Reports

• Simplified

  • Category I ECRMs - limited calculation projects using historical paybacks and estimate of implementation cost.

  • Category II ECRMs - SimpCalc or other simplified calculation procedure

• Detailed

  • Category III ECRM - detailed calculations and documentation required
LoanSTAR Results from Simplified and Detailed Audits
(Reviewed by ESL, 1/92 - 5/93)

<table>
<thead>
<tr>
<th></th>
<th>Investment Cost</th>
<th>Annual Savings</th>
<th>Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>million $</td>
<td>million $/yr</td>
<td>Yrs</td>
</tr>
<tr>
<td>Simplified</td>
<td>6.7</td>
<td>1.8</td>
<td>3.7</td>
</tr>
<tr>
<td>Detailed</td>
<td>20.0</td>
<td>4.7</td>
<td>4.3</td>
</tr>
<tr>
<td>Total</td>
<td>26.7</td>
<td>6.5</td>
<td>4.1</td>
</tr>
</tbody>
</table>
LoanSTAR Audit Results from Simplified Reports (Reviewed by non-ESL Personnel)

- $3.1 million investment cost
- 0.89 million annual savings
- 3.5 year simple payback
- 4.0 million sq. ft.
- 20 audit reports
Major LoanSTAR Funding Opportunities*

<table>
<thead>
<tr>
<th></th>
<th>Investment Cost</th>
<th>Annual Savings</th>
<th>Payback</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>million $</td>
<td>million $/yr</td>
<td>Yrs</td>
</tr>
<tr>
<td>TECCP (ESL)**</td>
<td>30.5</td>
<td>10.9</td>
<td>2.8</td>
</tr>
<tr>
<td>Detailed (ESL)</td>
<td>66.4</td>
<td>18.7</td>
<td>3.6</td>
</tr>
<tr>
<td>Simplified (ESL)</td>
<td>6.7</td>
<td>1.8</td>
<td>3.7</td>
</tr>
<tr>
<td>Simplified (Non-ESL)</td>
<td>3.1</td>
<td>0.89</td>
<td>3.5</td>
</tr>
<tr>
<td>Total</td>
<td>106.7</td>
<td>32.3</td>
<td>3.3</td>
</tr>
</tbody>
</table>

*Not complete.

**TECCP was originally $42.8 million in investment costs and $19.9 million in annual savings with 2.2 year payback.
- LoanSTAR "Dipstick" ECRMs

  - $250,000 investment cost
  - $120,000 annual savings
  - 2.1 year simple payback
  - Used in 4 reports

- Types of projects

  - Energy-efficient Motors (1)
  - Incandescent to Fluorescent (2)
  - Incandescent exit lamps to 9-W Fluorescent (1)
  - Time clock shut down of HVAC equipment (1)
  - 40-W to 34-W Fluorescent (1)
• **Simplified LoanSTAR Report Problems (noted by ESL)**

  • 9 of 21 reports have major problems

  • Major problem is cost savings or implementation cost change in review of 5% or more

<table>
<thead>
<tr>
<th>Report</th>
<th>Change in Cost Savings, %</th>
<th>Change in Implementation Cost, %</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cypress-Fairbanks ISD</td>
<td>-35</td>
<td>+17</td>
<td>no lighting data</td>
</tr>
<tr>
<td>Dallas ISD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mesquite ISD</td>
<td></td>
<td>+60*</td>
<td>Other major problems</td>
</tr>
<tr>
<td>County of El Paso</td>
<td>-6</td>
<td>-14</td>
<td></td>
</tr>
<tr>
<td>City of New Braunfels</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nolan County</td>
<td>+40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SWCID</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercedes ISD</td>
<td>+35</td>
<td>-5</td>
<td>not sealed</td>
</tr>
<tr>
<td>Howard County</td>
<td>-7</td>
<td>-28</td>
<td></td>
</tr>
<tr>
<td>Matagorda County</td>
<td>-10</td>
<td>-25</td>
<td>not sealed</td>
</tr>
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</table>

*The displayed investment costs changed by 60%. The actual investment cost in the first version was obscured by poor communication and unacceptable reporting practices.*
TASK A

BUILDING MONITORING ON THE LoanSTAR PROJECT: AGENCY UPDATE

Dennis O'Neal
Chuck Bohmer
John Bryant
Curtis Boecker

Monitoring Analysis and Review Committee Meeting
June 2-3, 1993
Austin, Texas
FUNCTIONS OF TASK A

- Determine metering requirements at each site
- Oversee installation of equipment
- Maintain monitoring equipment
UPDATE SINCE LAST MARC MEETING

- 15 new buildings on line

- Maintenance is still an important part of Task A
  
  - Flow Meters
  
  - Data Loggers
  
  - Electrical Components
  
  - Pressure Transducers
UPDATE (CONTINUED)

• Equipment database expanded

• Continued integration with Task B in the Calibration Laboratory
  • Calibration of all existing flow research flow meters during summer 1992
  • Recalibration of RH transducers
  • Calibration of new flow meters for new installations
## SITES COMPLETED SINCE MAY 1992

<table>
<thead>
<tr>
<th>SITE</th>
<th># BLDGS</th>
<th># POINTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NACOGDOCHES ISD</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>GALVESTON ISD</td>
<td>5</td>
<td>30</td>
</tr>
<tr>
<td>UT AUSTIN</td>
<td>3</td>
<td>28</td>
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<tr>
<td>CAPITOL COMPLEX CHW METERING</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>SITE</td>
<td># BLDGS</td>
<td># POINTS</td>
</tr>
<tr>
<td>-------------------------</td>
<td>---------</td>
<td>----------</td>
</tr>
<tr>
<td>GALVESTON ISD</td>
<td>5</td>
<td>5</td>
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<td>UT PAN AMERICAN</td>
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<td>TSTC HARLINGEN</td>
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<td>UT MEDICAL BRANCH</td>
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<tr>
<td>TEXAS DEPT. OF HEALTH</td>
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## SITES UNDER CONSTRUCTION

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<tr>
<th>SITE</th>
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<tr>
<td>UT ARLINGTON</td>
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<td>40</td>
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<td>CAPITOL BUILDING</td>
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<tr>
<td>CAPITOL EXTENSION</td>
<td>2</td>
<td>11</td>
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NEW SITES THAT MAY SOON START CONSTRUCTION

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<th># BLDGS</th>
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<tbody>
<tr>
<td>• TEXAS A&amp;M/COLLEGE STATION</td>
<td>3</td>
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<tr>
<td>• TEXAS WOMAN'S UNIVERSITY</td>
<td>4</td>
</tr>
<tr>
<td>• EL PASO COMMUNITY COLLEGE</td>
<td>3</td>
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</table>
MANY EQUIPMENT PROBLEMS HAVE BEEN RESOLVED

<table>
<thead>
<tr>
<th>TYPE OF EQUIPMENT</th>
<th># INSTALLED</th>
<th>TOTAL # OF PROBLEMS</th>
<th># OF PROBLEMS LAST YEAR</th>
<th># PROBLEMS FIXED</th>
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<tbody>
<tr>
<td>INSERTION FLOWMETERS</td>
<td>55</td>
<td>20</td>
<td>6</td>
<td>20</td>
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<tr>
<td>PRESSURE TRANSDUCERS</td>
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<td>1</td>
<td>4</td>
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<td>BTU METERS</td>
<td>52</td>
<td>9</td>
<td>6</td>
<td>8</td>
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<tr>
<td>CTs</td>
<td>1700+</td>
<td>3</td>
<td>0</td>
<td>3</td>
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<tr>
<td>DATA LOGGERS</td>
<td>72</td>
<td>13</td>
<td>8</td>
<td>13</td>
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<td>MODEMS</td>
<td>60</td>
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TYPICAL METERING PROBLEMS

- Phone lines down during bad weather

- Gas company meters non-functional (poor response time for repairs - up to 3 months)

- Retrofit contractors damage or disable metering equipment

- Electronic metering components fail (data loggers, Btu meters, communications boards)

- Signal wires broken by contractors

- Physical failure of equipment
TASK B

CALIBRATION LABORATORY

Dan Turner, P. I.
Dennis O'Neal
Jeff Haberl
Chuck Bohmer
John Bryant
Kelly Milligan
Jay Robinson
CALIBRATION LABORATORY
SUPPORT ACTIVITIES

• CALIBRATION OF SENSORS (Temperature and Relative Humidity) FOR WEATHER STATIONS IN TEMP-HUMIDITY CHAMBER

• CALIBRATION OF SOLAR RADIATION SENSOR FOR WEATHER STATIONS

• TESTING AND VERIFICATION OF ACCURACY OF NEW C180-E LOGGER VS. C180-A1 LOGGER

• SENT EPPLEY PSP's AND PYRHELIOMETER TO EPPLEY FOR RECALIBRATION

• PURCHASED PORTABLE CALIBRATION INSTRUMENTATION FOR FIELD CHECKS AND USE AT LAB

• IN-HOUSE REPAIR OF DK BTU METERS AND SYNERGISTICS DAS MOTHER BOARDS

• PROVIDED VALUABLE FIELD STAFF SUPPORT TO TASK A
Constant Temp Bath

RTD Calibration

Percent Difference

ATSM Standard Temp (F)

-10
-8
-6
-4
-2
0
2
34.  53.  75.  95.  112

RTD04931  RTD04932  RTD04933  RTD04934
Test RH Sensor for TSTC

- **NaCl**
- **MgNo**
- **LiCl**

Relative Humidity (%) vs Temperature (F)

Temperature (F): 30, 40, 50, 60, 70, 80, 90, 100, 110

Relative Humidity (%): 10, 20, 30, 40, 50, 60, 70, 80, 90, 100
Accuracy of MagnaLab CT's tested with Ohio Semitronics Precision Watt Xducer
1993 MARC MEETING UPDATE
ON THE FLOW LOOP

• The orifice plates were tested and performed to within
±2% of the Load Cells. This gave confirmation to the previous tests and gave an adequate secondary standard.

• Flow Research and Data Industrial meters were tested in the 10" test section.
  
  – The DI was accurate to ±3%.

  – The FR was 7% low.

  – FR tests run with a corrected pulse per gallon (PPG) factor were within ±3%.

  – The EMCO (axial turbine) meter was accurate to ±3% of the flow rate.
• The 4" test section was constructed:
  
  - The Flow Research was tested at two different insertion depths 0.5" and 1.5"
  
  - At 0.5" ID, the meters recorded 28% low
  
  - At 1.5" ID the meters recorded ±4%
  
  - The DI recorded ±3% of the flow rate

• Beginning at the end of last Summer and carrying into the Fall, meters were pulled from the field and "post-calibrated"
  
  - Results showed little degradation in meter performance due to field use.
  
  - It was determined that tests run in 4" pipe would translate to larger pipe sizes. This speeds up the testing process.
Comparison of Dirty and Clean Meters That Showed No Improvement

Percent Difference (Sensor-L.C.)/L.C.

Actual Flow (fps)

+ Dirty Meter  × Clean Meter
Results of Multi-Pipe Test

Meter A

Percent Difference (Sensor-L.C.)/L.C.

-10%  -8%  -6%  -4%  -2%  0%  2%  4%  6%  8%  10%

Actual Velocity (fps)

+  4" Pipe  *  6" Pipe  ×  8" Pipe
Conclusions

1. After two years of use, the meters perform nearly as well as a new meter.

2. Testing and Re-calibration can be performed in 4" pipe and the results extended to larger pipe sizes.

3. Buildup of scale does not dramatically affect meter performance.
The load cells were re-calibrated by the Department of Agriculture.

- On average, the load cells were off by less than 0.5% of a given reading.

- The actual error was a maximum of 15 pounds per 4000 pound increment or 0.375%.

Final Corrections were made to the existing data based on flow calibration results from the lab. Sample curves are included which show the results of the corrections applied.
Operation Change
Re-Calibration of Controls
TEXAS LOANSTAR
MONITORING AND ANALYSIS
PROGRAM

TASK C
DATA HANDLING AND RETRIEVAL

ACCOMPLISHMENTS

Jeff S. Haberl, P.I.
Robert Sparks
Dean Willis
Ron Chambers

June 1993
TASK C - RESPONSIBILITIES

. MAINTAIN AND EXPAND THE STATEWIDE NETWORK AND COMPUTER DATA BASE.

. RETRIEVE AND HANDLE OVER 3.0 MBYTES OF DATA PER WEEK AND INTERFACE BETWEEN DIFFERENT LOGGERS, AND COMPUTER SYSTEMS.

. STORE VERIFY AND EVALUATE DATA COLLECTED.
TAMU Logical Ethernet Backbone

Network Regions Used Heavily by LoanSTAR
Energy Systems Lab Computers

Servers:

UNIX Server
   Data General Aviion AV-4020 RISC Multiprocessor
   64 MB RAM
   3.5 GB Disk

NetWare Server
   ALR Business VEISA 386-33
   16 MB RAM
   1.5 GB Disk
   EISA Bus-Master SCSI I/O controller

Floating License Server
   Generic 80386SX-20
   4 MB RAM
   40 MB Disk

Other:

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TASK C - ACCOMPLISHMENTS

RETRIEVE AND ANALYZE OVER 3.0 MBYTES OF DATA PER WEEK.

- Develop and use public domain POLLC180 software for polling Synergistics loggers.

- Collect and process 15-minute data from Synergistics loggers at GISD thermal storage sites.

- Enhance polling routines with additional Q.C. routines (power outage, check logger clock, analog calib check).

- Develop automated daylight savings reset and time shift routines.

- Expand EMCS feasibility study to include the Teletrol system at the State Capitol. Final report updated 3/93.

- Power factor software developed for calculating PF from KVA-KWH Synergistics data.
TASK C - ACCOMPLISHMENTS

CURRENT Q.C. PROCEDURES:

- Date, site and time stamp for each record retrieved.
- Analog calibration check and power outages checked using POLLC180.
- High/low limits checked using ARCHIVE.
- Missing data inserted with MISSING.
- Hardcopy IPNs reviewed by LoanSTAR staff.
- Weather channels cross checked with nearby N.W.S. Aviation Weather Observations.
- Database indices developed for checking long-term trends.
- Advanced data displays prototyped for improving Q.C.
TEXAS LOANSTAR MONITORING AND ANALYSIS PROGRAM

TASK 6
IMPROVED ENERGY AUDIT PROCESS

ACCOMPLISHMENTS

Jeff S. Haberl, P.I.
John Houcek
Mingsheng Liu

June 1993
TASK 6 - RESPONSIBILITIES

- INVESTIGATE THE USE OF "DIPSTICK" AUDITS (DOE/BATTELLE).
- INCORPORATE DEMAND DATA AND OTHER SHORT TERM MONITORING INTO AUDITOR'S WORK.
- INVESTIGATE THE USE OF PRESCREENING INDICES INTO AUDIT.
- USE RESULTS FROM MEASURED SAVINGS TO IMPROVE THE AUDIT PROCESS.
- DEVELOP A WORKSHOP/WORKBOOK TO TRAIN OTHERS TO USE DATA ACQUISITION SYSTEMS AND LOANSTAR SOFTWARE.
TASK 6 - ACCOMPLISHMENTS

- LoanSTAR Monitoring Workshop developed and delivered.
  > Austin, TX, August 26, 1992.

- LoanSTAR Monitoring Seminar presented at Region VII ASHRAE CRC meeting.
  > San Antonio, TX, April 24, 1993.

- LoanSTAR Monitoring Workshop presented (USDOE Co-sponsor).
  > Minneapolis, Minn., May 5, 1993

- Graphical indices developed from LoanSTAR database.

- Initiated fieldwork for determining O&M prescreening indices.
You are invited to attend a building energy monitoring workshop that has been developed to familiarize building professionals with techniques that are used to gather and process hourly building energy and environmental data. This workshop will be presented by Texas A&M University using the procedures and software that have been developed for the Texas LoanSTAR program.

The workshop will emphasize a hands-on approach that covers the basics of measuring energy use and environmental conditions, including:

• connecting sensors to a logger,
• programming a logger,
• polling a logger, and
• preparing 2-D and 3-D graphs.

The workshop will also include a tour of a LoanSTAR site at the University of Texas at Austin.

Each workshop attendee will receive a 130+ page workbook that contains instructions and details about connecting a logger to a building, programming the logger, and quickly processing the data into useful plots on a PC with inexpensive graphics and spreadsheet programs.

A diskette is included in each workbook that contains public domain data processing routines and examples to guide the user in setting-up their first site and producing the plots.

WORKBOOK CONTENTS (W/SOFTWARE):
INTRODUCTION
• Designing an experiment.
• Types of programs.
• Identifying experimental parameters.
• Extent of monitoring.
• Basic monitoring in the program.

MEASUREMENT TECHNIQUES
• Basics of electricity monitoring.
• Measuring temperature.
• Measuring humidity.
• Measuring flow, Btus, etc.
• Installing and calibrating sensors.
• Analyzing errors.

USING A DATA LOGGER
• Connecting the sensors to the logger.
• Survival commands.
• Setting-up and polling a logger.

WHAT TO DO WITH THE DATA
• Processing and plotting raw data.
• Creating summary pages from raw data.
• Creating 3-D graphics with a spreadsheet.

There is no charge for the workshop. For more information call: Dr. Jeff Haberl at Texas A&M University, College Station, TX, (409)845-6065.
3.2 SURVIVAL COMMANDS FOR PROGRAMMING THE LOGGER (cont.)

FIGURE 3-13:
DIAGRAM OF AN EXAMPLE LOGGER SET-UP.


ELECTRONIC MULTIPLIER WAVEFORMS
UNITY POWER FACTOR

Governor's Energy Office
Texas LoanSTAR Monitoring Program

(C) Energy Systems Laboratory
Texas A&M University
4.2 CREATION OF SUMMARY PAGES RAW DATA AND AREA WEATHER DATA (CONT).

FIGURE 4.6: FLOW CHART FOR SUMMARY PAGE UTSUMM.BAT.
FIGURE 4.5 Example summary plot for site 101.
TABLE 4-12 Files included with the distribution diskette.

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Governor's Energy Office
Texas LoanSTAR Monitoring Program

(C) Energy Systems Laboratory
Texas A&M University
# PEOPLE WHO HAVE ATTENDED LoanSTAR MONITORING WORKSHOPS

**Austin, TX**  
**August 26, 1992**

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<th>Name</th>
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<td>Yuk-Lun Lam</td>
<td>Governor's Energy Office</td>
<td>PO Box 12428, Austin, TX 78701</td>
</tr>
<tr>
<td>Gene Hackman</td>
<td>Waugh Engineering</td>
<td>PO Box 160582, Austin, TX 78716</td>
</tr>
<tr>
<td>Scott Clark</td>
<td>Carter &amp; Burgess, Inc.</td>
<td>1100 Macon, Ft. Worth, TX 76102</td>
</tr>
<tr>
<td>W. Brown</td>
<td>Energy Systems</td>
<td>11901 Hamrich Court, Austin, TX 78759</td>
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<tr>
<td>Jaswir S. Judge</td>
<td>ECSD, City of Austin</td>
<td>City of Austin, 206 E. 9th St., Austin, TX 78701</td>
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<td>Steve Jaeger</td>
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<td>Jay Johnston</td>
<td>Texas Energy Engineering Services, Inc.</td>
<td>B-127 Capitol View Center, 1301 Capitol of Texas Highway, Austin, TX 78713</td>
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<td>Miles Abernathy</td>
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<tr>
<td>Chuck Ashe</td>
<td>Wisconsin Power &amp; Light Co.</td>
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<td>Kim Zuhlke</td>
<td>Wisconsin Power &amp; Light Co.</td>
<td>222 W. Washington Avenue, Madison, WI 53701-0192</td>
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<td>Mike MacDonald</td>
<td>Oak Ridge National Laboratory</td>
<td>Building 3147, M.S. 6070, PO Box 2008, Oak Ridge, TN 37831-6070</td>
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<tr>
<td>Terry Sharp</td>
<td>Oak Ridge National Laboratory</td>
<td>Building 3147, M.S. 6070, PO Box 2008, Oak Ridge, TN 37831-6070</td>
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<tr>
<td>Max Harelizk</td>
<td>Texas MHR Maintenance &amp; Construction</td>
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<td>Jim Rodriguez</td>
<td>Rodriguez Construction Engineers, Inc.</td>
<td>7073 A San Pedro, San Antonio, TX 78216</td>
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<tr>
<td>Hardy Romine</td>
<td>Romine, Romine, &amp; Burgess</td>
<td>4216 Felkirk Dr. West, Ft. Worth, TX 76109</td>
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<tr>
<td>Scott Jarman</td>
<td>Energy Environment Inc.</td>
<td>311 Ranch Rd., 620 S. Suite 200, Austin, TX 78734</td>
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<tr>
<td>Jack Roberts</td>
<td>Fanning, Fanning, &amp; Associates</td>
<td>6355 74th St., Lubbock, TX 79423</td>
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<tr>
<td>Joe Grimes</td>
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<td>PO Box 45, Wofford, TX 79382</td>
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<td>Everett Hall</td>
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<td>John Houcek</td>
<td>Energy Systems Laboratory</td>
<td>Texas A&amp;M University, Mechanical Engineering Dept., Energy Systems Laboratory, College Station, TX 77840</td>
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<td>Cromwell Truemper Levy Thompson Woodsmall, Inc.</td>
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<td>Henry W. Wade</td>
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<td>Raymond Taylor, Jr.</td>
<td>United States Air Force</td>
<td>10825 Edgecrest, San Antonio, TX 78217</td>
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<td>Howard Godfrey</td>
<td>G&amp;G Controls, Inc.</td>
<td>11002 East 51st Street South, Tulsa, OK 74146</td>
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<td>Don Angle</td>
<td>H.G. Angle Co., Inc.</td>
<td>456 West 61st St., Shreveport, LA 71106</td>
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<td>Donald C. Carter</td>
<td>The University of Oklahoma</td>
<td>160 Felgar St. Room 101K, Norman, OK 73019-0460</td>
</tr>
<tr>
<td>Ed Garcia</td>
<td>Vista Chemical</td>
<td>PO Box 120024, Austin, TX 78720</td>
</tr>
<tr>
<td>Larry Eckert</td>
<td>United States Air Force</td>
<td>47 SPTG/EDMC, 250 4th St., Laughlin AFB, TX 78840-5121</td>
</tr>
<tr>
<td>Richard E. Rhodes</td>
<td>JWP Brandt Engineering Co.</td>
<td>321 W. Ben White, Suite #104, Austin, TX 78704 or 12755 Cogburn Ave., San Antonio, TX 78249</td>
</tr>
<tr>
<td>Mike Welborn</td>
<td>Powers of Arkansas</td>
<td>1601 Westpark Dr., Suite 7, Little Rock, AR 72204</td>
</tr>
<tr>
<td>Jarrell D. Pruitt</td>
<td>Southwest Research Institute</td>
<td>6220 Culebra Road, PO Drawer 28510, San Antonio, TX 78228-0510</td>
</tr>
<tr>
<td>Robert J. Sullivan</td>
<td>Mechanical/Electrical/Energy Consultants, Inc.</td>
<td>1412 South Boston, Suite 710, Tulsa, OK 74119</td>
</tr>
<tr>
<td>Jerry A. Baldwin</td>
<td>Air Distribution Products, Inc.</td>
<td>707 Loyola Drive, Little Rock, AR 72211-5530</td>
</tr>
<tr>
<td>Davis</td>
<td>Brown &amp; Root, Inc.</td>
<td>10200 Bellaire Boulevard (77072-5299), P.O. Box 4574, Houston, TX 77210-4574</td>
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<tr>
<td>Kessner</td>
<td>Carrier Corporation</td>
<td>4307 Vineland Road, Suite H-9, Orlando, FL 32811</td>
</tr>
<tr>
<td>Jim Hall</td>
<td>Trinity Contractors, Inc.</td>
<td>2425 Dillard, Grand Prairie, TX 75051; P.O. Box 6278, Arlington, TX 76005</td>
</tr>
<tr>
<td>Harry Romine</td>
<td>Tarrant County Hospital District John Peter Smith Hospital</td>
<td>1500 South Main St., Ft. Worth, TX 76104</td>
</tr>
<tr>
<td>name</td>
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<tr>
<td>Mohan N. Amberker</td>
<td>Amberker Associates Inc.</td>
<td>9211 Plymouth Ave N, Minneapolis, MN 55427</td>
</tr>
<tr>
<td>Brian L. Benson</td>
<td>Ellerbe Becket</td>
<td>800 Lasalle Ave, Minneapolis, MN 55402</td>
</tr>
<tr>
<td>David O. Bergstrom</td>
<td>Macalester College</td>
<td>1600 Grand Avenue, St. Paul, MN 55105</td>
</tr>
<tr>
<td>Paul M. Bothwell</td>
<td>Moose Lake Reg. Treatment</td>
<td>1000 Lakeshore Drive, Moose Lake, MN 55767</td>
</tr>
<tr>
<td>Ray Boyer</td>
<td>North Dakota State University</td>
<td>SU Station, PO Box 5383, Fargo, ND 58105-</td>
</tr>
<tr>
<td>Lou Boyon</td>
<td>Rochester Institute of</td>
<td>P.O. Box 9887, Physical Plant, Rochester, NY</td>
</tr>
<tr>
<td>Michael H. Brewer</td>
<td>Muhlenberg College</td>
<td>2400 Chew Street, Allentown, PA 18104</td>
</tr>
<tr>
<td>Susan C. Dahlin</td>
<td>Northern States Power Company</td>
<td>414 Nicollet Mall, Minneapolis, MN 55401</td>
</tr>
<tr>
<td>John R. Gustafson</td>
<td>Minnesota Power</td>
<td>30 West Superior St., Duluth, MN 55802</td>
</tr>
<tr>
<td>Neil A. Howell</td>
<td>University of WI-System</td>
<td>1930 Monroe St., Room 203, Madison, WI 53711</td>
</tr>
<tr>
<td>Bill Lemcke</td>
<td>Central Michigan University</td>
<td>216 Combined Services Bldg, Mount Pleasant, MI</td>
</tr>
<tr>
<td>Frank L. Marsili</td>
<td>St. Meinrad Archabbey</td>
<td>Physical Facilities Office, St. Meinrad, IN</td>
</tr>
<tr>
<td>Blake C. McGibbon</td>
<td>McGill University</td>
<td>840 Dr. Penfield, Montreal, Quebec H3A 1A4, CANADA</td>
</tr>
<tr>
<td>Roberto Meinrath</td>
<td>Yale University</td>
<td>PO Box 2964, 20 Ashmun St., New Haven, CT 06520-2964</td>
</tr>
<tr>
<td>Vergil Moneo</td>
<td>University of Regina</td>
<td>Physical Plant/Mtce. Bldg., Regina, SK S4S OA2, CANADA</td>
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<tr>
<td>John P. Morris</td>
<td>Colorado State University</td>
<td>Facilities Services Center, Fort Collins, CO 80523</td>
</tr>
<tr>
<td>William F. Mueller</td>
<td>University of Minnesota</td>
<td>100 Union Street SE, Shepard Labs, Minneapolis, MN 55455</td>
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<tr>
<td>Robert M. Pumroy</td>
<td>University of Minnesota</td>
<td>1936 Commonwealth Ave., St. Paul, MN 55108</td>
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<tr>
<td>Dan G. Puzak</td>
<td>Honeywell</td>
<td>12001 State Highway 55, Plymouth, MN 55441</td>
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<tr>
<td>Mike W. Sachi</td>
<td>Center for Energy &amp; Urban Env.</td>
<td>510 1st Ave N, suite 400, Minneapolis, MN 55403</td>
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<tr>
<td>Michael A. Sheils</td>
<td>University of Minnesota</td>
<td>Facilities Management Shops Bldg. 200,</td>
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<td>Elmer Smolinsky</td>
<td>Augustana College</td>
<td>Facilities Management, 200 Shops Building,</td>
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<tr>
<td>Daniel P. Wichman</td>
<td>Hennepin County</td>
<td>Minneapolis, MN 55455</td>
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<tr>
<td>Jim Borer</td>
<td>MnBRC</td>
<td>Room 220, 1425 University Avenue SE,</td>
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<tr>
<td>Charlie Huizenga</td>
<td>University of California-</td>
<td>Room 220, 1425 University Avenue, Minneapolis, MN 55455</td>
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<tr>
<td>Barry Bridges</td>
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<tr>
<td>Jim Douglas</td>
<td>MnBRC</td>
<td>UBEFP Room 220, 1425 University Avenue Se,</td>
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<tr>
<td>Jeffrey J. Gale</td>
<td>2510 Consultants</td>
<td>Room 220, 1425 University Avenue, Minneapolis, MN 55455</td>
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<td>Martin Gerads</td>
<td>MnBRC</td>
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<td>71.</td>
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<td>Jack Ikoal</td>
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<td>Lester S. Shen</td>
<td>Underground Space Center</td>
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<td>Rajan Thomas</td>
<td>State of Minnesota</td>
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<td>Charles Walin</td>
<td>MnBRC</td>
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<td>81.</td>
<td>Steve Winkelman</td>
<td>MnBRC</td>
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TEXAS LOANSTAR
MONITORING AND ANALYSIS
PROGRAM

TASK D
ANALYSIS OF DATA AND SOFTWARE
DEVELOPMENT

ACCOMPLISHMENTS

David E. Claridge, P.I.
Jeff S. Haberl, P.I.

June 1993
TASK D - RESPONSIBILITIES

- VERIFY 3.0 MBYTES PER WEEK OF INCOMING INFORMATION

- DEVELOP PROCEDURES/ANALYZE COLLECTED ENERGY DATA.

- MECR, AECR, AND DSN PRODUCTION SOFTWARE.

- DESIGN AND DEVELOP SOFTWARE FOR HANDLING LOANSTAR DATA.
TASK D ACCOMPLISHMENTS
ANALYSIS & SOFTWARE
DEVELOPMENT PRESENTATIONS:

Database Summary Notebook & Advanced Visualization - Jeff Haberl

Software Development - Robert Sparks

Analysis Development - David Claridge

Savings Measurement - David Claridge & Kelly Kissock
TEXAS LOANSTAR
MONITORING AND ANALYSIS
PROGRAM

TASK D
ANALYSIS OF DATA AND SOFTWARE
DEVELOPMENT

DATABASE SUMMARY NOTEBOOK

Jeff S. Haberl, P.I.
Ron Chambers, Database Administrator

June 1993
Education Bldg (EDB)

Motor Cont. Cen. (kWh/h)

1992

1991

1990

Weeks are Sundays thru Saturdays
Hourly Pre-Retrofit CHW Consumption
10/13/90 - 5/30/91

Hourly Post/Const.-Retrofit CHW Consumption
5/30/91 - 12/31/92
Education Bldg (EDB)
Daily Averaged Values

Pre(4) 10/13/90-5/30/91  Post/Const.(4+) 5/30/91-12/31/92
Chilled Water Temperature Humidity Solar Rad Wind Speed
(kBtu/h) (degrees F) (lbw/lba) (W/sq.m) (mph)

FREQUENCY

FREQUENCY

FREQUENCY

FREQUENCY
W.B. Electric & M.C.C as kWh/h

Pre-Retrofit Period

10/13/90 - 8/30/91

Post-Retrofit Period

5/30/91 - 12/31/92
TEXAS LOANSTAR
MONITORING AND ANALYSIS
PROGRAM

TASK D
ANALYSIS OF DATA AND SOFTWARE
DEVELOPMENT

SOFTWARE DEVELOPMENT

Robert Sparks, Programming Manager
Ron Chambers, Database Administrator
Jeff S. Haberl, P.I.

June 1993
LoanSTAR Database Structure and Status

- 1020 channels of information (over 12 million individual readings to date)
- Growth rate greater than 162000 records per week (2.5 Mb/week)
- < 2% data marked bad
- ~ 6% data requiring correction after collection
MECR Production

Original Production Methods

- 3 production machines (2 PCs, 1 UNIX)
- Local databases on production machines requiring distribution time and painstaking propagation of changes
- Each section produced independently requiring frequent operator interaction
- Multiple graphing tools used making maintenance (particularly adding new sites) difficult.

Current Production Methods

- All work done on one machine (UNIX)
- All data accessed directly from relational database
- Entire report for a site initiated with a single command. No further operator attention required.
- All graphics produced in a similar fashion using a single graphing tool (SAS).

Graph/Table Production Times

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<td>Totals</td>
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<td>Computing time for 51 sites</td>
<td>16 hours 34 min</td>
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iComment
Centralized Commenting and Logging

Polling Logs
Task A Field Notes
IPN Review
Calibration Lab
MECR Review
AECR Review
DSN Review
Data Management Logs

Relational List of Comments

Notebook
Task A
Task B
Task C
Task D
Task E
TEXAS LOANSTAR
MONITORING AND ANALYSIS PROGRAM

TASK D
ANALYSIS OF DATA AND SOFTWARE DEVELOPMENT

ADVANCED DATA VISUALIZATION

Jeff S. Haberl, P.I.
Robert Sparks, Programming Manager

June 1993
ADVANCED DATA VISUALIZATION: HOW CAN IT HELP LOANSTAR?

- Need to quickly identify problematic sensors and report to field crew.

- Difficult to detect bad data from normal data across 70 sites.

- Typical graphical problems:
  > severe data overlap,
  > detection,
  > distance judgments,
  > limited to weekly plots.

- Consulted the literature on exploratory data analysis (Tukey, Tufte, Cleveland).
ADVANCED DATA VISUALIZATION:
HOW TO PROCEED?

EFFECTIVENESS OF ELEMENTARY
GRAPHICAL TASKS
(1. MOST > 7. LEAST EFFECTIVE)

1. Position along a common scale.
2. Position along an identical non-aligned scale.
3. Length.
4. Angle and slope.
5. Area.
7. Color hue, color saturation, density.
ADVANCED DATA VISUALIZATION:
HOW TO IMPROVE THE LOANSTAR INSPECTION PROCESS.

1. *Contour* hourly data points to improve the detection of the central tendency of a group of points.

2. Use *dashed horizontal and vertical lines* to assist with the distance judgments (dashed = minor feature).

3. *Add a line* to represent the statistical model (if needed) to aid in superposition.

4. Add *time-sequencing* (or animation) to enhance super-positioning.

5. Add *date stamp* to assist with frame by frame tracking.
Decimal Time (days since 1/1/80)

Chilled Water Use (MMBtu/h)

Ambient Temperature (°F)

Chilled Water Use (MMBtu/h)
# AVAILABLE SOFTWARE

These packages are available for distribution now. Others will be added as they are ready. 
Send inquiries to the attention of Mr. Robert Sparks, ph. 409-847-8779.

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
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<tr>
<td>1</td>
<td>Adjusts time stamps in columnar data to convert from the 0-23 representation of hours to 1-24 representation.</td>
<td>$15.00</td>
</tr>
<tr>
<td>2</td>
<td>A Lotus 1-2-3 macro that facilitates graphing 3D surfaces using Intex Solutions' 3D-Graphics.</td>
<td>$15.00</td>
</tr>
<tr>
<td>3</td>
<td>A Microsoft Excel v4.0 macro for producing 3D surface plots.</td>
<td>$15.00</td>
</tr>
<tr>
<td>4</td>
<td>Performs psychrometric calculations on columnar data.</td>
<td>$15.00</td>
</tr>
<tr>
<td>5</td>
<td>A flexible MS Windows compatible program for producing X-Y animation of columnar data.</td>
<td>$15.00</td>
</tr>
<tr>
<td>6</td>
<td>Princeton Archive with A&amp;M patches.</td>
<td>$15.00</td>
</tr>
<tr>
<td>7</td>
<td>Converts columnar data to a matrix suitable for input to Intex Solution's 3D-Graphics add-in for Lotus 123.</td>
<td>$15.00</td>
</tr>
<tr>
<td>8</td>
<td>Converts dates and times between Gregorian, Julian and decimal formats.</td>
<td>$15.00</td>
</tr>
<tr>
<td>9</td>
<td>An MS-Windows program for browsing, manipulating, and modeling columnar data (with special features for time series data). It is copyrighted by TEES and Kelly Kissock for distribution in the public domain.</td>
<td>$100.00</td>
</tr>
<tr>
<td>10</td>
<td>A PC-based interface to the Acurex Autocalc which includes program editing and real time graphics.</td>
<td>$15.00</td>
</tr>
<tr>
<td>11</td>
<td>This workbook is intended to be a stand-alone survival guide to acquiring energy use and environmental data in buildings. It includes monitoring procedures and data analysis routines developed for the Texas LoanSTAR program and is copyrighted for distribution in the public domain.</td>
<td>$35.00 - Write for availability.</td>
</tr>
<tr>
<td>12</td>
<td>Produces contour animation from time series data using Golden Software's SURFER and Lantern Corporation's MOVIE.</td>
<td>$15.00</td>
</tr>
<tr>
<td>13</td>
<td>Creates a 3D animation from time series data using Lotus 123, Intex Solution's 3D Graphics and Lantern Corporation's MOVIE.</td>
<td>$15.00</td>
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<tr>
<td>14</td>
<td>Creates a 3D surface animation from time series data using Golden Software's SURFER and Lantern Corporation's MOVIE.</td>
<td>$15.00</td>
</tr>
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<td>15</td>
<td>Prepares time series data for compilation into Lantern Corporation's Voyager.</td>
<td>$15.00</td>
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<tr>
<td>16</td>
<td>Converts an n-minute data stream to an m-minute data stream where n divides m. (e.g. 15 min. to hourly or hourly to daily)</td>
<td>$15.00</td>
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<tr>
<td>17</td>
<td>Moves timestamps in a file by an arbitrary number of minutes (useful for correcting for DST)</td>
<td>$15.00</td>
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<tr>
<td>18</td>
<td>Replaces missing records (rows) in columnar data.</td>
<td>$15.00</td>
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<tr>
<td>19</td>
<td>Unattended polling of Synergistics C180.</td>
<td>$15.00</td>
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<tr>
<td>20</td>
<td>Calculates power factors from KW &amp; KVA on an arbitrary number of phases.</td>
<td>$15.00</td>
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<tr>
<td>21</td>
<td>Graphs the output of the Esterline Angus Power Reporter Module in real time.</td>
<td>$15.00</td>
</tr>
<tr>
<td>22</td>
<td>A .plt template of a psychometric chart for use with Golden Software's Grapher.</td>
<td>$15.00</td>
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<tr>
<td>23</td>
<td>Cleans Synergistics data for use with Archive (see the LoanSTAR Monitoring Workbook).</td>
<td>$15.00</td>
</tr>
<tr>
<td>24</td>
<td>Combines two timestamped data streams, merging on the timestamp fields.</td>
<td>$15.00</td>
</tr>
<tr>
<td>25</td>
<td>X windows utility psychometric calculator.</td>
<td>$15.00</td>
</tr>
<tr>
<td>26</td>
<td>A graphical preprocessing program that plots Olgay's sunpath diagram and shading protractor for any location. Requires Grapher.</td>
<td>$15.00</td>
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</tbody>
</table>
TEXAS LoanSTAR
MONITORING & ANALYSIS PROGRAM

TASK D

ANALYSIS & SOFTWARE DEVELOPMENT:
ANALYSIS DEVELOPMENT
ACCOMPLISHMENTS

David E. Claridge, Ph.D., P.E.
Jeff S. Haberl, Ph.D., P.E.
T. Agami Reddy, Ph.D.
Srinivas Katipamula, Ph.D.
Kelly Kissock

Presentation to the MARC Meeting

by

David E. Claridge
June 3, 1993
SAVINGS MEASUREMENT

For the case with adequate pre-retrofit data savings are measured as the difference between a pre-retrofit baseline and measured post-retrofit consumption as illustrated.

Typical Pre and Post-Retrofit Air Handler Electricity Use

Typical Pre and Post-Retrofit Chilled Water Energy Use
INVESTIGATION OF THE ANNUAL PREDICTIVE ABILITY OF MODELS FROM SHORT PRE-RETROFIT PERIODS

Motivation
• The majority of our pre-retrofit data sets are less than a year long.
• Models from these "short" data sets may not accurately predict annual energy use.
• This may influence our determination of energy savings.

Objectives of Study
• Determine if and by how much models from short data periods mispredict annual energy use.
• Determine the characteristics of short data periods which influence their annual predictive ability.
• Outline methods to adjust models from short data periods to more accurately predict annual energy use.

Methodology
• Limit study to simple linear regression models.
• Divide 5 year-long data sets into groups of short data sets that range from one to five minutes in length.
• Compare the annual predictive ability of models from the short data sets to the actual annual energy use using:
  Normalized Annual Energy Use = \frac{E_{\text{short}}}{E_{\text{annual}}}

Average Annual Prediction Error of Models Based on One, Three and Five Month Sliding Windows

\[
\text{Average Annual Prediction Error} = \frac{12}{12} \sum_{i=1}^{12} |NAEU_i - 1|
\]
CONCLUSIONS

• Models based on short data periods may seriously misrepresent annual energy use.

• Models from longer data periods are more accurate than models from shorter data periods.

• The best predictors of both cooling and heating annual energy use are models from data-sets with mean temperatures close to the annual mean temperature.

• Cooling models from warm months tend to over-predict annual energy use and models from cool months tend to under-predict annual energy use.

• Heating models from warm months tend to under-predict annual energy use and models from cool months tend to over-predict annual energy use.
Estimating Uncertainty in Measured Retrofit Savings

- Statistical models are not "perfect". Energy use models have strong residual patterns which invalidate use of standard equations for estimating uncertainty.

- "Hybrid" model approach has been developed which is akin to Ordinary Least Squares in terms of model prediction but which is far more realistic in terms of estimating uncertainty bounds.

- Currently in the process of coding the equations for uncertainty in the LoanSTAR retrofit savings routines.
Comparison of Uncertainty Bounds

Four Different Building & Energy Types

95% Prediction Bounds (%)
Retrofit Savings In Buildings With "Mixed" Data

- "Mixed" data - Pre-retrofit utility bills
  Post-retrofit monitored data

- Unnormalized utility bill comparison.

- Calibrated method - monitored data used to develop a statistical model which is calibrated to pre-retrofit utility bills.

![Graph of electricity consumption over time](image-url)
Electricity savings summary
08/91-07/92

VHS COST SAVINGS SUMMARY

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<th>ELEC. TOTAL ($/MON)</th>
<th>GAS ($/MON)</th>
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<td>-3573.2</td>
<td>18924.62</td>
<td>15351.42</td>
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Regression Model Based on Engineering Principles

![Graph showing relationship between Cooling Energy Use and Outdoor Dry-Bulb Temperature (F).]

Balance Point of Exterior Zone
Dehumidification Starts

Outdoor Dry-Bulb Temperature (F)

Piece-Wise Multiple Linear Model Above is a Function of:

- $T_o$: Outdoor Dry-Bulb Temperature
- $T_{dp}^+$: Positive Values of $(T_{dp} - T_s)$
- $T_{dp}$: Outdoor Dew-Point Temperature
- $T_s$: Surface Temperature of Cooling Coil
- $q_i$: Internal Gains
- $T_{eb}$: External Zone Balance Point Temperature
Change in CV With Addition of Independent Variables to VAV Models

**Daily**

**Hourly**
Energy Efficiency Index due to Mixing (EEM)

- Simultaneous Heating and Cooling of Air Streams due to Multiple Zones in Building

\[ EEM = \frac{\text{Single-Zone Building Load}}{\text{Actual Heating and Cooling Energy}} = \frac{|CW - HW|}{CW + HW} \]

where CW: whole-building cooling energy use
HW: whole-building heating energy use

- EEM\text{Ideal (1-zone)} = 1
- EEM\text{Ideal (2-zone)} < 1

- Index can be used to rate HVAC performance on ABSOLUTE basis (similar to Carnot Efficiency for heat engines)
Building A

Pre-Retrofit

Post-Retrofit

Building B

Post Retrofit
Additional Analysis Development Initiated

- Fourier Series Modeling of Hourly Data

- Artificial Neural Net Modeling

- Demand Modeling of Chillers
LOANSTAR MONITORING & ANALYSIS PROGRAM

TASK D

ANALYSIS & SOFTWARE DEVELOPMENT:
SAVINGS MEASUREMENT
ACCOMPLISHMENTS

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Kelly Kissock
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Presentation to the MARC Meeting

by

David E. Claridge
Kelly Kissock

June 3, 1993
SAVINGS OVERVIEW

Savings determined at 24 sites representing 38 buildings

Types of Savings
- Cooling (18 sites)
- Heating or Gas (20 sites)
- Air Handler Electricity (20 sites)
- Lighting Electricity (4 sites)
- Electrical Demand (3 sites)

Savings Measurement Methodologies
- Regression models of daily energy use (18 sites)
- Regression models of hourly energy use (2 sites)
- Utility billing data and hourly energy use (2 sites)
- Calibrated simplified systems models (2 sites)
One, Two and Four Parameter Baseline Models for Savings Measurement
# SAVINGS CALCULATION METHODOLOGIES

<table>
<thead>
<tr>
<th></th>
<th>Daily Regression Models</th>
<th>Hourly Regression Models</th>
<th>Utility Billing Data and Hourly Energy Use</th>
<th>Simplified Systems Models</th>
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# Types of Savings

<table>
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<tr>
<th></th>
<th>Cooling</th>
<th>Heating or Gas</th>
<th>Air Handler Electricity</th>
<th>Lighting Electricity</th>
<th>Electrical Demand</th>
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EModel

Description
- EModel is a new tool for the analysis of building energy use data.
- EModel integrates the previously laborious tasks of data processing, graphing and modeling in a user-friendly, M.S. Windows environment.
- EModel's built-in features allow for quick determination of baseline energy use for calculation of retrofit savings and identification of operational and maintenance problems.

Data Processing Capabilities
- Sub-set selection
- Weekday/weekend, calendar or user-defined grouping
- Automatic deletion of missing data
- Automatic calculation of model residuals
- Day of week calculation
- Modification of variables
- Creation of new variables

Graphical Displays
- Time series graphs
- Relational (XY) graphs
- Animated relational graphs
- Histograms

Modeling Capabilities
- Total
- Mean models
- Two, three and four parameter regression models
- Multiple regression models
- Bin-fit models
OBJECTIVES

Task E: Reporting and Technology Transfer

• Disseminate LoanSTAR Results
  – Produce Monthly Energy Consumption Reports
  – Produce Annual Energy Consumption Reports
  – End-Use Database Development

• Increase the Renown & Effectiveness of LoanSTAR
  – Identify & Assist in Implementation of O&M Measures
  – Publish/Present/Distribute LoanSTAR Results
LOANSTAR MONITORING & ANALYSIS PROGRAM

TASK E PRESENTATIONS

O&M Identification & Implementation    David E. Claridge

Reporting the Results      David E. Claridge

Technology Transfer      W. Dan Turner
TASK E

O&M IDENTIFICATION & IMPLEMENTATION

David E. Claridge, Ph.D.,
Jeff S. Haberl, Ph.D.,
John K. Houcek
Mingsheng Liu, Ph.D.,
Aamer Athar

Presentation to MARC Meeting

David E. Claridge
June 2, 1993
O&M RESPONSIBILITIES

- Develop Efficient Methodology & Procedures
- Review All Site Data for O&Ms
- Follow Up on O&M Opportunities Identified
- Continue Timely Feedback
O&M IDENTIFICATION PROCEDURE

- Poll once/week
  - Weekly data Collection
  - Discuss Problems

- IPN once/week
  - Response

- MECR once/month
  - Discuss Problems
  - Response

- AECR once/year
  - Discuss Problems
  - Data Summary once/year

- O&M Problem Identification from Data Review

- O&M Problem Identification from Direct Contact

- Follow-up, Site Visit

LoanSTAR O&M Staff
O&M FOLLOW-UP PROCEDURE
AFTER PROBLEM IS IDENTIFIED

• Research Site from IPN, MECR, AECR, Site Notebook and Audit Report

• Telephone Site Contact and Advise of O&M Potential

• Mail or Fax Supporting Data

• Schedule Site Visit

• Site Visit
  • Interview Operator
  • Conduct Daytime Walk-through
  • Conduct Nighttime Walk-through
  • Perform Short Term Test

• Analyze Data

• Write Report

• Present Report

• Follow Up Report
CURRENT SITES FOR O&M FOLLOW-UP

- Capitol Complex - From MECR Analysis and Agency Request

- Fort Worth ISD - From AECR Analysis

- U. T. Austin - From IPN and Agency Request

- U. T. Arlington - From MECR Analysis and Agency Request
Comparison of Audit and Measured Savings in a Typical School Day
SITE VISIT

- Data Logger Confirmation → Good data quality
  Method: check CT connection during daytime walk-through

- Retrofit Confirmation → Installed & Operating
  Method: check the status of HVAC systems and lighting fixtures during daytime walk-through

- Operating Pattern Confirmation
  Method: interview school teacher and building operator during daytime walk-through and inspect site during nighttime walk-through.

- Improved Operating Pattern Confirmation
  Method: perform short term test at night

- Other O&M Opportunities
Measured Other-than-lighting Electricity Consumption during Short-term Test

(8 March, 1993)
### Summary of Annual Consumption and Annual Savings at Dunbar Middle School

<table>
<thead>
<tr>
<th></th>
<th>Utility Cost $/year</th>
<th>O&amp;M M Saves $/year</th>
<th>% Savings</th>
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<tbody>
<tr>
<td><strong>HVAC</strong></td>
<td></td>
<td></td>
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<tr>
<td>Electricity</td>
<td>$85,510</td>
<td>$32,248</td>
<td>37.7</td>
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<tr>
<td>Gas</td>
<td>$9,591</td>
<td>$2,437</td>
<td>25.4</td>
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<tr>
<td><strong>Lighting</strong></td>
<td></td>
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<tr>
<td>Late Night</td>
<td>$22,185</td>
<td>$2,839</td>
<td>12.8</td>
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<tr>
<td>Day-time</td>
<td>$22,185</td>
<td>$481</td>
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<td><strong>Total</strong></td>
<td>$117,280</td>
<td>$40,457</td>
<td>34.5</td>
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</table>
Measured O&M Savings at Dunbar Middle School

Note: Measured Whole Building Electricity Consumption from 2 March to 12 April at Dunbar Middle School. Note: site visit was performed on 8 March, 1993; Shut-down started on 15 March 1993.
## O&M Measures Summary

<table>
<thead>
<tr>
<th>O&amp;M Opportunity Identified</th>
<th>Locations Where Applicable</th>
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<tbody>
<tr>
<td><strong>Lights</strong></td>
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<tr>
<td>Lighting control</td>
<td>All sites except NUR, RAS, GAR</td>
</tr>
<tr>
<td>Delamp or reduce lighting levels when in excess of IES standard</td>
<td>JHR, ZEC, INS</td>
</tr>
<tr>
<td>Convert incandescent to compact fluorescent</td>
<td>ZEC, JHW</td>
</tr>
<tr>
<td><strong>Equipment Operation</strong></td>
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<tr>
<td>Change zone HVAC setpoints</td>
<td>LBJ, WBT, SFA</td>
</tr>
<tr>
<td>Raise AHU cold deck temperature</td>
<td>LBJ, WBT, SFA</td>
</tr>
<tr>
<td>Lower AHU hot deck temperature</td>
<td>LBJ, WBT, SFA</td>
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<tr>
<td>Turn off AHUs at night</td>
<td>All Capitol Complex, DUN, SIM, RAS, GAR</td>
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<tr>
<td>Turn off HW pump in summer</td>
<td>ZEC, WBT</td>
</tr>
<tr>
<td>Repair leaky pipes, valves, and/or ductwork</td>
<td>SFA</td>
</tr>
<tr>
<td>Turn off steam valve during summer</td>
<td>PCL</td>
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<tr>
<td><strong>Occupant Habits</strong></td>
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<tr>
<td>Turn off PCs and office machines</td>
<td>All Capitol Complex Buildings</td>
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<tr>
<td>Turn off lights</td>
<td>All sites except NUR, RAS, GAR</td>
</tr>
<tr>
<td><strong>Administrative</strong></td>
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<tr>
<td>Verify EMS operation, reprogram if necessary</td>
<td>DUN, SIM</td>
</tr>
<tr>
<td>Optimize custodial operations in the evenings</td>
<td>All Capitol Complex, DUN, SIM</td>
</tr>
</tbody>
</table>
**CATEGORY 1**

O&M Identified, Implemented and Savings Measured

Total Area Screened Under Category 1: 1 Million sq. ft

<table>
<thead>
<tr>
<th>Site Name</th>
<th>O&amp;M Measured Savings ($/yr.)</th>
<th>O&amp;M Savings (%)</th>
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<tbody>
<tr>
<td>Zachry Eng. Center</td>
<td>2,700</td>
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<tr>
<td>Perry Castaneda Library</td>
<td>132,000</td>
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<td>Garrison Hall</td>
<td>2,600</td>
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<td>Dunbar Middle School</td>
<td>40,500</td>
<td>35</td>
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<td><strong>Total</strong></td>
<td><strong>177,800</strong></td>
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### CATEGORY 2

O&M Identified & Savings Calculated  
Not Yet Implemented

Total Area Screened Under Category 2:  
2.7 Million sq. ft

<table>
<thead>
<tr>
<th>Site Name</th>
<th>Estimated O&amp;M Savings ($/yr.)</th>
<th>O&amp;M Savings (%)</th>
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<td>State Capitol Complex (10 buildings)</td>
<td>486,000</td>
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<tr>
<td>Zachry Eng. Center</td>
<td>17,300</td>
<td>4</td>
</tr>
<tr>
<td>R. A. Steindam Hall</td>
<td>9,300</td>
<td>22</td>
</tr>
<tr>
<td>Sims Elementary School</td>
<td>16,700</td>
<td>30</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>529,300</strong></td>
<td><strong>11</strong></td>
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</tbody>
</table>
CATEGORY 3

O&M Potential Identified from Data

Total Area Under Investigation:
7.6 Million sq. ft

- UT Austin 13 Buildings
- FWISD 43 Schools
- UT Arlington 3 Buildings
- Victoria ISD 2 Schools
- UTHSC Houston 2 buildings
- State Capitol 2 Buildings
## O&M Summary

<table>
<thead>
<tr>
<th>Category</th>
<th>Area (ft²)</th>
<th>Number of Buildings</th>
<th>Annual Energy Cost ($/yr.)</th>
<th>O&amp;M Savings (%)</th>
<th>O&amp;M Savings (% of Retrofit Savings)</th>
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<tbody>
<tr>
<td>1</td>
<td>954,848</td>
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<td>1,368,955</td>
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<td>2</td>
<td>2,686,946</td>
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<td>4,339,408</td>
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<td>Total</td>
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<td>17</td>
<td>5,708,363</td>
<td>12</td>
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</table>
O&M SUMMARY

- $705,057/yr. Identified and Implemented or in Process

- Over 90% of LoanSTAR Buildings Benefit from O&M Follow-up

- Appears Probable that O&M Follow-up will ultimately increase LoanSTAR Savings by 40% or More
LOANSTAR MONITORING & ANALYSIS PROGRAM

TASK E

REPORTING THE SAVINGS

David E. Claridge, Ph.D., P.E.
Jeff Haberl, Ph.D., P.E.
Aamer Athar
Ron Chambers
Srinivas Katipamula, Ph.D.
Kelly Kissock
Robert Sparks

Presentation to the MARC Meeting

by

David E. Claridge

June 3, 1993
REPORTING OUTLINE

• Reporting Summary

• Air Handler Savings

• End-Use Data

• 1992 Annual Energy Consumption Report
REPORTING SUMMARY

- Monthly Energy Consumption Reports to 51 Sites at 20 Locations
- Annual Energy Consumption Report to 50 sites at 19 locations
- Voyager Software at 7 locations for 15 sites
- Inspection Plots Distributed on a Request Basis
- Monthly Follow-up with Agencies
Total Measured Reduction in Electricity Demand (2 MW)

- HVAC: 60%
- Lights: 37%
- Thermal Storage: 3%
Electricity Energy Savings From HVAC Retrofits

Hourly AHU Electricity Demand Reduction From Retrofits
WHOLE BUILDING ELECTRIC

Data is for entire LoanSTAR Monitoring Period for each Site

Watts per Square Foot

Site Column Number

TOT-WBE.XLC 4/20/93
AIR HANDLER UNITS ELECTRIC

Data is for entire LoanSTAR Monitoring Period for each Site

Watts per Square Foot

Site Column Number

TOT-AHU.XLC  4/20/93
CHILLED WATER ENERGY

Data is for entire LoanSTAR Monitoring Period for each Site

Without Site Number 34 (JSN, LoanSTAR #400)
LoanSTAR Monitoring and Analysis Program

Annual Energy
Consumption Report

1992

Submitted to the
Texas Governor's Energy Office
by the
Monitoring Analysis Task
David E. Claridge, Principal Investigator
Changes In Cumulative Chilled Water Savings Due to Flow Adjustment
(Start of Data - December, 1992)
Changes In Cumulative Chilled Water Savings Due to Flow Adjustment
(Start of Data - December, 1992)
End-Use Savings As Percent of Total Savings

Audit Estimated (24 Sites)  
- Hot Water/Steam: 29%
- Electricity: 42%
- Chilled Water: 29%

Measured (24 Sites)  
- Hot Water/Steam: 22%
- Electricity: 36%
- Chilled Water: 43%
Texas LoanSTAR Monitoring and Analysis Program
Annual Energy Consumption Report
1992 Summary of Measured Energy Consumption and Savings

<table>
<thead>
<tr>
<th></th>
<th>Electricity</th>
<th>Chilled Water</th>
<th>Hot Water/Steam</th>
<th>Total</th>
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<tbody>
<tr>
<td>Pre-Retrofit Use</td>
<td>$4,601,000</td>
<td>$2,790,000</td>
<td>$1,107,000</td>
<td>$8,498,000</td>
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<tr>
<td>Post-Retrofit Use</td>
<td>$3,832,000</td>
<td>$1,761,000</td>
<td>$563,000</td>
<td>$6,156,000</td>
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<tr>
<td>Measured Savings</td>
<td>$750,000</td>
<td>$1,029,000</td>
<td>$524,000</td>
<td>$2,303,000</td>
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<tr>
<td>% of Pre-Retrofit Use</td>
<td>16.3</td>
<td>36.8</td>
<td>47.2</td>
<td>27</td>
</tr>
<tr>
<td>% of Total Measured Savings</td>
<td>32.6</td>
<td>44.7</td>
<td>22.7</td>
<td>100</td>
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<tr>
<td>Audit Estimated Savings</td>
<td>$883,453</td>
<td>$550,779</td>
<td>$537,167</td>
<td>$1,908,583</td>
</tr>
</tbody>
</table>

The cumulative pre- and post-retrofit energy costs by end-use (electricity, chilled water and hot water/steam) and the cumulative total energy costs for the twenty-four sites where retrofits are complete are shown in the table above. The pre-retrofit energy costs reflect the costs had the individual retrofits not been installed in the twenty-four sites. They are the sum of the energy costs represented by the dashed lines on page 2 of the individual site reports. In some sites the retrofit was completed in the middle of the year, in such cases it would be the sum of the dashed line in the post-retrofit period and the solid line in the pre-retrofit period.

The post-retrofit energy costs are the measured data from each site. They are the sum of the energy costs represented by the solid lines on page 2 of the individual site reports. The third row in the table above shows the cumulative savings by end-use and the cumulative total savings for the twenty-four sites. The fourth row shows the end-use savings as a percent of the total savings. The last row shows the savings estimated by the audit firms for the twenty-four sites. The graph shows the cumulative total savings in millions of dollars for all twenty-four sites.

Comments

The cumulative pre- and post-retrofit energy costs by end-use (electricity, chilled water and hot water/steam) and the cumulative total energy costs for the twenty-four sites where retrofits are complete are shown in the table above. The pre-retrofit energy costs reflect the costs had the individual retrofits not been installed in the twenty-four sites. They are the sum of the energy costs represented by the dashed lines on page 2 of the individual site reports. In some sites the retrofit was completed in the middle of the year, in such cases it would be the sum of the dashed line in the post-retrofit period and the solid line in the pre-retrofit period.

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Summary

Texas Governor's Energy Office
LoanSTAR Monitoring & Analysis Program

1992 Annual Energy Consumption Report

Energy Systems Lab
Texas A&M University
Texas LoanSTAR Monitoring and Analysis Program
Energy Consumption Report
October 1990 – March 1993 Summary of Measured Energy Consumption and Savings

<table>
<thead>
<tr>
<th></th>
<th>Electricity</th>
<th>Chilled Water</th>
<th>Hot Water /Steam</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Retrofit Use</td>
<td>$9,208,000</td>
<td>$5,612,000</td>
<td>$2,309,000</td>
<td>$17,129,000</td>
</tr>
<tr>
<td>Post-Retrofit Use</td>
<td>$7,674,000</td>
<td>$3,687,000</td>
<td>$1,353,000</td>
<td>$12,714,000</td>
</tr>
<tr>
<td>Measured Savings</td>
<td>$1,514,000</td>
<td>$1,925,000</td>
<td>$956,000</td>
<td>$4,395,000</td>
</tr>
<tr>
<td>% of Pre-Retrofit Use</td>
<td>16.4</td>
<td>34.3</td>
<td>41.4</td>
<td>25.8</td>
</tr>
<tr>
<td>% of Total Measured Savings</td>
<td>34.4</td>
<td>43.8</td>
<td>21.8</td>
<td>100</td>
</tr>
<tr>
<td>Audit Estimated Savings</td>
<td>$1,483,000</td>
<td>$1,049,000</td>
<td>$1,039,000</td>
<td>$3,571,000</td>
</tr>
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</table>

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Summary

Texas Governor's Energy Office
LoanSTAR Monitoring & Analysis Program
1 Quarter 1993 Energy Consumption Report

Energy Systems Lab
Texas A&M University
Cumulative Savings From LoanSTAR Retrofits: March 1993

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<thead>
<tr>
<th></th>
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</tbody>
</table>
### Table 1
Types of LoanSTAR Information Disseminated

<table>
<thead>
<tr>
<th>Type</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td># MECRs/AECRs to agencies with buildings in LoanSTAR</td>
<td>384</td>
</tr>
<tr>
<td># MECRs/AECRs to agencies without buildings in LoanSTAR</td>
<td>111</td>
</tr>
<tr>
<td># Monitoring Workbooks issued</td>
<td>83</td>
</tr>
<tr>
<td># Data and Software/software information requests</td>
<td>528</td>
</tr>
<tr>
<td># Total requests for reprints of papers and reports through May 1993</td>
<td>1535</td>
</tr>
</tbody>
</table>

### Table 2
Organizations Receiving LoanSTAR Information

<table>
<thead>
<tr>
<th>Type</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td># Texas agencies (state &amp; local governments, school districts, etc.)</td>
<td>414</td>
</tr>
<tr>
<td># Utility requests (Texas and outside the state)</td>
<td>81</td>
</tr>
<tr>
<td># Academic requests (Texas and outside the state)</td>
<td>76</td>
</tr>
<tr>
<td># Private industry/engineer requests</td>
<td>367</td>
</tr>
<tr>
<td># State agency requests outside Texas</td>
<td>70</td>
</tr>
<tr>
<td>States: Arizona, California, Colorado, Georgia, Florida, Minnesota, Pennsylvania, Oregon, Wisconsin</td>
<td></td>
</tr>
<tr>
<td># National Lab or other Federal Government requests</td>
<td>371</td>
</tr>
<tr>
<td># International requests Countries: Australia, Belgium, Brazil, Canada, Cuba, France, Guatemala, Holland, Hong Kong, Israel, Italy, Japan, Mexico, New Zealand, Norway, P.R. China, Sweden, Singapore, Russia, United Kingdom</td>
<td>57</td>
</tr>
<tr>
<td># Total organizations/individuals receiving information through May 1993</td>
<td>1436</td>
</tr>
</tbody>
</table>
FUTURE DIRECTION
TASK 1

- Continue reviews, guideline/format revision, and training as required by the Energy Office

- In the past, Task 1 has been involved in
  
  - Eliminating independent ECRM calculations
  
  - Eliminating M&O calculations
  
  - Introducing Category I (limited calculation) ECRMs
FUTURE DIRECTION
TASK 1

- Short payback items - installation decisions clearly based on "professional judgment"
- Supported by limited calculations

- Paybacks near limit - gray area
- Supporting calculations required

- Long payback items - installation decisions clearly based on "professional judgment"
- Usually no calculations supplied
TASK A
FUTURE DIRECTIONS

- NCAT will close Texas office July 15

- Focus for next 3 to 6 months will be
  - Maintenance
  - Recalibration
  - Documentation
FUTURE DIRECTIONS
TASK B

• The project for the summer is the testing of meters in "field type" locations.

  – A 4" elbow section has been constructed and meters will be tested at various locations downstream of the elbow.

  – Meters will be tested immediately following other obstructions such as temperature sensors and orifice plates.

  – Depending on 4" results, tests may be conducted in large pipe sizes.

• We are still having some flow irregularities at higher velocities (75 fps) in the 8" and 10" pipes due to the configuration of the test sections.

  – May require modification of test loop.

• Complete Temperature-Humidity Mapping Tests
Pyranometer with shadow band to eliminate beam radiation
(source: Eppley Laboratories)

LI-COR LI-200SA Pyronameter Sensor
(source: LI-COR)

Epply Normal Incidence Pyrheliometer mounted on an altazimuth tracking mount. (source: Epply Laboratories)

Multi Pyranometer Array Configuration
(source: Curtiss, 1992)
TASK C & D - FUTURE DIRECTION

- Continue to explore advanced data displays for data browsing and diagnostics, and develop remote browsing capabilities for the LoanSTAR database using the internet and dial-up facilities.

- Develop and test LoanSTAR routines for polling and archiving data from stand-alone, portable battery powered loggers (Campbell, Synergistics).

- Develop and implement Informix/SAS IPN, implement iComment and continue development of the Basic On-line Inspection NotebooK (BOINK).

- Develop dynamic range checking for incoming data, machine learning and neural network capabilities for checking incoming data.
TASK C & D - FUTURE DIRECTION
(CONT.)

- Modify and implement POLLC180 for use within 15-minute data.

- Expand LoanSTAR monitoring/analysis capabilities to the whole-campus level.

- Develop and prototype the LoanSTAR Monitor to facilitate real time operator feedback.

- Automate savings Calculations

- Investigate polling directly with the Unix server.

- Develop and implement Level-0 database and reporting.
TASK 6 - FUTURE DIRECTION

- Continue with the LoanSTAR Monitoring Workshop (Co-sponsored by USDOE).
  > Dallas, TX, Fall 1993.

- Continuation of the development and testing of prescreening indices (Co-sponsored by USDOE and USEPA).

- Develop improved audits using advanced indices (Co-sponsored by USDOE and USEPA).
FUTURE DIRECTIONS

Task D - Analysis

EModel - Refine and fully implement use of EModel
- Add capability to EModel for calibrated post retrofit-to-monthly pre retrofit models

Neural net models - further evaluate capability

Fourier series models - Develop diagnostic capability with Fourier series models for O&M identification

VAV Retrofit Behavior - Analyze behavior of VAV retrofits and develop diagnostics for improved audits (EPA cofunding)

Energy Efficiency index for Mixing (EEM) - Refine EEM and develop its application for O&M diagnostics and audit diagnostics (DOE cofunding being sought)
FUTURE DIRECTIONS

Task E - Reporting

MECR - Continue to publish and distribute MECR and add sites as needed

AECR - Publish and distribute 1993 AECR with sites added as needed

Task E - O&M Identification and Implementation

O&M Implementation
- Implement O&M Measures Identified at Capitol Complex
- Implement O&M Measures Identified at ZEC and TU sites

O&M Identification
- Complete Identification and Seek Implementation of O&M Measures at 43 additional Fort Worth ISD Schools
- Identify O&M Measures at UT Arlington
- Investigate O&M Measures at UT Austin
- Check Remaining sites where Retrofits in Place for O&Ms
O&M Methodology
  • Refine and Systematize Methodology for Identifying and Implementing O&M Measures


