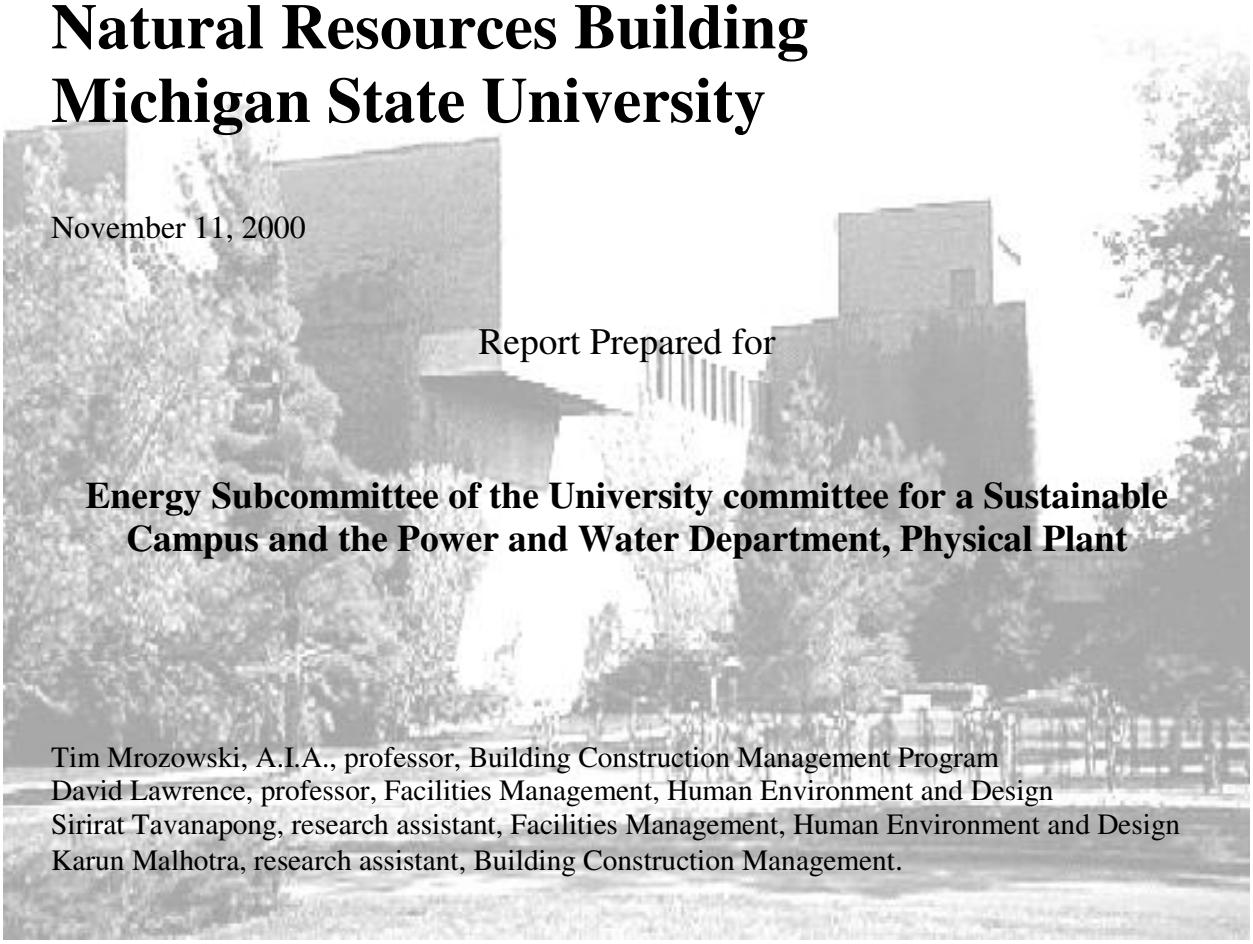
EXECUTIVE SUMMARY

Development of an Energy Assessment Methodology for University Academic Buildings

Case Study of the Natural Resources Building Michigan State University



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Report Prepared for

Energy Subcommittee of the University committee for a Sustainable Campus and the Power and Water Department, Physical Plant

Tim Mrozowski, A.I.A., professor, Building Construction Management Program
David Lawrence, professor, Facilities Management, Human Environment and Design
Sirirat Tavanapong, research assistant, Facilities Management, Human Environment and Design
Karun Malhotra, research assistant, Building Construction Management.

Introduction

This project was conceived in response to a Request for Proposals (RFP), which was issued in June of 1999 by the Power and Water Department, Physical Plant Division and the Energy Subcommittee of the University Committee for a Sustainable Campus (UCSC) at Michigan State University (MSU). The RFP sought proposals to conduct a building energy assessment of a university academic building with emphasis on building users. In response to the RFP this project was developed and consisted of two core activities which included: 1) the development of an energy assessment of the Natural Resources Building and 2) the development of an energy assessment methodology which could be employed throughout the university to assess other similar buildings on campus.

The Natural Resources Building was selected as the case study project because it had not undergone any significant energy upgrade renovation and is typical of several academic buildings on campus constructed during MSU's period of expansion during the 1960's. The building envelope, materials, systems and use patterns are typical of buildings of this vintage on the MSU campus.

Project Phases

The proposed project consisted of two phases, which included a Phase One Technical Study and a Phase Two Building User Study. Phase One was conducted from September 1999 through May 2000. Phase Two was conducted from January 2000 through May 2000.

During the course of the project a third project phase consisting of structured interviews of campus administrators was added to the project. This third phase is geared toward general campus policies and practices that are nonspecific to the Natural Resources Building and are being reported in a separate Volume Two of this report.

Objectives

The primary objectives of the study were as follows:

1. To develop an energy assessment methodology appropriate to university academic or residence hall buildings at MSU and other major universities.

2. To develop a detailed energy assessment of an existing university academic building, for the purpose of learning about energy use and assessment.

3. To develop recommendations for appropriate changes for the case study building in the building envelope, electrical, and HVAC systems, which will lead to energy savings.

4. To develop recommendations for appropriate changes in building use, operation, maintenance, and administration which lead to energy savings.

5. To involve undergraduate and graduate students in energy assessment and to provide students with an enhanced understanding of how building designs, materials, systems, use and management impact energy consumption.

Student Involvement

An important objective was to involve undergraduate and graduate students in the project in an effort to encourage them to develop an energy mind set. Four graduate students and eight undergraduate students were involved with the project at various stages. It is hoped that these

students will take the lessons learned through their involvement with the project outside MSU, and encourage a more sustainable lifestyle from the organizations and individuals that they come into contact with.

Phase One Technical Study

Phase One of the project focused on the technical Aspects of the Natural Resources Building. The core activities included: 1) the study of the building envelope, 2) study of the HVAC systems, 3) study of the electrical systems and 4) a study of the energy monitoring and metering systems in the building.

The envelope study included characterization of building assemblies and calculation of building heating and cooling loads, as well as a thermographic study of the exterior walls. The mechanical and electrical systems study focused on characterizing and describing the existing systems and load calculations. The energy monitoring and metering study included energy consumption and energy monitoring data collection and analysis.

StructureTec Inc., Kalamazoo, Michigan, was employed to develop the thermographic infrared study of the exterior building walls. Engineers from StructureTec Inc. met with students, explained how to use the equipment, conducted the infrared photography and helped to interpret the results. William Bezdek P.E., Bezdek Associates, Engineers, Mason, Michigan, consulted on the assessment of and recommendations for the building HVAC system and electrical systems.

Phase Two Building Users Study

The managerial and behavioral aspects of energy consumption have received less attention within organizations than technical solutions. This approach requires users and organizations to examine the way they utilize energy. Indeed, "gaining control and maintaining energy efficiency takes a corporate commitment first and foremost" (the UK Department of the Environment, 1993) The Phase Two study addresses building users and their impact on energy consumption and makes recommendations as to how energy could be saved by changing their use patterns.

The primary objectives of the Phase Two Building User Study were twofold and included: 1) an assessment of the impact of building users on the Natural Resources Building and 2) the study of how user assessments should be incorporated into a general energy assessment methodology for university buildings.

The Building User Study as proposed consisted of seven principle activities which included: 1) a review of available literature, 2) the development of a conceptual framework, 3) the development and administration of a survey of student users, 4) a faculty and staff survey, 5) discussions with administrators and users, 6) building observation, and 7) the development of recommendations on changes in building user patterns which could save energy.

Conclusions

Both undergraduate students and regular building users are interested and willing to implement energy saving measures. However, both groups indicated that they did not feel that energy savings was a high priority of MSU campus faculty and administrators. In short they had not been told that saving energy was important in the campus setting. Potential exists to save significant amounts of energy by motivating users to alter the way that they use energy consuming equipment.

Electrical consumption in the Natural Resources Building averages approximately 1600 MWHRS annually at a cost of $84,000. Operation of lighting and personal computers accounts for a

significant portion of the annual costs. Lighting is estimated to cost $13,000- $15,000 per year. The use of computers and office equipment is estimated at approximately $20,000 per year.

Researchers observed that many computer systems throughout the building are not turned off when rooms are not occupied. Computer systems are left on overnight, weekends, and over holidays. Utility cost for these computers average approximately $75 each annually. If personal computers, monitors, and printers were turned off during non-use periods, significant savings could be generated. If for example computer use averaged 40 hours per week rather than continuously, an annual savings of $12,000-$15,000 could be generated for the building. Because some computers are needed for after-hours work, laboratories, and graduate students it is more realistic to expect that annual savings would be $10,000 from policies that encouraged computers to be turned off at night, weekends, and holidays (when not in actual use).

Frequently, classroom lighting was left on when classes were not in session. Typically, classroom lights were turned on for the first class of the day in the room, and then left on until the end of the day, regardless of whether a class was being taught. Laboratory and graduate student spaces also showed similar patterns. It is expected that approximately $1,500-2,000 could be saved annually if lighting was turned off in classrooms and lab spaces, when these rooms were not in use for extended periods.

The costs savings projected for managing computers and lighting are based on electrical consumption alone. Significant additional savings would be generated from reduction of cooling loads, however, some increase in winter heating requirements might occur, due to loss of internal heat sources. The researchers did not calculate cost impacts on the HVAC system from reductions in lighting and computer use.

Total savings of $10,000-12,000 in electrical costs could be expected by changing these use patterns in the building. Productivity losses in staff would be expected to be minimal and generally would entail only computer boot-up time. One potential obstacle is the belief by many users that it damages the computer system to shut down and start up these systems, or that start up energy is excessive and therefore it is recommended to leave these systems continuously running. Several building users indicated that they would welcome university guidelines on when to shut off computers and office systems.

The technical study of the Natural Resources Building identified numerous possible technical changes to the building HVAC, envelope, and electrical systems. A parameter of the project from the outset was that recommended changes should be cost effective and meet realistic payback periods of three years or less. Many of the changes recommended previously by Diclemente (1996) were found to be not cost effective. Some suggestions are made in this report, such as changing over to T8 lamps with electronic ballasts, dock seals, motion sensors in large classrooms, and digital displays of energy information. However, it is anticipated that the greatest savings will come from policy and user behavioral changes rather than technical retrofits.

Recommendations

Twenty-six specific recommendations are made for university policy, and twelve are made for the Natural Resources Building. The Natural Resources Building recommendations include both technical and building user change recommendations. Policy, technical and user recommendations were developed as a result of the Phase One Technical Study and the Phase Two User Study and are reported below.

Policy and Administration

1. Establish a "corporate commitment" to energy management. Establish energy management and saving energy as priorities for the university. This commitment must start at the highest levels and be articulated to all levels within the organization.

2. Establish and publish a university wide energy policy or philosophy on reducing energy and encouraging sustainable practices.

3. Establish and articulate goals for saving energy. Goals should be developed for all organizational levels.

4. Establish a campus administrative staff position to oversee and lead a campus wide energy reduction effort.

5. Communicate goals to administrators, faculty, staff and students. Faculty and staff are in the best position to impact daily energy usage. Faculty impact energy consumption by how they use their own spaces, by policies they set for labs and classrooms, and by their influence on graduate and undergraduate students.

6. Consider establishing the "pay back" period for immediate implementation of energy reduction measures at five to seven years rather than the current zero to five-year period.

7. Consider establishing a demonstration building so that impacts of user patterns and technological changes are demonstrated, evaluated, and publicized.

8. Develop a database of energy, use, and building data. The database should be available for comparison between buildings of similar characteristics.

9. Develop a “building use” rating or classification system for qualifying and quantifying use for the database recommended in item 8 above.

10. Provide communication and feedback on energy consumption from the Physical Plant directly to departments on a building by building basis.

11. Work with computer experts to establish and publish clear guidelines for when to shut down computers and office equipment during nonuse periods.

12. Develop a Physical Plant newsletter reporting energy reduction progress and providing suggestions on energy saving ideas periodically throughout the year.

13. Consider establishing an energy budget for individual buildings. Departments are not accountable for their energy usage and consequently are not motivated to conserve.

14. Encourage department chairpersons to report energy consumption and energy reduction progress to faculty and staff.

15. Designate within buildings an "energy manager" who is responsible for overseeing energy reductions within each building.

16. Develop incentive programs for buildings to reduce energy. Several suggested ideas are:

    Return a portion of savings to operating budgets of departments.
    Return a portion of savings to departments and faculty via overhead on research projects.
    Acknowledge successful buildings and faculty through awards/competitions etc.
    Allocate energy merit raises to departments and faculty for successful energy programs.

17. Create digital displays of energy metering in prominent places such as the main lobby of buildings to provide building users with constant visual feedback on energy consumption within the building.

18. Create "turn off" policies for computers and lighting within the building.

19. Encourage the purchase of “Energy Star” compliant computers that go into “sleep mode” after a preset time of inactivity.

20. Create "turn off" reminder signage for computers and lighting within the building

21. Consider motion sensor controlled lighting for larger classroom spaces. Costs for retrofit sensors need to be evaluated for the specific classroom, based on amount of lighting, number of entrances, frequency of use, etc.

22. Establish accurate, effective, and reliable metering and monitoring systems. Bench-marking of energy consumption is important in assessing impacts of practice and technology changes.

23. Create a policy to changeover fixtures, ballasts, lamp-holders, and lamps to electronic ballasts and T8 fluorescent fixtures when making room renovations.

24. Create undergraduate courses, which have energy and sustainability as major themes.

25. Faculty and administrators should let students know that energy usage is important to the university and society. Students seem ready for this issue, but are looking for faculty leadership.

26. Consideration should be given to scheduling all evening courses into a few buildings campus wide so that HVAC systems may be shut down in buildings rather than keep systems operating for one evening class.

Specific Recommendations for the Natural Resources Building

1. Consider interconnecting the electrical and steam metering systems with the energy monitoring room.

2. Consider motion detectors in lecture hall 158, and larger second floor classrooms.

3. Create a policy to changeover fixtures, ballasts, lamp-holders, and lamps to electronic ballast and T8 fluorescent fixtures when making room renovations.

4. Consider dock seals at loading dock area.

5. The 1996 Diclemente study recommended numerous upgrades to the HVAC systems and window replacement. Costs were $1,700,000 and $450,000 respectively. The purpose of these improvements was to improve thermal comfort and control. The proposed modifications were evaluated as not cost effective based on energy savings alone by this study. However MSU may wish to implement these recommendations for thermal comfort reasons.

6. Provide communication and feedback on energy consumption from the Physical Plant directly to departments housed in the building.

7. Establish and publish clear guidelines for when to shut down computers and office equipment during nonuse periods.

8. Department chairpersons should report energy consumption and energy reduction progress to faculty and staff.

9. Designate within the buildings an "energy manager" who is responsible for overseeing energy reductions within the building.

10. Develop incentive programs for buildings users to reduce energy.

11. Create a digital display of energy metering in a prominent place such as the main lobby to provide building users with constant visual feedback on energy consumption within the building.

12. Create "turn off" reminder signage for computers and lighting within the building

Energy Assessment Methodology for Campus Academic Buildings

An important goal of this research project was to develop a methodology, which could be utilized to assess energy use in campus academic buildings. A variety of activities were undertaken which contributed to the researchers' understanding of the Natural Resources Building, its users, the university, administrative practices, building technology, and energy assessment methods. Through the project the researchers were able to determine the types of relevant information that exits in various campus departments. The case study of the Natural Resources Building helped to identify user behaviors that may be typical of users in other buildings. The case study helped also to identify typical technological aspects of buildings that should be assessed. Lastly administrative policies and practices were identified as playing a key role in energy management. Based on the research, the following methodology for assessing other campus buildings is being recommended.

The research showed that existing building technology, daily user patterns, user behaviors, and administrative practices all play a major role in energy use. Therefore it is recommended that each of the above components be incorporated into a standard methodology for energy assessment in campus academic buildings. Because there is a strong relationship between each of these items, it is further recommended that these elements be integrated and correlated. It is clear that administrative policies impact behavior for example, and occupants respond to thermal comfort aspects of building systems.

Each building on campus has different characteristics and use patterns. The methods used for each study should be carefully planned for the specific building. For example, in some buildings an envelope analysis may be essential, however a building known to consist of double glazing and well insulated walls may not justify a computational analysis of the envelope, because it is not likely to yield upgrade recommendations that will be cost effective.

The methodology below identifies specific recommended activities for six phases of assessment which include: 1) gathering of base building information 2) technical study, 3) daily user study, 4) administrative practices and policies, 5) integration and correlation and 6) recommendations.

Recommended Energy Assessment Methodology

Base Information

- Obtain floor plan layouts from Engineering and Architectural Services, Physical Plant. For some buildings floor plan layouts are available in electronic .dwg or .dxf file formats.

- Obtain copies of construction documents and specifications for original building and relevant renovations. These documents are available from Engineering and Architectural Services.

- Obtain space allocations from the Office of Planning and Budgets (available on their website). Establish room square foot areas and use. This information can be obtained from the Office of Planning and Budgets and is also incorporated in the computer .dwg format files available from Engineering and Architectural services.

- Interview department chairs in the building to obtain an overview of

  Activities in building
  Intensity of activities
  Makeup of department staff
  Location of activities and staff
  Hours and use periods of activities (daytime, nighttime, etc.)
  Known energy or comfort problems

- Conduct building inspections with Department Chairperson to become familiar with the building and to correlate plans with actual building uses.

- Obtain class schedule for building from Registrar's office. Construct a profile/schedule of class times and locations.

- Develop descriptive and quantified statements, which classify level of principle activities such as "research intensive in 20% of floor area" or "constant classroom use during building hours in 15% of building floor area".

- Obtain current energy cost factors for steam and electricity from the MSU Power Plant for use in calculating cost/benefit analysis.

- Obtain benchmark and historical metering data for steam and electricity from the Power and Water Department, Physical Plant.

- Verify the accuracy and consistency of metering data with the Metering Division of the Power Plant. Investigate anomalies in data.

- Calculate annual and monthly costs of energy.

- Identify similar campus buildings and to the extent possible, compare the performance of the study building with other similar buildings on campus. Make adjustments to account for known variances. Energy utilization per square foot is available as part of metering data identified in item 7 above.

Technical Study

The focus of the Technical Study is to assess whether capital investments in the building should be undertaken. Potential upgrades to the building envelop, HVAC systems and electrical systems should be evaluated.

- Review construction documents obtained from Physical Plant to characterize the following and develop narrative description of the following:

  Envelope
  Assemblies
  Areas
  General efficiency (i.e. single gazing 20% of exterior of exterior skin)

  HVAC
  Electrical Distribution and Power
  Lighting types/quantities

- Discuss with Physical Plant to confirm characterization of assemblies and systems.

- Determine if there are known problems with the envelope or systems:

  Interview of department chairpersons
  Interviews of Physical Plant staff

- Review available relevant studies and reports on performance, maintenance, or evaluations.

- Determine if there are future renovations or upgrades scheduled or planned for the building. Check with department Chairs, Office of Planning and Budgets, Physical Plant, Power Plant, Campus Park and Planning, and Computer Center.

- Conduct field inspection with Physical Plant to observe and characterize HVAC and electrical systems

- Obtain information from Energy Monitoring room including: equipment schedules, metering data if connected, temperature set points, and schematic view of systems

- Analyze baseline information, energy utilization comparisons between similar buildings from above, as well as information collected during this technical phase to determine if the building is generally efficient or inefficient by comparison.

- Based on above items, determine if there are obvious areas of the building or its systems that could be improved and would be cost effective

- Design a data collection approach that is focused on those elements that are likely to be cost effective.

- Determine which of the following is necessary:

  Envelope computational analysis heat loss/heat gain
  Thermal resistance and transmittance by assemblies
  Area of assemblies
  Heat loss/heat gain
  Thermographic analysis
  Roof
  Walls
- Engineering study of HVAC systems

- Inspection of equipment

- Determine best type of system for the particular application

  Schedules of operation
  Air test and balance
  Diversity factors
  Load calculations

- Electrical systems study

  Lighting analysis
  Equipment analysis
  Equipment and load analysis
  Exhaust hoods
  Use/operation

- Determine if outside consultants are required for any of the above analyses or can in-house staff prepare studies?

- Conduct technical studies focused on known problems or elements likely to lead to low payback solutions.

- Determine cost effectiveness of alternative solutions.

- Make recommendations.

Building User study

The focus of the Building User Study is to determine if user patterns and behaviors are leading to excessive energy use when compared to other similar facilities and to identify if acceptable changes or modifications in use patterns can be made which will lead to energy savings. Again, activities should be individualized to the building being assessed based on the baseline information determined. The costs associated with data collection should be evaluated and based on the information likely to be generated, and the need to acquire the information.

Data collection methods could consist of the following:

- Interviews of

  Department chairpersons and administrators
  Faulty and staff
  Service personnel
  Students

- Attitude and practice surveys of

  Department chairpersons and administrators
  Faulty and staff
  Service personnel
  Students
- Building observation studies

  Informal
  Formal

- Focus groups

  Department chairpersons and administrators
  Faulty and staff
  Service personnel
  Students

- Room by Room analysis of equipment and lighting

  Equipment schedules
  Use analysis-quantitative

- Characterize building use and patterns from the baseline information above.

- Develop schedule of use and uses for the building from the baseline data.

- Confirm schedule with department chair and custodial staff interviews.

- Compare building use energy patterns with similar buildings.

- Determine administrative practices and policies that influence building user patterns and practices.

- Through building observation establish general user behaviors and their impact.

- Compare user patterns to Natural Resources Case Study findings.

- Determine if administrative policies exist that impact user behaviors with respect to energy.

- Determine impact of maintenance and custodial staff, and polices on energy utilization.

- Determine potential improvement areas:

  Hours of use
  Schedules
  Policies
  Communications

- Determine data collection approach and objective of collecting data:

  Are formal interviews, surveys, focus groups or observation methods necessary?

  Target sample size
  Budget and cost effectiveness

- Collect data.

- Develop recommendations for policies and user pattern changes.

- Test acceptance of policy or user pattern changes by users and administrators.

- Evaluate savings and costs to the organization associated with changes in policies or user practices.

- Propose recommendations along with implementation and communication plan.

Administrative Practices and Policies

The purposes of this study are to identify any administrative practices or policies at various levels that impact energy utilization, and to determine if there are obvious policy or practice changes, which could be implemented.

- Develop an organizational outline showing how the building and its users are administered.

- Determine if published or established policies exist which impact energy use.

- Determine if policies are unique to the building or are if they are typical to other similar buildings.

- Determine organizational "commitment" to saving energy.

- Determine receptiveness to changes in policies.

- Determine receptiveness to communication of policy changes.

- Determine data collection approach. Are surveys or interviews needed?

- Collect data.

- Analyze data and determine recommendations regarding policy changes.

- Evaluate acceptance and obstacles to implementation of proposed policy changes.

- Determine savings and costs to organization of implementing policy changes.

- Determine communication efforts necessary to implement policies.

Integration and Correlation

The role of this phase is to integrate and correlate the findings of the baseline, technical, building user, and administrative practices studies. The principle activities are aimed at analysis of the individual studies to see if they are interrelated. This phase recognizes that changes in user behaviors impact the operation of technical systems and vice versa.

- Correlate results from the baseline, technical, building user and administrative policies.

- Determine how the findings are interrelated.

- Determine if opportunities exist in integrating actions items from the various studies.

- Develop recommendations.

- Evaluate savings and costs to the organization of proposed items.

- Identify barriers to implementation.

Recommendations

This phase makes final recommendations based on the individual and integrated studies for the specific building. Recommendations should report cost benefit implications as well as opportunities and obstacles to communication and implementation.

- Develop and present recommendations

Summary

The above methodology is designed to systematically assess each of the primary aspects of building technology, users, and administrative polices and to determine how they impact energy utilization in university academic buildings at MSU. It is a multi-phase approach where baseline information is developed early, so that each of the following studies are operating from common information, and can be tailored to effectively concentrate on those activities which are most useful. Each building is unique and an individualized approach should be determined. The outline of activities provides an overall approach for collecting and analyzing data and was developed from the Natural Resources Case Study project.