RESEARCH FOUNDATION
RESEARCH FOR THE NFPA MISSION

Evaluation of Electrical Feeder and Branch Circuit Loading: Phase 1

MEETING MINUTES

PROJECT TECHNICAL PANEL MEETING

CONFERENCE CALL
TUESDAY, 18 OCTOBER 2016; 1:00 PM

1) Call to Order and Attendees. The meeting was called to order at 1:00 pm by Casey Grant of the Fire Protection Research Foundation. The purpose of the meeting was indicated to further review various scoping and directional details. The following were in attendance:

- Mike Anthony, University of Michigan (MI)
- Jeff Gambrall, University of Iowa (IA) (Alt to Lou Galante)
- Tammy Gammon, Jasper Georgia (GA)
- Casey Grant, Fire Protection Research Foundation (MA)
- Jim Harvey, University of Michigan, (MI)
- Brian Liebel, Illuminating Engineering Society of North America (NY)
- Brian Meyers, University of Nebraska (NE)
- Bob Wajnryb, The Ohio State University (OH)
- Bob Yanniello, Eaton Corporation (OH)

2) Review of Project Work Plan. Tammy Gammon provided an overview of the project and the work plan using the slides included in Attachment A, and a draft of the work plan included as Attachment B. This resulted in the following observations, questions and comments:

- The literature review is composed of the following three sections: lighting; energy codes; and transformers
- IES, NFPA and IEEE all have useful information, and this coordination will be valuable.
- Oversized transformers are a concern, not only for efficiency but also as an inherent electrical hazard.
- NEC Articles 220.12 and 220.14 are the prime focus for this project.
- Utilities use different sizing approaches for transformers via the National Electrical Safety Code from IEEE, which has traditionally addressed electrical installations up to but not including within buildings.
- With the preliminary literature review as background, the data collection Plan was discussed.
- We need to keep in mind what will ultimately be helpful for ultimate code changes, including the inclusion of statistically significant data as appropriate.
- Panel members and sponsors need more time to review the draft work plan and digest its content.

- Everyone should review and provide additional comments
- Plan for next meeting in mid-November. In the meantime all should provide specific comments on the data collection plan, which Tammy will address in preparation for the next meeting.
- It was agreed that the next meeting will be on Tuesday 15/Nov/2016 at 10:30 am Eastern time.
- Circulate the current draft, and emphasize that everyone needs to comment back to Tammy.

3) Next Steps. Casey Grant will circulate the draft work plan and solicit specific comments directly back to Tammy, in preparation for the next conference call which will be on Tuesday 15/Nov/2016 at 10:30 am Eastern time. A meeting invite will be circulated.

4) Adjournment. Panel members were thanked for their participation, and the meeting adjourned at 2:00 pm.

(Meeting Summary by C. Grant, 22/October/2016)

Attachments

Attachment	Description	No. of Pages
A	PowerPoint Slide of Project Work Plan	2
B	Draft Project Work Plan	13

Fire Protection Research Foundation

Evaluation of Electrical Feeder & Branch Circuit Loading: Phase 1

Tuesday October 18, 2016, 1:00 pm EDT

Tammy Gammon, PhD, PE

Technical Panel: Mark Hilbert, Robert Arno, Mark Early, & Brian Liebel

Sponsors: University of Minnesota, Ohio State, University of Iowa, UT-Austin, Michigan State, Michigan Assoc. of Physical Plant Administrators, Notre Dame, University of Nebraska, Ohio State, Eaton

Fire Protection Research Foundation

Evaluation of Electrical Feeder & Branch Circuit Loading: Phase 1

Update and Open Discussion for Phase 1 Tasks

Task 1: Review of Literature

Task 2: Data Collection Plan

Literature Review...Topics Studied

- Electricity usage in by various sectors in this country & NEC
- Geographic regions in US – Census divisions, ASHRAE, and DOE
- Commercial buildings: types and demographics, energy and electricity consumption, major and minor end use loads
- MELs (Miscellaneous Electric Loads), including transformers and plug-loads
- Models for energy usage in buildings: DOE commercial building reference model and EIA (U.S. Energy Information Administration) NEMS (national energy modeling system) CDM (commercial demand module)

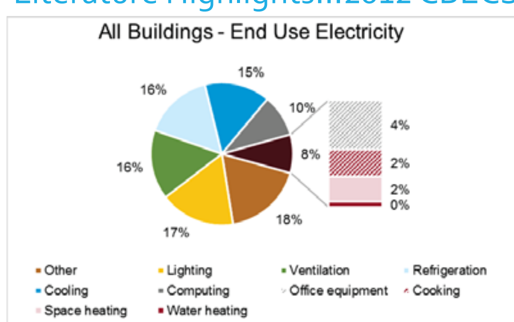
Literature Review...Work In Progress

- Lighting – communication with IES and PNNL, ASHRAE specifications
  - Needed: Review material provided by Eric Richman (PNNL) – technical documents on conversion of IES illuminance requirements to electric power density, contact IEEE (Steven Townsend)
- Energy Codes – ASHRAE and IECC, adoption, interior & exterior lighting
  - Needed: To more carefully study and understand relationship with electrical equipment selection and electrical stipulations contained
- Transformers – Review of Cadmus study (loading) and treatment as MEL
  - Needed: Impact of manufacturer date, type and loading level on efficiency, calculating losses, relationship of capacity to % impedance (available fault current)

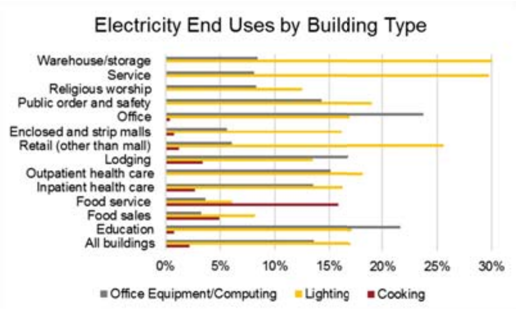
Literature Review...Work Remaining

- Current practices in electrical feeder and branch circuit design, including IEEE guidelines and NEC requirements
- Current practices in equipment sizing
- Final task: report of literature review

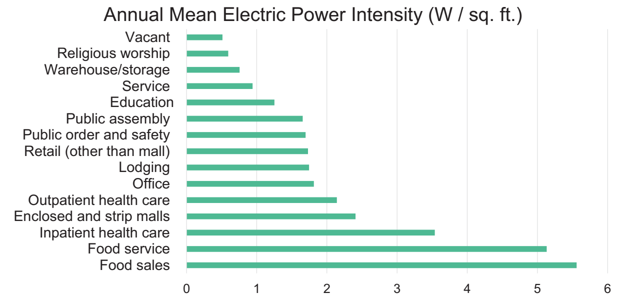
Literature Highlights...2012 CBECS



Literature Highlights…2012 CBECS

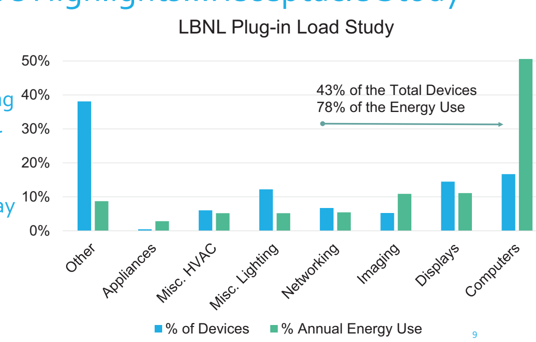


Literature Highlights…2012 CBECS



Literature Highlights…Receptacle Study

- 6-month+ study
- LBNL office building
- Power densities for
- Receptacle load:
- 1.1 W/ft² during day
- 0.47 W/ft² at night



Literature Highlights…Transformers

- A 2013 Navigant Study of 13 Commercial MELs estimated that distribution transformers consumed 43 TW-hours of electricity in 2011, more that any other MEL in the study.

Measured Transformer RMS Load Factors in 1999 Cadmus Study

RMS Load Factor	15-30 kVA	45 kVA	75 kVA	112.5-150 kVA	225-300 kVA
Average	23.4%	15.6%	14.0%	12.3%	19.9%
Maximum	62.4%	50.0%	40.2%	34.3%	35.6%
Minimum	1.3%	1.1%	0.9%	0.0%	11.0%
Number of Trans-formers (89 Total)	12	28	34	10	5

Data Collection Plan…Work in Progress

- Preliminary draft of data collection plan sent to project technical panel, project sponsors, and others involved in project.
- Data collection plan will be modified and further developed….based on input from you.

TEAM ROLL CALL: WHAT DO YOU THINK?

Project Technical Panel:

Mark Hilbert?	Robert Arno?	Mark Early?
Brian Liebel/Mark Lien?		

Project Sponsors:

Michael Berthelsen?	Brett Garrett?	Lou Galante?
Dean Hansen?	Kane Howard?	Michael Hughes?
Jim Jackson?	Paul Kempf?	Brian Meyers?
Bob Wajnryb?	Bob Yanniello?	

Anyone else?

Mike Anthony?	Jim Harvey?	Richard Robben?

Fire Protection Research Foundation Project

Data Collection and Analysis Plan for Evaluation of Electrical Feeder and Branch Circuit Loading Project Phase II

Drafted by Tammy Gammon, PhD, PE

Motivation for Project

Although electrical systems are utilized from the bottom up, they are designed from the top down. When a building is constructed, the transformer supplying the main feeder is installed before the procurement of all electrical equipment serving the building. Engineers determine the building power requirements based on the connected and demand load calculations subdivided in the following (or similar) categories:

Receptacle	Lighting	Heat	Cooling
Motor	Other	Spare	

The “Heat” load might consist of electric heating elements in the HVAC system, permanent space heating, and water heaters. In a commercial building, the “Motor” load might include elevators, exhaust fans, and pumps required for building function. The “Other” load might consist of any dedicated building equipment identified early in the design process. The “Heat,” “Cooling,” “Motor” and “Other” loads are based on known building service demands. The power required for these loads may be based on the specified equipment or estimated from other equipment capable of meeting the service demand.

Spare capacity may be added to one or all building panels to accommodate both anticipated and unforeseen additional load. Panel and feeder sizing are based on the demand power requirements which often includes spare capacity.

Branch circuit requirements for receptacle load power density are specified in NEC 220.14. The receptacle load is calculated at 180VA for each single or multiple receptacles on one yolk. Equipment with four or more outlets is calculated at a minimum of 90VA per receptacle. For feeder and service-load calculations, NEC 220.44 permits that the calculated receptacle demand load may be 100% of the first 10kVA plus 50% of the remaining kVA. Many practicing engineers question the 180VA design requirement especially in today’s changing technology market and changing receptacle usage. Morever, the NEC 180VA requirement dates back 1937. The National Electrical Code has been adopted statewide in 47 states, and its enforcement lies upon the authority having jurisdiction. However, even engineers in areas with statewide adoption have been known to not always adhere to the NEC; a review of a few sets of electrical plans uncovered three variations of the NEC feeder and service-load receptacle calculations, in addition to engineering judgement in the branch circuit design.

Like heat, cooling, motor, and other loads, lighting fixtures are fixed loads with specific power requirements. The Illumination Engineering Society has set guidelines on the illumination levels required to adequately light a space for specific work tasks. Engineers and lighting designers design fixture layouts to provide adequate illumination levels. But it has also been estimated that up to 40% of all lighting projects are designed by electrical contractors [Source: Mark Lien from IES]. The NEC specifies the minimum lighting load power density by occupancy type in Table

220.12, included as Table 1 here. As Table 1 illustrates, the load requirements have largely been in effect since at least 1968 with few modifications, yet lighting technologies have advanced and become much more energy efficient in the last fifty years.

The commercial reference building model for new construction, developed for the U.S. Department of Energy, uses the lighting power densities of ASHRAE 90.1-2004. Lighting power densities for ASHRAE 90.1 building area types equivalent to NEC occupancy types are listed in Table 1. The lighting power densities of ASHRAE 90.1-2013 and even 90.1-2004 differ significantly with the 2017 NEC.

Table 1. NEC and ASHRAE 90.1 Lighting Power Density (W/ft^2) by Occupancy Type

Type of Occupancy	NEC 1968	NEC 1971	NEC 1981	NEC 2017	90.1-2004	90.1-2013
Armories and auditoriums	1			1		
Banks	2	5	3½	3½		
Barber shops & beauty parlors	3			3		
Churches	1			1	1.3	1
Clubs	2			2		
Court rooms	2			2	1.2	1.01
Dwelling Units	3			3		
Garages – commercial (storage)	½			½		
Hospitals	2			2	1.2	0.94
Hotels, motels & apts. (no cooking)	2			2	1	0.87
Industrial commercial (loft) bldgs.	2			2		
Lodge rooms	1½			1½		
Office buildings	5		3½	3½	1	0.82
Restaurants	2			2	1.4	0.9
Schools	3			3	1.2	0.87
Stores	3			3	1.5	1.26
Warehouses (storage)	¼			¼	0.8	0.66
Assembly halls, & auditoriums*	1			1		
Halls, corridors, closets, & stairways*	½			½		
Storage spaces*	¼			¼		
***Except in individual dwelling units**						

In recent National Electrical Code editions, exceptions to these requirements are permitted if the building complies with local energy codes and a monitoring system is installed (2014 NEC). In the 2017 NEC, the lighting load specified by Table 220.12 for office and bank area may be *reduced by* 1 W/ft^2 when the local authority has adopted any energy code specifying an overall lighting density less than 1.2 W/ft^2. At least 45 states have energy conservation codes in effect. California and part of Hawaii have locally adopted codes; other states except Vermont have adopted ASHRAE 90.1-2004 or a later edition. In many states local energy codes are not enforced; however, even before state adoption of NEC's 2014 edition, engineers in various areas nationwide have to based lighting power density requirements on local energy conservation codes.

The National Electrical Code may be considered the Gold Standard for the design and installation of electrical equipment. For the NEC to remain the unrefuted standard nationwide, the requirements of the NEC must be well-founded and up-to-date with today's technology and building design. At one time, the NEC focused exclusively on the design and installation of electrical equipment. Today it also encompasses safety issues addressed by NFPA 70E, *Standard for Electrical Safety in the Workplace*; these issues include electric shock, arc flash hazards, and other forms of electrical injury. Recent NEC 2017 exceptions in Section 220.12 demonstrate that the NEC is also becoming responsive to growing national concern for energy conservation.

The U.S. Department of Energy has mandated greater efficiency requirements for transformers effective January 2016. For several years, government entities and electric utility providers have publicized the energy saving benefits of replacing older electrical equipment, including transformers and lighting fixtures, with new more energy efficient equipment. Financial incentives are often given.

There has been recent utility interest in "right-sizing" transformers to reduce energy losses associated with older oversized transformers. A 1999 Cadmus study of in-house low-voltage dry-type transformers found the average rms loading of transformers at 16% of capacity. A 2013 report prepared by Navigant for the U.S. Energy Information Administration estimated 43 TW-hours of energy loss generated by in-house, low-voltage dry-type transformers in commercial buildings in 2011. The Navigant study determined the energy consumption of thirteen MELs (Miscellaneous Electric Loads), including low-voltage dry-type transformers; as a group, the transformers, consumed more energy than any other MEL in the study.

Environmental science focuses on the importance of sustainability in new building construction. Sustainability is becoming a more important issue in electrical system design in buildings. Specifying oversized electrical equipment might be viewed as wasteful of national and planetary resources. Excess capacity may lead to higher available fault current which might increase electrical safety hazards, such as the potential energy associated with an arc flash event. "Rightsizing" equipment may also save in capital investment.

The intent of this research study is to evaluate electrical feeder and branch circuit loading in view of present NEC requirements, electrical safety, and energy conservation and sustainability issues.

The lighting and receptacle load is of particular interest because of the long-standing power densities established by the NEC. The lighting and receptacle load power densities in new building construction need to be measured to ensure that the NEC requirements reflect today's technology and usage in building spaces.

Furthermore, many commercial buildings are provided 480V which is stepped down to 208Y-120V by in-house transformers. The research project includes monitoring load levels on all transformers within the building and supplying the main service.

Relevance of Project Focus

In June 2016, electric utilities had close to 150 million customer accounts, including 18.3 million commercial accounts. Assuming each customer has at least one electrical service feeder, the number of service feeders must be close to 150 million and the numbers of distribution feeders and branch-circuits must exceed a billion. Feeders and branch circuit might be considered pipelines for electricity. In 2015, residential, commercial, and industrial sectors purchased over 3.7 trillion kW-hours of electricity.

The U.S. Energy Information Administration (EIA) estimated that, in 2012 in the United States, there were close to 5.6 million commercial buildings with a total floor space over 87 billion square feet. The EIA also estimated that lighting accounted for 17% of all electricity consumption; furthermore, other miscellaneous electric loads including computing and office equipment accounted for 32% of the total electricity consumption. In the 2012 Commercial Building Energy Consumption Survey (CBECS) funded by the EIA, office buildings alone accounted for 19% of the total number of commercial buildings, 19% of the total floor space, and 20% of electricity consumption.

A study on electrical feeder and branch circuit loading in commercial buildings will provide substantive data, more valuable than estimation, on the major and minor end-use loads in commercial buildings in the U.S. The average commercial building age is about 32 years. The results of this project may also serve as impetus for retrofitting equipment to realize energy savings and quality enhancements.

In addition, new data on transformer loading and measured power losses of working transformers might be warrant a reassessment of the transformer efficiency test procedures specified by the U.S. Department of Energy.

The results from this project will provide NEC code making panels data to reassess current NEC branch-circuit, feeder, and service load calculations, particularly for lighting and receptacle load.

The results of this project may stimulate additional national, standards, and professional group discussion on energy conservation and sustainability specifically in regard to building electrical systems.

Data Collection Plan

Objective

The objective is to locate fifty commercial buildings where electrical feeder loading can be monitored for one calendar year. Previous studies in the reliability of electrical equipment found that at least forty samples were needed for the results to be statistically meaningful. Ten additional office buildings have been added to enhance the statistical value and to compensate for any sites withdrawing, data being lost, or any unforeseen event which might reduce value of the building’s contribution to the study.

Selection of Types of Commercial Buildings

Three potential groups of commercial buildings have been identified for study. The final selection of which group of commercial buildings should be monitored may depend on budget, interest, and Phase II sponsorship.

Building Selection Option 1

- The Fifteen Commercial Building Types as identified in the 2012 CBECS
  - 192 commercial buildings total -- 12 for each of the 14 types except offices
  - 12 for office buildings up to 50,000 sq. ft. and 12 for those over 50,000 sq. ft.

Electrical feeder and branch circuit loading study is needed for different types of commercial buildings. The 2012 CBECS, costing in the tens of millions, collected detailed information about 6720 commercial buildings to project energy consumed by major and minor end-use loads in all commercial buildings. Although the study collects information about electricity usage, the specific energy consumption of end-use loads is not measured; it is estimated based on survey information about building HVAC equipment, lighting types, general numbers of computer and office equipment, etc.

The U.S. Department of Energy has developed its Commercial Building Reference Models from the 2003 CBECS and information found in ASHRAE standards.

The U.S. Department of Energy, the U.S. Energy Administration, and standards need data on the electricity consumption of specific load types in all types of commercial buildings. The U.S. government might use this information to help shape energy-related policies and develop more accurate models for electricity consumption in buildings. Consumption data on heating, cooling, ventilation, and refrigeration data would shed light on demand and mean power consumption of equipment with respect to manufacturer specifications, building needs, and electrical system design requirements. Inventory information and power and energy requirements for lighting and receptacles would shed light on usage and power demand requirements.

Furthermore, the U.S. Department of Energy mandates efficiency requirements and defines test procedures for measuring distribution transformer energy loss in the Code of Federal Regulations. Transformer efficiency is a transformer loading; 10 CFR §431.196 specifies transformer loading during the testing at 35% of rated load. If 35% loading is not representative of transformer loading, the DOE test procedure may not provide a good assessment of energy loss in working transformers.

Different building types may have different load profiles and transforming loading.

Building Selection Option 2

- Large University Campuses
  - 137 commercial buildings, with a focus on 50 office buildings as follows:
  - 25 offices up to 50,000 sq. ft. and 25 offices over 50,000 sq. ft.
  - 25 residence halls, 25 education buildings, 25 laboratories, 12 hospitals

Large university complexes might benefit from this study on electrical feeder and branch circuit loading because the results might help bring about changes in standards which might ultimately reduce capital investment in new construction. Results may also provide evidence for realizing energy savings through decisions to retrofit older, lossy equipment. Older equipment also has a higher probability failing, interrupting service, and even starting fire; furthermore, it is more likely to pose as an electrical hazard not only to maintenance workers but also to end users, including students. New equipment may also bring additional benefits such as improved lighting quality.

Building Selection Option 3

- Fifty Commercial Office Buildings
    - 25 offices up to 50,000 sq. ft. and 25 offices over 50,000 sq. ft.
    - 25 offices under 25,000 sq. ft. ideally equally divided as three groups: 1,000-10,000 sq. ft., 10,000-25,000 sq. ft., and 25,000-50,000 sq. ft.
    - For 25 offices over 50,000 sq. ft., ideally include 10 offices over 100,000 sq. ft. and 5 over 200,000 sq. ft.

The Request for Proposal issued by for the Fire Protection Research Foundation stated the initial focus was commercial office occupancies.

Geographic Selection

The monitoring sites should be selected to represent different climate zones, time zones, and Census regions. Many aspects of climate can influence daily power requirements, including: temperature, humidity, precipitation, cloud cover, and winds. In offices conducting interstate business, time zones might influence operating hours. In different regions of the country, building construction and engineering design practices may differ to due climate differences and local building and energy conversation codes.

Site locations should be selected to represent each IECC climate zone shown in Figure 1, but a higher percentage of monitoring sites should be concentrated in zones with higher population densities which also have greater building densities. A population density map produced by the United States Census Bureau has been attached as Appendix A.

The distribution of site selection is suggested in Table 2, modeling a study focusing on university campuses (Building Selection Option 2). If all major commercial building types (Building Selection Option 1) is selected for study, geographic distribution for each building type should be similar to the distribution for hospital selection in Table 2. If the commercial office building study (Building Selection Option 3) is conducted, office buildings should be selected as in Table 2. Ideally site selection for the two main groups of 25 office buildings (based on size) would be similar to the distribution for residence halls, education, or laboratories.

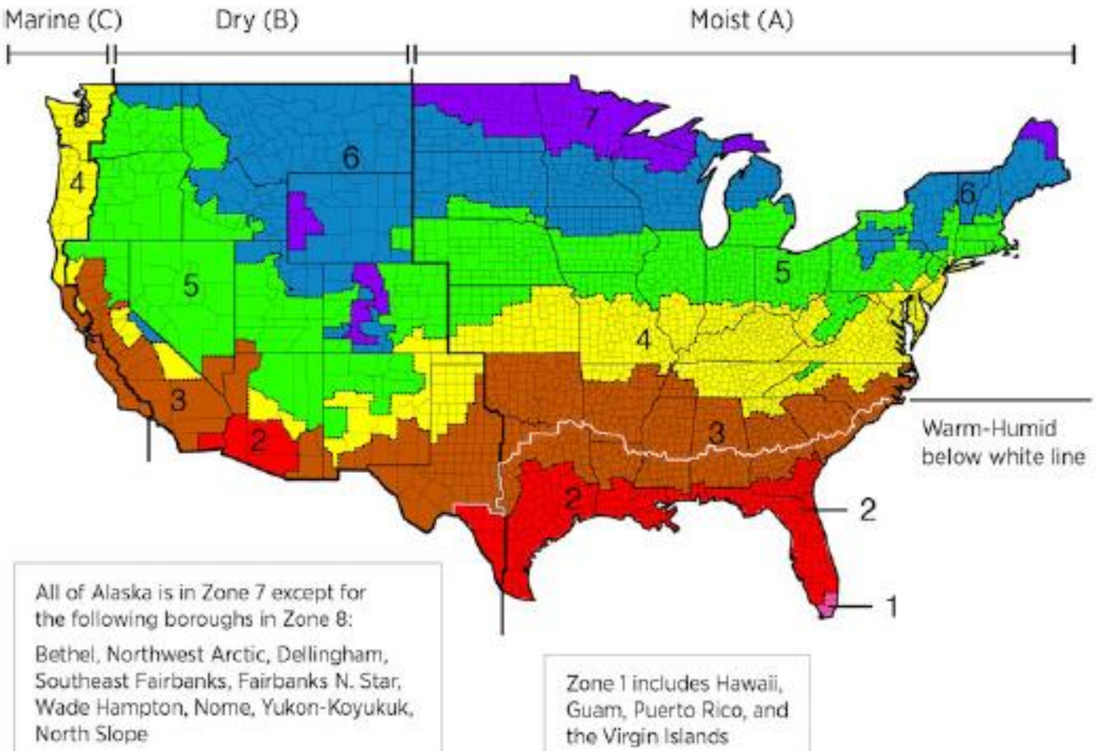


Figure 1

Table 2. Geographic Selection and Number of Monitoring Sites

	13 IECC Zones	3 DOE Added	Most Populated City	Office	Resi-dence Halls	Edu-cation	Labs	Hos-pitals
1	1		Miami	1				
2	2A		Houston	5	4	4	4	2
3	2B		Phoenix	2				
4	3A		Atlanta	5	3	3	3	1
5	3B	Other	Las Vegas	3				
6	3B	CA-coast	Los Angeles	3	4	4	4	2
7	3C		San Francisco	3				
8	4A		Baltimore	7	4	4	4	2
9	4B		Albuquerque	1	2	2	2	1
10	4C		Seattle	3				
11	5	5A	Chicago	7	4	4	4	2
12	5	5B	Denver	4	2	2	2	1
13	6	6A	Minneapolis	3				
14	6	6B	Helena, MT	1	2	2	2	1
15	7		Duluth, MN	1				
16	8		Fairbanks, AK	1				
			Total	50	25	25	25	12

Building Selection Criteria

Selected buildings should be less than three years old (preferably two) with all equipment installed and operating. Building should be functioning at designed capacity (in terms of building function, number of employees, etc.).

Other factors which should be made known during the site selection:

- Building service voltage
- Primary energy sources for heating, cooling, and hot water
- Number of in-house transformers and their rating

Ideally, selected buildings will have management and contact personal interested in participating in the project and willing to assist.

Required Building Documents and Information

Electrical plans including outdoor lighting plan and lighting fixture schedule

For all on-site transformers, the following nameplate information: manufacturer name, model and date; capacity; type (temperature rise); impedance; k-factor rating; primary and secondary voltages (and currents where specified); primary and secondary winding connection type

Mechanical plans with detailed HVAC and other mechanical equipment load information (including manufacturer and model information) for mechanical loads powered by electricity

Two-years of utility load data (including the year of which monitoring takes place)

Building size (should be part of drawings)

General description of building function and how employees carry out work (in an office building, if work primarily conducted through telephone and computer use, do employee tasks involve engaging with the general public)

Photos of building, representative interior spaces, and major equipment including: parking lot, main entry, office areas, reception area, breakroom or kitchen, corridor, server/IT room, mechanical and electrical room, RTUs, transformers, etc.

Numbers of full-time and part-time employees and target number of employees (with quarterly updates during the monitoring period). Additional employee demographics on age, gender, and race desirable if available).

If other buildings in addition to offices are selected for study, additional building benchmark information will need to be provided. For example, hospitals would need to provide number of beds and monthly reports on utilization. Education buildings would need to provide student capacity and utilization.

General building operating schedule and fixed or flex employee workhours on weekdays and weekends

General building schedules for heating, cooling, and ventilation (automatic or manual, location specific; fixed by time of day, day of week, and/or season; determined by employee comfort or directly controlled by employee?)

Schedule for lighting operation (automatic or manual, fixed by time of day, day of week, season)

Any building policies for turning office equipment, computers and/or monitors off during weekdays, evenings, or weekends

Inventory of items connected to receptacles (including manufacturer name and year, model, power requirements if available). Receptacle inventories should be labeled by building floor and space areas (as can be identified on building plans). Inventories can be self-reported by employees (including cleaning and maintenance staff), and updated or verified quarterly. The inventory list should also contain corded-equipment or tools (such as vacuum cleaners and drills) which are connected to receptacles on as-need basis.

Site Monitoring

<Your input here would be appreciated. What level of monitoring is feasible, practical, and/or doable. All monitoring suggested here would not be practical for hospital monitoring as part of university campus study.>

The following require continuous one-year monitoring of current, voltage, and power. Some project sponsors like government agencies may prefer monitoring all sites during a single calendar year beginning on January 1 and ending on December 31. Otherwise, it may be easier to begin monitoring once a suitable monitoring site has been identified and the site is ready to participate; conducted in this manner, the window of data collection for all sites should be 18 months or less.

- Main service feeder (may be provided as electric utility data, but need current and voltage harmonic content)
- All feeders supplying panels (will also provide information about transformer loading)
- All individual loads rated over 10 kVA, including any RTUs, elevator motors, dock equipment, water heaters, and large pumps. Exception: When HVAC equipment such as fan powered terminals and fixed space heating equipment are fed from a dedicated panel, monitoring the panel is sufficient.
- In addition, current harmonics and power should be monitored on all feeders supplying transformers. (Power loss calculated as power supplied to feeder supplying transformer subtracted from power supplied to downstream feeder supplying panel)

Ideally the lighting panels would be dedicated to lighting load. However, if other are loads fed from lighting panels, they should be continuously monitored individually, unless they represent less than 20% of the panel's demand load.

In larger buildings supplied by 480V, 208V panels primarily serve receptacle load. However, a wide range of miscellaneous equipment may also be served; these loads include ductless air conditioners and heat pumps, water heaters, low-voltage lighting, and smaller mechanical loads including dock equipment, pumps, fans, and electric vehicle charging stations.

Ideally, the building will have low-voltage panels dedicated to receptacle load. But even monitoring dedicated receptacle panels will not provide sufficient information about receptacle load. Receptacles are placed throughout buildings to provide convenient and easy access to electric power; in office buildings, receptacle locations include office areas, conference rooms, breakrooms, kitchens, restrooms, hallways, reception areas, filing and storage rooms, server/IT rooms, and exercise rooms. Receptacle load varies according to space, scheduling, time of day, and day of week.

Branch circuit monitoring for two[1] months is needed on low-voltage panels serving receptacle load. This monitoring would ideally occur during the coldest months if task lighting needs are higher seasonally or if portable heater usage is a common practice, although portable fans and dehumidifiers may also be used seasonally during warmer months.

Monitoring Equipment

<Your input here would be appreciated.>

Minimum accuracy requirements and sampling frequency

Ease, type (non-invasive and permanent?) and method of installation

Data logging and transmittal

Project would need to provide equipment, unless the project is sponsored by universities using their own equipment.

Suggestions for manufacturer websites for monitoring equipment? Any specific types or models recommended?

Data Collection

Project management will generate documents to more systematically collect building information from building contact personnel. Preferred document form is an Excel file for easy organization and analysis. Excel files might also be transformed for use in Access.

An internet location should be provided for monitoring site to upload requested documentation and information and data. Monitoring sites should provide monitoring data on a monthly basis (or more frequently).

Data Analysis

Evaluation of Lighting Load

1. Review electrical drawings and lighting schedule; note primary type of lighting used in different building spaces.
2. Calculate building lighting power densities from connected and demand load on panel schedules. Compare with NEC lighting power density. (If time and building layout permits, calculating lighting power density for office area specifically may be a useful comparison.)
3. Review measured data. Observe any hourly, weekly, and seasonal patterns. Record peak power. Calculate mean power and other useful statistics.
4. Compare measured data with panel schedule connected and demand load.
5. As feasible from measured data, calculate peak and mean lighting power densities. Compare with power densities in Step 2.

[1] A plug-load study at Lawrence Berkeley National Labs found that a 2-month study of plug-loads was long enough to estimate annual energy consumption with reasonable accuracy. The study monitored 455 plug loads for at least 6 months and many for over a year. The monitored plug-loads were selected from 4,454 inventoried plug-loads in an 89,500 square feet office building on site.

Evaluation of Receptacle Load

1. Review electrical drawings. As feasible with time constraint, record the number of receptacles assigned to each branch circuit. Compare receptacle count with connected and demand load listed on receptacle panel and the main distribution panel schedules.
2. Review measured data. Observe any hourly, weekly, and seasonal patterns. Record peak power. Calculate mean power and other useful statistics.
3. Compare measured data with panel schedule connected and demand load.
4. With results of Step 3, comment on NEC receptacle VA requirements and receptacle load after demand factors applied.
5. Review receptacle inventory. As feasible and time permits, analyze power requirements of the inventoried plug-in equipment and compare with measured load and calculated load. Comment on NEC receptacle VA requirements.

Evaluation of Other Loads

1. Review electrical and mechanical drawings and panel schedules. Note presence or absence of electrical heating, cooling, and hot water equipment. Note connected and demand load for “large” loads (over 10kVA) and any panels which exclusively serve one type of equipment (other than lighting and receptacle).
2. As feasible, compare panel schedule connected and demand load requirements with power requirements listed on mechanical schedule. (Ideally these will be manufacturer requirements, if not look up manufacturer requirements as time constraints and feasibility permit).
3. Review measured data. Observe any hourly, weekly, and seasonal patterns. Record peak power. Calculate mean power and other useful statistics.
4. Compare measured data with panel connected and demand load, and also with manufacturer requirements for any “large” loads monitored.

Evaluation of In-House Feeder Sizing and Transformer Loading

1. Review and comment on transformer power loss with reference to expected efficiency based on DOE requirements. As feasible and time permits, compare measured losses with estimations based on standard transformer tables and efficiency curves.
2. Review and comment on harmonic content. Calculate K-factor, if not directly measured. Compare measured K-factor with transformer K-factor rating, and K-factor rating recommended for load type.
3. Compare NEC feeder size requirements with feeder size and peak and mean measured loading. Note impact of spare capacity added to panels.
4. Compare panel schedule connected and demand load on panel served by transformer with transformer capacity, and peak and mean transformer loading.

Evaluation of Main Feeder Size and Service Transformer Loading

1. Review and comment on transformer power loss with reference to expected efficiency based on DOE requirements. As feasible and time permits, compare measured losses with estimations based on standard transformer tables and efficiency curves.
2. Review and comment on harmonic content, including in context of IEEE 519.
3. Calculate K-factor, if not directly measured. Compare measured K-factor with transformer K-factor rating, and K-factor rating recommended for building type.

4. Review the measured load data. Observe hourly, weekly, and seasonal patterns. Note if previous main service loading similar to previous year. Calculate peak and mean power density for building.
5. Compare connected and demand power requirements of main service panel, feeder size and transformer rating, and feeder size and transformer rating needed to meet peak power measured.

General Evaluation of Power Quality

1. Note any power interruptions and duration.
2. Review voltage data. Comment on voltage stiffness and relationship to levels established in ANSI C84.1. Note the presence and frequency of any voltage fluctuations, sags, or surges.
3. Review and comment on harmonic levels.

Deliverables

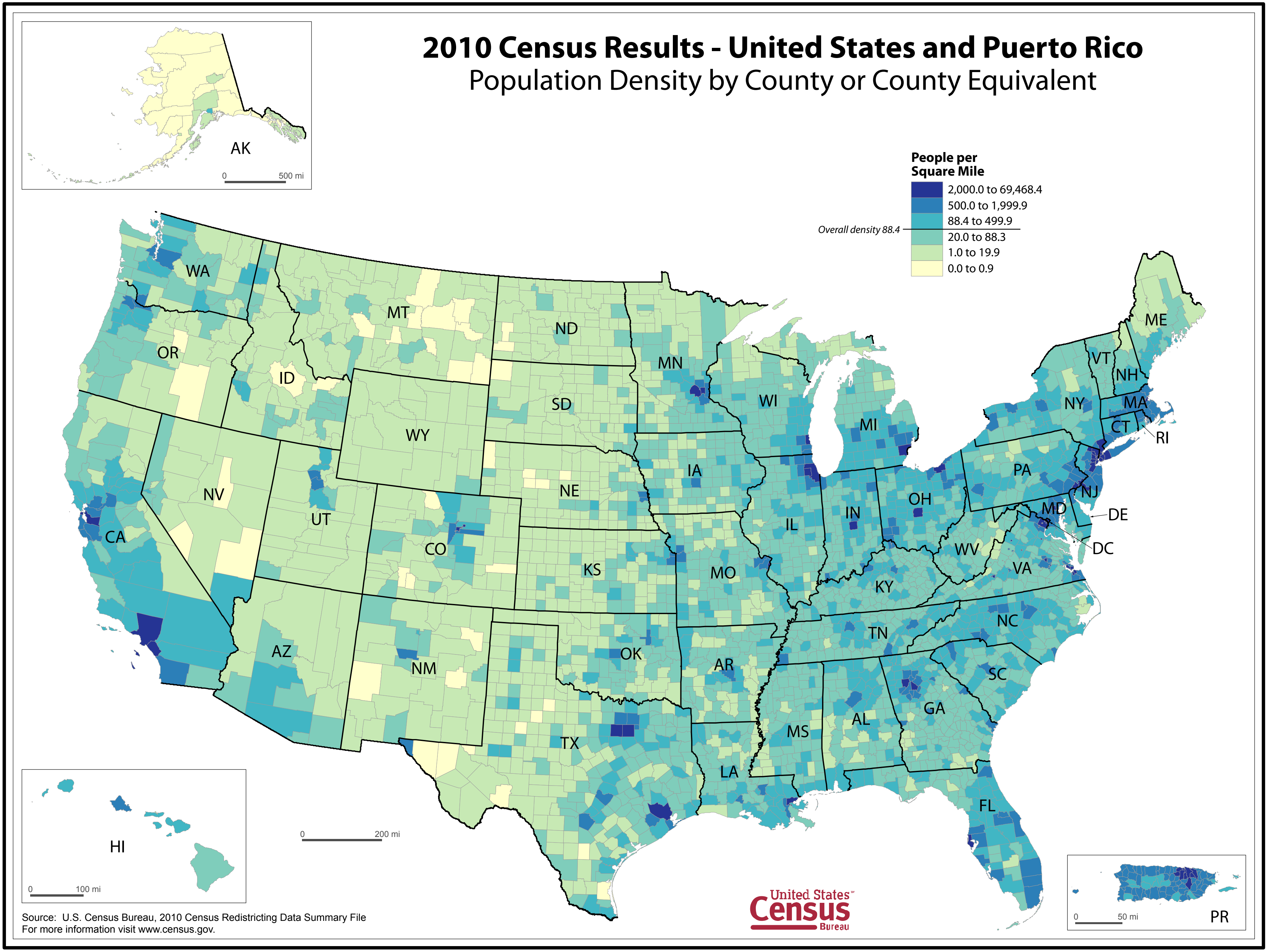
The final deliverables will be:

- Report which contains an extensive loading evaluation of each site and a comparison of sites, noting commonalities and differences.
- An executive summary with a database or one more spreadsheets. Key site information will be provided, including square foot, year of construction, number of employees, DOE geographic region, service voltage, and energy source for heating, cooling and hot water. Other summary information will include mean and peak power consumption (W/ft^2), lighting, receptacle, HVAC, and other loads as applicable. Transformer capacity and mean and peak power requirements will also be included.
- Individual site archives: all requested documentation and information and data.

Budget

The budget depends largely on research project sponsorship and final group of commercial buildings selected. For example, if universities sponsor the project (with locations identified in Table 2), provide monitoring equipment, and a working staff to install the monitoring equipment and supervise data collection on site, the only out-of-pocket expense would be for project management. Project management costs might be estimated to cover a two-year period from project inception to delivery of final report.

Appendix A


2010 Census Results - United States and Puerto Rico
Population Density by County or County Equivalent
People per Square Mile
2,000.0 to 69,468.4
500.0 to 1,999.9
88.4 to 499.9
Overall density 88.4
20.0 to 88.3
1.0 to 19.9
0.0 to 0.9
AK
0
500 mi
WA
OR
CA
NV
ID
MT
WY
UT
AZ
CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MI
IN
OH
KY
TN
MS
AL
GA
FL
SC
NC
VA
WV
PA
NY
VT
NH
ME
MA
CT
RI
NJ
DE
MD
DC
0
200 mi
HI
0
100 mi
PR
0
50 mi
United States Census Bureau
Source: U.S. Census Bureau, 2010 Census Redistricting Data Summary File
For more information visit www.census.gov.