Guidelines

\# 05--2012

Analyzing and Optimizing Facility Lighting

Background/Rationale: Facility lighting is seldom systematically analyzed, and as a result is often inefficient, using an unnecessary and expensive amount of electricity. Cost efficient yet high quality lighting is essential for any company concerned about energy efficiency as well as employee productivity, safety and comfort. Some older technology lights contain mercury, a hazard which must be disposed of properly, entailing time and costs. When considering lighting changes, there are many variables to consider, including lumens/lux, color-rendering index, temperature and candle power. Any business seeking to make operations more sustainable should take steps to fully understand its lighting needs and implement strategies to make the entire array of lighting more energy efficient. Optimizing facility lighting and reducing energy consumption will, in turn, indirectly help reduce greenhouse gas emissions and any adverse environmental impact associated with excess emissions.

Some improvements may be relatively simple and inexpensive to implement, while others may be more complex and require assistance from experienced professionals. The material contained in these guidelines is intended for use by persons who have a basic level of technical training/competence and familiarity with source reduction concepts and strategies.

Step 1: Assess the Current Situation/Define the Scope of the Situation

1.1. Collect and analyze information about current operations, including but not limited to:

- identify key/relevant sources of information (see Appendix 1, Examples 1 and 2):
  - the environmental cause champion,
  - maintenance and/or facility supervisor(s),
  - purchasing or accounts payable personnel,
  - key suppliers/vendors,
  - business representative at local electric utility
  - NOTE: Many electrical supply vendors and local utilities assist with or perform complete lighting assessments at low or no cost to customers.
- collect pertinent documents and information (see Appendix 1, all examples):
  - policies/procedures related to lighting:
    - formal/informal guidelines/expectations regarding use
  - formal/informal guidelines/expectations for routine maintenance
  - maintenance records, equipment specifications
  - utility bills identifying billing rates and energy usage
- understand definitions and use of common terms used in lighting evaluations:
  - light intensity is also known as candle power and is measured in units called candelas or lumens. It is not a common measure for lighting assessments since it is based on a uniform point source of light and not an exposed area.
  - illuminance is usually measured in footcandles or lux and is commonly used to describe how well an area is lit. A footcandle describes the intensity of light of one lumen on a one

square foot area. The term footcandle and lumen are often used synonymously. Lux is the SI derived unit, and one footcandle is equal to approximately 10 lux.
  - color rendering index (CRI) is a measurement of the ability of a light fixture to display the colors of objects compared to what they would be in natural light. It is measured on a scale of zero to 100, with 100 being the closest to natural light.
  - color temperature is used to rate the warmness or coolness of the color of a light and is measured in Kelvin (K). Lights that are rated from 2,700 to 3,000 K are warm, with a more white-yellow or red tinge. Lights that are rated above 5,000 K are cool, with a blue-white tinge.
  - T5, T8, and T12 describe lamp shape and size. The T describes the shape of the fluorescent lamp, which in this case is tubular. The number after the T describes the diameter of the lamp in the number of 1/8 inches. For a T12 lamp, its diameter is 12 times 1/8 inch, or 1.25 inches. This continues for the smaller lamps of T8, with a one inch diameter, and T5, with a 5/8 inch diameter.
- keep track of, document and distinguish between key assumptions, known or reported values, and information which is calculated (see Appendix 1, all examples)
- identify location/design of lights/lighting network (see Appendix 1, Examples 2-4):
  - develop lighting map using existing blueprints or new diagram to represent lighting/network being analyzed so that everyone involved understands the scope and details of what is being analyzed
  - count and describe each lamp by type, e.g., high pressure sodium, incandescent, etc. and wattage of bulb and fixture/ballast
  - may require expert consultation for some aspects (e.g. hazardous waste involved)
  - Note: Exit signs are usually treated as a special category within a comprehensive lighting assessment. They should not be overlooked or forgotten since their impact can be significant. (see Appendix 1, Example 5)
- conduct use analysis (see Appendix 1, all examples):
  - identify hours of operation
  - identify method of lighting operation (manual vs. automatic)
  - identify routine and special uses through interviews, direct observation or using testing equipment:
    - per area/unit/end use
    - identify current and optimal lighting requirements taking into account employee productivity, safety, and comfort
  - identify unnecessary uses and insufficiently and/or overly lit areas by direct observation or interviews with key personnel
  - identify maintenance schedule
    - identify tasks performed: frequency of bulb changes related to bulb lifespan, time and steps required for bulb changes, etc.
    - identify reports, documentation related to maintenance
- calculate amount/cost of electricity for entire facility and amount/cost associated with lighting to compare the impact of the lighting on the overall energy use at the facility (see Appendix 1, Example 1):
  - verify utility rate per kWh (including kWh cost for peak loading) from evaluation of the electric bills (NOTE: for some businesses this may require including an estimate of the

demand charges when the highest demand occurs during periods when the lights in question are turned on)
    - estimate the annual hours of operation/ calculate cost for lights by area/unit
    - identify the cost of replacement bulbs, ballasts or other fixtures and labor rates for maintenance activities
- conduct lumen/color/temperature analysis (see Appendix 1, Example 2):
    - use light meter to determine lumens/color/temperature in current lighting
        - light meters should be calibrated/recertified by the manufacturer to ensure accuracy of readings
    - tag and possibly photograph areas needing adjustment, and plot on diagram or map of facility.
    - prioritize lights for adjustment—fixing largest energy users first
- calculate life cycle impact on greenhouse gas emissions from the energy consumed by the facility lighting (see Appendix 3 for examples)

1.2. Conduct necessary research and calculations using the following useful material:

The following references are used to help calculate energy waste and to identify potential strategies for improving lighting:

1. An energy savings calculator for comparing incandescent lights to compact fluorescents is available online at: http://www.bulbs.com/resources/energycalc.aspx?cm_sp=Homepage-_-Bugs-_-EnergyCalcBug

The following references are used to calculate life cycle impact on greenhouse gas emissions:

1. U.S. EPA' Pollution Prevention (P2) Greenhouse Gas (GHG) Calculator, available online through the National Pollution Prevention Roundtable at: http://www.p2.org/category/general-resources/p2-data-calculators/

2. U.S. EPA, Clean Energy. "eGRID 2007 Version 1.1." February 2009. Dowloadable ZIP file: eGRID20071_1year05_aggregation.xls, tab NRL05 and US05 available online at: http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html#download

3. US EPA, Downloadable Document: "Unit Conversions, Emissions Factors, and Other Reference Data, 2004." Table I, Page 1 available online at: http://www.epa.gov/climatechange/emissions/downloads/emissionsfactorsbrochure2004.pdf

The following reference is used to determine the appropriate amount of lighting needed in a variety of different industrial settings such as office and assembly areas. It should be noted that this standard does not take into account modern thinking about energy conservation.

1. American National Standard A11.1-1965, R1970, Practice for Industrial Lighting, for recommended values of illumination.

Step 2: Identify Feasible P2 Opportunities

2.1. In general:

- research a full range of possible operational improvements/modifications/suggestions relevant for the situation at hand (several commonly applicable suggestions are listed below)
- be specific about the "unit" for application, i.e. which lights/networks to modify
- keep track of, document and distinguish between key assumptions, known or reported values, and information which is calculated (see examples throughout appendices)
- include a thorough cost analysis: use a chart to compare current to proposed costs and calculate payback period
- include relevant vendor information (the vendor information included in these guidelines is for example only)
- identify how to monitor/measure impact for each suggestion if implemented, e.g. install gauge or electric meter, compare bills, monitor use

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2.2. Selected strategies to consider, including techniques and calculations to perform:

- implement a "lights off" or educational program
    - see Appendix 2, Example 1
- replace bulbs in existing fixtures:
    - incandescent with energy efficient florescent
    - see Appendix 2, Example 2
- retrofit/replace light fixtures and types of lamps:
    - high bay high pressure sodium/metal halide with T5 fluorescent
    - incandescent exit signs with LED exit signs
    - see Appendix 2, Examples 3a and 3b
- calculate life cycle impact on greenhouse gas emissions compared to current processes
    - see Appendix 3 for examples

Step 3: Identify Barriers to and Benefits of Implementation for Each Opportunity

After analyzing the facility lights and identifying feasible opportunities for realizing savings, you will want to make as strong a business case as possible for making changes. Be proactive and identify key barriers to and benefits of implementing the opportunities you want to recommend. To help you do this, the P3 program offers the following information.

Based on experiences over the past 15 years, the P3 program has found that simple projects with thorough documentation and short pay back periods or projects with compelling cost and environmental savings have a high likelihood of being implemented. For example, suggestions for replacing incandescent or older technology bulbs with newer more energy efficient bulbs are often implemented. An analysis of reassessment data for 2008-2011 shows that eight out of eight times (100%) recommendations for replacing incandescent bulbs or older T12 bulbs with newer fluorescent bulbs were implemented. Companies are typically receptive to opportunities which reduce utility costs and increase productivity, safety and comfort for employees. Steps to reduce environmental impact often simultaneously have a positive impact on the health and safety of the working environment.

On the other hand, suggestions which are high cost, with long payback periods, or which have complex implementation logistics, or are not adequately researched or quantified are typically not implemented. For example, suggestions for replacing entire light fixtures/networks with relatively costly alternatives may not be favorably considered, at least in the short run. An analysis of reassessment data for 2008-2011 shows that only two out of four times (50%) were recommendations for installing LED exit signs to replace older model signs implemented. Interestingly, some low cost, quick payback suggestions which involve changing employee behavior may not be implemented due to the common human tendency of resistance to change. For example, implementing a "lights off" campaign may not be a strategic priority. An analysis of reassessment data for 2008-2011 shows that only two out of three times (66%) were recommendations for installing "turn lights off" light switch reminder labels implemented.

See Appendix 2 for examples of implemented P2 lighting suggestions from the Nebraska intern program. These are annotated to make it clear what information is needed to perform these calculations for a different facility and to explain why some suggestions were implemented and others were not.

Common Barriers:

<u>Beliefs & Attitudes</u>

- resistance to change—employees set in ways and enjoy convenience of leaving lights on throughout the workplace
- skepticism—employees skeptical about safety/comfort of operating in reduced lighting areas
- other/higher strategic priorities—the company may have other issues is sees as more important to address in the short run
- misinformation or lack of understanding about the costs of lighting:
    - that small fixes can yield measurable results
    - how using unnecessary energy can affect the environment
    - lack of technical understanding that certain tasks require less/different light
- reluctance to embrace rapidly changing technology until the marketplace has stabilized. (need to just "change again")

Costs and Investments

- cost (time, effort and money) of implementing suggestions
  - capital investment-"up-front costs"
  - operating constraints: interrupting operations to implement changes
  - time/costs of retrofitting fixtures
- timeline for return on investment (ROI)—length of payback period
- perception of cheap and available lighting
- overall low cost of lighting relative to entire bottom line

Technical Issues: What to Do and How

- lack of knowledge/skills re: what needs to be done/how to implement strategies
  - access to equipment for analyzing lighting
  - access to electrician for lighting modifications
- concern re: managing logistics and process changes, including down time

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Common Direct and Indirect Benefits:

Cost Savings

- reduces costs and improves efficiency of operations by using less energy to accomplish same work/product
- increased productivity for employees
- reduces maintenance costs involved in replacing bulbs with short life spans

Environmental Impact

- reduces impact of operational processes on the environment:
  - reduces use of natural resources/raw materials to produce energy
  - reduces greenhouse gas emissions related to energy production
  - conserves/preserves/provides clean environment/quality of life for future generations

Education

- educates employees and general public in efficiency and responsibility when information is posted about the change and why it was made

Health and Safety

- improves safety and comfort of work environment for employees

Company Image

- demonstrates social responsibility and best management practices

Step 4: Make the Business Case for Change

4.1. Develop a written report for submission to decision makers.

- include a thorough assessment of the system, with process descriptions, flow charts and lighting use/cost information.
- outline specific P2 Opportunities/Suggestions with the following information:
    - recommended action
    - brief summary of current operations
    - cost of implementing recommendation
        - include labor costs/savings in your economic analyses.
    - summary of benefits (acknowledge barriers but discuss how benefits outweigh):
        - potential cost savings ($)
        - air/electricity use reduction(s)
        - simple payback
        - indirect benefits: safety, risk/liability reduction, GHG reductions, etc.
- always identify how to monitor/measure impact for future analysis: e.g. install electric meter, monitor use on the plant floor
- incentives to change: conclude the report with a summary of the benefits to be realized from implementing the recommendations made. Stress environmental stewardship. Call for action!
    - you may want to reference previous successes in similar businesses as a selling point
    - see Appendix 2 for example projects implemented and their results

4.2. Make an oral presentation to summarize your findings and call to action:

- focus on pertinent details of system assessment and P2 opportunities
- make it interesting yet include sufficient technical detail to be convincing and make the business case for change— include a picture of the product/change in action
- develop a final "impact" slide with table of metrics—call for action/change
- allow time for question/answer period

4.3. Advocate for change based on metrics/facts and environmental ethic:

- use informal interactions to establish trust in your abilities and to build a foundation for change
- use written report and formal presentation to communicate your findings and provide the formal information/rationale for implementing recommendations
- emphasize sustainability (triple bottom line) and preserving resources for future generations
    - energy conservation and the relationship to greenhouse gas emissions is particularly important for lighting changes
- use examples of implemented suggestions from past projects (see Appendix 2)

4.4. Report potential Greenhouse Gas (GHG) emission reductions as an important indirect benefit:

- include in written report and oral presentation
- include explanation of why GHG emissions are relevant/of concern to all businesses
- calculate potential carbon dioxide equivalent (CO2e) emission reductions for each recommendation
- include an appendix in written report documenting calculations (see Appendix 3 for details and example calculations for lighting situations)
- see Appendix 4 for additional tips for making the business case for change.

Appendix 1
Example Assessments of Lighting

Note: *Several examples of lighting assessments are included below. Each of these addresses one or more of the steps needed to accomplish a thorough assessment. In these examples, we have attempted to clarify for the reader what information is known or reported, what is logically assumed, and what has been calculated. This is embodied within the narrative for easy reference. In an actual report, these details would likely be in attached appendices so as not to interrupt the flow of the report.*

Example #1: Examination of Electricity Bills for Lighting Impact (adapted from reports by Holly Lohmeier and Lauren Swadener, 2010)

One step in a lighting assessment is to examine electricity bills for prior years, determining the total facility kWh usage, demand and cost, and then to calculate the portion that is reasonably related to lighting. It may be helpful to work with representatives from the local utility company on this research.

As shown in Figure 1 below, a plant's electricity bills were organized for the last 5 years, with some averages and patterns observed. This example shows the last five years electricity bills by monthly dollar amount. Cost increases were noted in June and December each year. This is due to two factors: in June, the electrical rates are changed to summer rates which are about 33% higher than winter rates and the fall and early winter is part of the 'busy' time of year for production, meaning more machines are used for longer periods and thus using more electricity. After evaluation of the energy consumption for the largest manufacturing machine users and discussion with the electricity service representative it was assumed that a large portion of these electricity costs go towards lighting the facility (approximately 50% or $3,000/year). From the energy rate ($0.05/kWh) this was calculated to be approximately 60,000 kWh/year. The plant wants to reduce annual electricity consumption by 3 percent. A slight overall trend of increases in the electric bills was also noticed, verifying the need to identify source reduction measures.

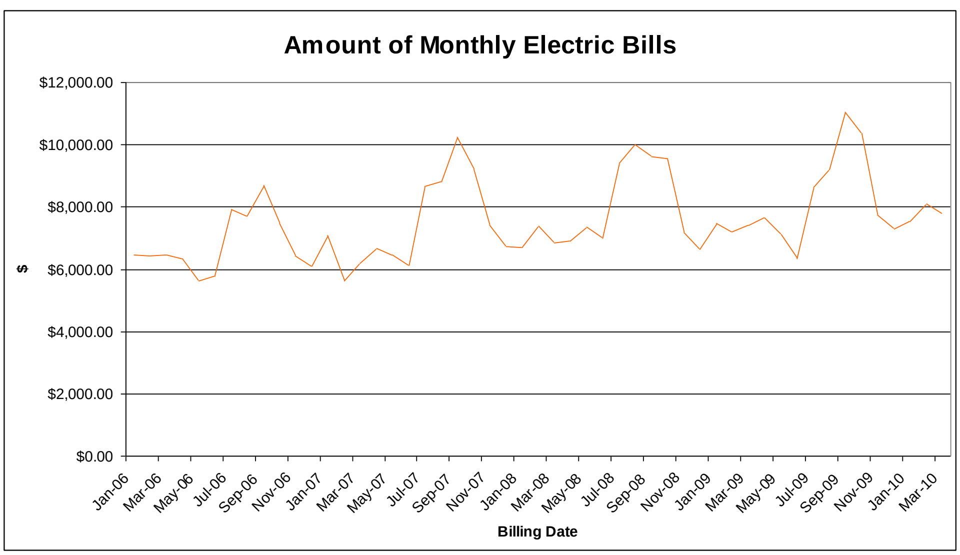

Figure 1. Five Year History of Electric Bills

Example #2: Descriptive Evaluation of Lighting Conditions (adapted from report by Lauren Swadener, 2010)

High Bay Lighting: With help from the company staff, the following information was gathered about the current high bay lighting:

- the building has approximately 35 feet high ceilings.
- the high bay lighting consists of
    - 95-400W and 4-1000W High Pressure Sodium lights
    - 129-400W and 12-1000W Metal Halide lights

The lighting quality provided by these lights deteriorates quickly over time. The lights are located so some aisles and areas are not as well lighted as others. The lights are needed for operations such as:

- forklift drivers going down aisles distributing or retrieving materials
- workers operating machines or assembling product
- workers and forklift drivers packing up products

The high bay lights in the warehouse stay on 24 hours a day, five days a week. This greatly shortens the bulb life so they have to be changed every two to three years. Figure 1 shows the area of the warehouse illuminated by the high pressure sodium and metal halide lights.

Figure 1: Metal Halide and High Pressure Sodium Lights

Low Bay/Work Lighting: In the low bay workspaces, employees assemble product. The lighting consists of one or two-bulb six foot T12 fluorescent lights. According to workers in the area, this does not provide sufficient light for the work going on here. Figure 2 below shows this work area.

Figure 2: T12 Fluorescent lighting

Two four-bulb T5 fluorescent fixtures were installed in one of the work areas to test how well they work for low bay lighting. Actually, both the T5 and T12 lights did not provide proper illumination for the work done in these areas. The T12 fixtures do not provide enough light in all areas and the T5 light fixtures provide too much light for the workspace due to the number of bulbs in the fixture and how close the lights are to the workspace. Because of this, these lights were rarely used in the work areas. This emphasizes how important it is to have site-appropriate lighting throughout a facility.

Office, Break Room, Bathroom, and Conference Room lighting

The lighting in the offices, break rooms, bathrooms, and conference rooms all use the same four foot four-bulb T12 fluorescent lights. The electrician has been slowly switching over all the lighting, as bulbs burn out, to T8 fluorescent lighting. Figure 3 below is an example of the T12 lighting used in these areas.

Figure 3: T12 Fluorescent Lighting in Offices, Break Rooms, Bathrooms, and Conference Rooms

Example #3: Quantitative Evaluation of Lighting and Energy Use (adapted from report by Lauren Swadener, 2010)

The facility has both a manufacturing area (workstation) and an office area that are lit with a variety of lamps and light fixtures. The power (in Watts) was determined from a study of the purchasing records and the manufacturer's specifications for the lamps and the existing lights. From an analysis of billing records and confirmation with the utility provider, the cost of electricity to the facility was determined to be $0.056/kWh. Using this information an analysis of the electricity use and cost for the facility was calculated and is shown below:

Calculations for Lighting in the Facility

Workstation Hours of Operation		Office Hours of Operation	
hrs/day	10	**hrs/day**	24
days/wk	5	**days/wk**	7
wks/yr	52	**wks/yr**	52
hrs/yr	2600	**hrs/yr**	8760

Current Lighting							
Bulb Type		**Wattage**	**Number of Fixtures**	**Operation Hours/Year**		**Conversion to kWh**	**Annual Operation Cost**
Metal Halide		458	95	8760		381,000	$ 21,300
		1060	4	8760		37,000	$ 2,100
High Pressure Sodium		468	129	8760		529,000	$ 29,600
		1060	12	8760		111,500	$ 6,200
	Total		240			**1,058,500**	**$ 59,200**
Fluorescent	2B T12 4ft	80	1	2600		200	$ 10
	2B T12 8ft	132	30	2600		10,300	$ 590
	1B T12 8ft	75	14	2600		2,700	$ 150
	HO T8 2B 4ft	110	3	2600		900	$ 50
	HO T5 4ft 6B	360					$ -
	HO T5 4ft 4B	200					$ -
	Total		48			**14,100**	**$ 800**
				TOTAL:		**1,072,600**	**$ 60,000**

Example #4: **Quantitative Description of Illumination Using a Light Meter** (adapted from report by Industrial Assessment Team, 2010)

There appears to be more light than needed in the lobby area, which creates demand for extra electricity generation and increases costs. The lamp fixtures operate 24 hours/day, but would not need to be in operation during daytime hours. Lighting guidelines developed by OSHA typically suggest that areas where employees operate computers require an illumination between 200 and 500 lux. It is assumed that seating areas should have similar lighting to provide adequate reading light for the customers. Visible light readings were taken from several locations throughout the lobby during daytime hours. It was observed that lighting throughout was similar in all areas except near sunlight and windows at the North and South ends of the lobby. See readings recorded on Figure 1 below.

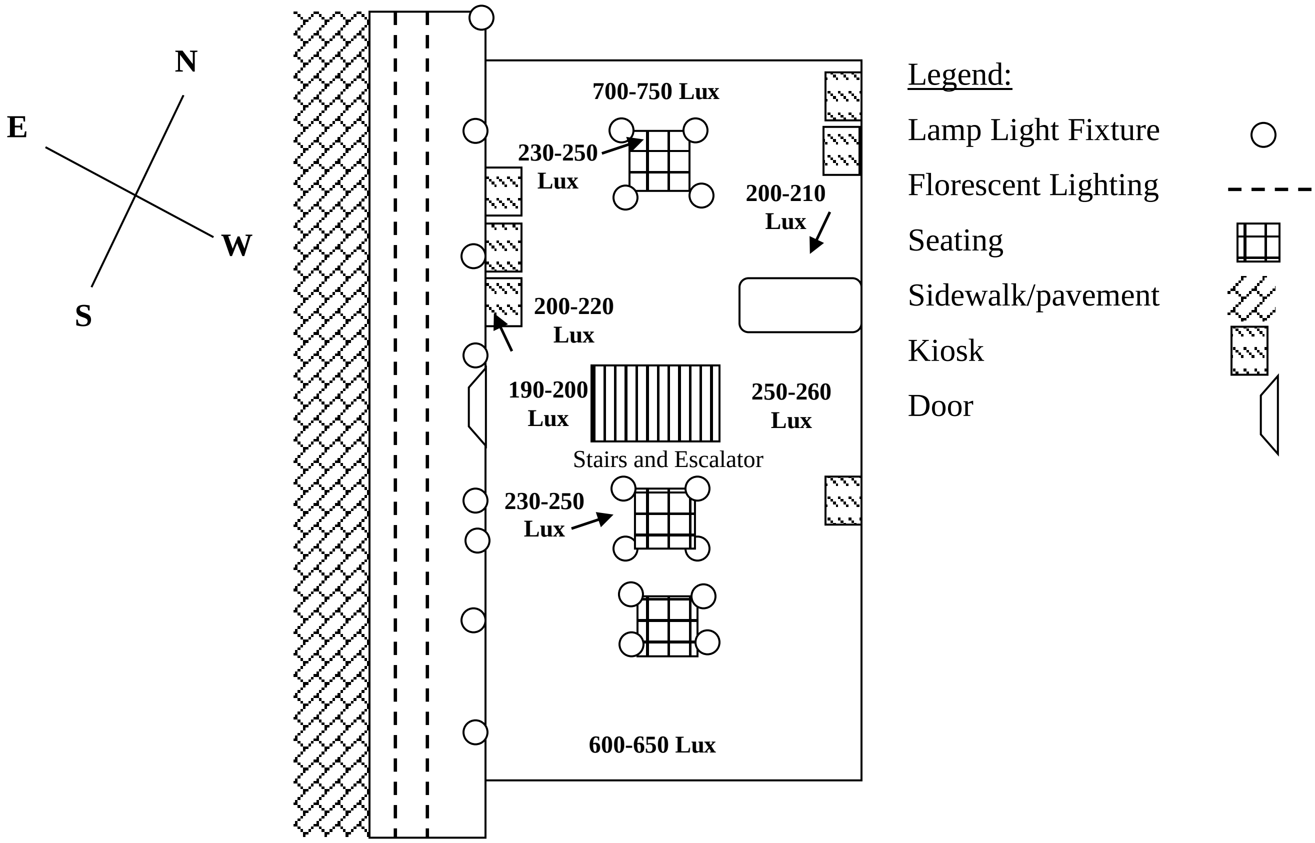

Figure 1: Diagram of First Floor Lobby

The present lighting in the kiosk and seating areas has lighting values approaching or exceeding 200 lux at all locations. The lamp light fixtures only marginally increase visible light in the seating areas. Electricity used by the twelve lamp light fixtures in this area is equal to **4000 kWh/year and costs $200/year in utility costs**. Calculations for energy use and cost savings are shown below. Note: Changes to the lighting could influence customer impression of the seating areas; therefore the company may want to consider conducting a survey about lighting quality in seating areas before and after any changes are made to assure customer comfort

Calculations for Energy and Cost Savings for Lamp Fixtures

Assumptions:

--lamp light fixtures in seating area use 75 Watt CFL bulbs (observed)

-- light fixtures operate 24/7 (per staff report)

-- electricity rate is $0.05/kWh (per staff report)

Calculations:

--(75 watts/fixture X 12 fixtures X 12 hours/day X 365 days/year) X1 kW/1000 watts = 4000 kWh/yr

--4000 kWh/yr X $.05/kWh = $200/yr

Example #5: Assessment of Exit/Emergency Lighting (adapted from report by Jessica Mohatt, 2006)

An analysis was conducted of the emergency exit lighting. A variety of exit signs are placed throughout the facility, including: two kinds of incandescent, fluorescent, LED, and a small number of self luminous signs. The facility consists of areas inside and also a number of outbuildings. The maintenance of exit lighting in the outbuildings takes about three times longer than in the facility so labor costs are more significant for those locations. Table 1 shows the number of each type of exit sign, the energy use, and the annual costs associated with each type of sign. Annual maintenance costs include the costs of replacement bulbs and the labor required to install them.

Table 1. Current exit sign quantity, energy use, and maintenance costs

Type of Sign	Number in Facility & Outbuildings	Bulb Life	Watts Used	Annual Energy Costs	Annual Maintenance Costs (Labor + Bulb Replace)
Incandescent (2 bulbs, 10 W each)	78	3 mos.	20	$680	$5,910
Incandescent (2 bulbs, 50 W each)	6	3 mos.	100	$260	$1,100
Fluorescent (6 W)	122	1 yr	6	$320	$1,700
LED	48	20 yr	2	$42	$0
Self Luminous	4	20 yr	0	$0	$0
Total	254	---	---	$1,300	$8,710

Detailed calculations for costs of incandescent and fluorescent bulbs are shown below.

Current Operational Costs for Non LED Exit Signs

Known Values:
--incandescent bulbs are replaced four times/yr; fluorescents one time/yr (per facility maintenance staff)
--it takes 15 minutes to change a bulb in the facility; 45 minutes in the out buildings (per facility maintenance staff)
--labor costs $24/hr
--electricity costs $0.05/kWh (per utility bills, including demand charge factor)
--lights are on 24 hrs/day, 365 days/yr = 8760 hrs/yr
--current LED signs use 2W (per product specifications)
--replacement bulb costs (per purchasing invoice):
  -10W incandescent $3.74/bulb
  -50W incandescent $4.75/bulb
  -6 W fluorescents, $5.90/bulb

Calculations:
Electricity Use:
(78 signs X 20W = 1560) + (6 signs X 100W=600) + (122 signs X 6W=732) = 2892 W
2892 W X 0.001 kW per W X 8760 hrs/yr = 25,334 kWh/yr
25,334 kWh/yr X $0.05/kWh = $1,267/yr

Replacement Bulbs:
10W incandescent: 78 signs X 2 bulbs/sign X 4 changes/yr X$3.74/bulb = $2165
50W incandescent: 6 signs X 2 bulbs/sign X 4 changes/yr X $4.75/bulb = $228
6W fluorescent: 122 signs X1 bulb/sign X 1 change/yr X $5.90/bulb = $720
$2165 + $228 +$720 = $3113/yr

Labor:
In facility:
10W Incandescent: 78 signs X 2 bulbs/sign X 4 changes/yr X .25 hr/change = 156 hr/yr
6W fluorescent: 101 signs X 1 bulb/sign X 1 change/yr X.25 hr/change = 25.25 hr/yr

Out Buildings:
50W incandescent: 6 signs X 2 bulbs/sign X 4 changes/yr X.75 hr/change = 36 hr/yr
6W fluorescent: 21 signs X 1 bulb/sign X 1 change/yr X.75 hr/change = 15.75 hr/yr

156 hr + 25.25 hr+ 36 hr+ 15.75 hr = 233 hr/yr X $24/hr + $5,592/yr

Total Cost: $1,267 (electricity) + $3,113 (bulbs) + $5,592 (labor) = $9,972 or ~$10,000/yr for non-LED lights

Appendix 2

Example P2 Opportunities for Improving Facility Lighting

Note: *Several examples of opportunities for improving facility lighting are included below (see separate Guideline # 003 for Use of Occupancy/Light Sensors). Each of the examples below addresses a different way to improve practices and achieve direct and/or indirect savings and each uses different techniques for encouraging implementation. In these examples, calculations are embodied within the narrative for easy reference, although in an actual report, these would likely be in appendices at the end so as not to interrupt the flow of the report.*

Example #1: Place "lights off" reminders labels by light switches (adapted from report by Scott Barker, 2009)

Using light switch reminder labels to prompt people to turn off lights when leaving the area, particularly in rooms that are only intermittently used such as storage rooms, bathrooms, some offices and conference rooms, can reduce electricity usage and cost. At this facility this addition can result in savings of $4,500/year through a reduction of 55,800 kWh/year. Placing light switch reminders throughout the facility will promote awareness and improve the company image among employees and the general public. A sample switch reminder is shown below in Figure 1.

Figure 1. Sample light switch reminder

Light Switch Reminder Calculations

Known Values:

--avg kWh per month use for entire facility: 620,000 kWh (per accounts payable)

--electricity cost $0.08 per kWh (per accounts payable)

Assumptions:

-- 5% of the total electricity use is for intermittently used rooms throughout the building

--15% energy used for lighting can be saved by using reminder labels on light switches (per published study in *Lighting Research & Technology, Vol. 19, No. 3, 1987, pp. 81 – 85.*)

$$\frac{620{,}000kWh}{month} \times .05 \times 15\% = 4650\frac{kWh}{mo} = 55{,}800\frac{kWh}{yr}$$

Savings in kWh = 55,800 kWh/yr

Cost Savings = 55,800 kWh * $0.08/kWh = $4,500/year

Cost of Implementation: negligible materials and time to make/post "lights off" reminder labels

Implementation Status: Implemented (adapted from reassessment report by Kurt Palu, 2010)

To reduce energy use, light switch reminders were placed in several storage rooms, bathrooms, offices and conference rooms that had lights left on when not occupied. It is estimated that the reminders reduce electrical use in those rooms by 15%, resulting in savings of **55,800 kWh and $4,500 per year**.

Key Barriers/Benefits: Environmental health and safety staff on site were supportive of and actually initiated implementation, using the savings calculations provided by the intern to reinforce the message and help spread P2 awareness among employees. Energy and cost savings were well documented. The project was simple. The implementation costs were negligible. The organization saves on operating costs, energy consumption, and related environmental impact on an ongoing basis.

Example #2: Replace incandescent bulbs with more energy efficient direct drop-in replacement fluorescents using existing fixtures (adapted from report by Scott Barker, 2009)

Currently incandescent bulbs are used in multiple areas within the facility. Because a small filament in the bulb is heated until it produces light, these are highly inefficient using only 10-15% percent of the energy to provide light. Replacing incandescent bulbs with compact fluorescent light bulbs (CFL) will reduce electrical costs for these lights by up to 80%. An inventory of bulbs and the patterns of use is used to calculate potential electricity savings. By replacing all incandescent bulbs the organization will **save 18,000 kWh and $1500 per year,** as calculated below.

Calculations for Replacing Incandescent Bulbs

Known Values

--29 incandescent bulbs operate 24 hrs/day; 19 operate 17 hrs/day; 3 operate 12 hrs/day
--incandescent bulbs are 60 W each; compact fluorescent light (CFL) bulbs are 13 W each
--cost per incandescent = $0.22 (per purchasing); cost per CFL = $1.29 (per purchasing)
--electricity cost $0.08/kWh (per electricity service provider)
--labor costs $18/hr (per management)

Assumptions

--avg. incandescent bulb life = 1,000 hrs; avg. CFL life = 10,000 hrs
--time to change bulb ~ 5-10 minutes

Current Incandescent Lights

Totals: 51 bulbs use ~23,000 kWh/year and cost~ $1900/year in electricity costs

Compact Fluorescents Lights

29 bulbs X 13 W X 24 hrs/day X 365 day X 1kW/1000 W = 3,300 kWh X $0.08/kWh = $300
19 bulbs X 13 W X 17 hrs/day X 365 day X 1kW/1000 W = 1,500 kWh X $0.08/kWh = $120
3 bulbs X 13 W X 12 hrs/day X 365 days X 1kW/1000 = 200 kWh X $0.08/kWh = $15
Totals: ~5,000 kWh/year and ~ $400/year

<u>Upfront Costs</u>
Labor to Replace Bulbs: 51 bulbs X .10 hrs X $18/hr = ~$90
Cost of Bulbs: 51 bulbs X $1.29 = ~$65

Estimated Annual Savings: ~18,000 kWh and $1500

Payback Period: Upfront Costs ($155) divided by Annual Savings ($1500) = .10/year or **1.25 months**

Implementation Status: Implemented (adapted from report by Kurt Palu, 2010)
The organization was already in the process of replacing incandescent light bulbs with higher efficiency CFL bulbs. The intern's report helped document the cost savings and environmental benefits for finishing the project. By replacing the bulbs the organization **reduced energy consumption by 15,000 kWh/year, saving approximately $1,200/year.**

Key Barriers/Benefits: Environmental health and safety staff on site were supportive of and actually initiated implementation, using the savings calculations provided by the intern to reinforce the message. Energy and cost savings were well documented. The project was simple. The implementation costs were small and well documented and the payback period was clearly calculated and short. The organization saves on operating costs, energy consumption, and related environmental impact on an ongoing basis.

Area #3: Retrofit or relamp area with new fixtures and types of lamps

Example #3a: Replace high bay lighting (high pressure sodium and metal halide) with T5 Fluorescent fixtures (adapted from report by Lauren Swadener 2010)

There are opportunities for improving high bay lighting in the facility by installing T5 Fluorescent High Bay fixtures in lieu of current metal halide and high pressure sodium lighting. An example of a 6-bulb T5 Fluorescent High Bay fixture is shown in Figure 1 to the right.


Figure 1: T5 Fluorescent High Bay Fixture

A comparison of the current lighting and replacement T5 lighting fixture annual electricity usage and cost is outlined in Table 1 below. An evaluation of the electricity bills determined the cost of electricity at the facility is $0.056/kWh.

Table 1: Comparison of Electricity Usage/Costs for Current and Proposed High Bay Lights

Lighting	# Fixtures/Hrs Operation	Electricity Usage/Yr	Cost of Electricity/Yr
Current: metal halide/high pressure sodium	240/8760	1,060,000 kWh	$59,000
T5 6-bulb Fluorescent Fixtures	240/8760	680,000 kWh	$38,000
Annual Savings		380,000 kWh	$21,000

The upfront costs for installing new fixtures includes the following:

- New six-bulb fluorescent fixtures range from $155-$200/each (estimates were gathered from two companies): **240 fixtures X $200 = $48,000**
- Replacing fixtures takes approximately one hour of labor at the cost of $60/hour for outside contractor: **240 fixtures X $60/hour labor = $14,400**
- The local utility company offers rebate **incentives totaling approximately $12,600** for switching all fixtures to more efficient lighting, which reduces the cost/payback period.
- **Cost: $48,000 + $14,400 -$12,600 = $49,800**
- Initial Cost $49,800 divided by annual savings $21,000 = **2.4 years simple payback period**

Additional Benefits:

- The fluorescent bulbs provide better light: they have a better color of light, with a CRI of around 85 and a color temperature of 3,000 to 5,000K and the lumen output for these lights will not drop below 95%, which is higher than current lighting
- They operate better at higher temperatures which is good for high bay lighting in summer heat conditions
- They are rated at more than 35,000 hours of lamp life, which decreases costs for replacing bulbs
- The lamps contain less mercury per fixture decreasing the amount of hazardous mercury put into landfills by 2,300 mg for the entire 240 fixtures
- The electricity savings reduces approximately 197 metric tons of CO_2 equivalent emissions of greenhouse gases (GHG) every year. (See Appendix)
- Only one building was analyzed for this report—the company may actually realize more electricity savings by implementing this opportunity in additional areas.

Implementation Status: Not yet reassessed to determine impact.

Example #3b: Replace incandescent exit signs with LED exit signs (adapted from report by Scott Barker, 2009, reassessed by Kurt Palu, 2010)

The organization should replace incandescent exit signs with LED exit signs. Currently there are 12 incandescent exit signs throughout the facility. Each sign contains two incandescent bulbs which are illuminated at all times for safety purposes. Using incandescent lighting for these fixtures is very inefficient and throughout the year will use a substantial amount of energy. Replacing exits signs will also improve safety because facility crews will not have to replace bulbs as frequently. The energy use of LED signs is approximately 1/30 of incandescent signs. By installing LED exit signs, for an initial cost of $820 (parts and labor), the organization will **save 6,200 kWh and $630 each year**. Calculations are shown below.

Calculations for Exit Signs

Assumptions:
Cost of electricity: $0.08/kWh

Annual Cost of Incandescent Bulbs:
Incandescent bulbs require changing one time per year
Maintenance: labor costs $18/hr

$$12\ exit\ signs \times \frac{0.5 hrs\ to\ change}{sign\ bulbs} \times \frac{\$18}{hrs\ to\ change} = \$108.00$$

Cost of Bulbs

$$12\ exit\ signs \times \frac{2\ bulb}{exit\ sign} \times \frac{\$1}{bulb} = \$24$$

Cost of Electricity

$$12\ exit\ signs \times \frac{2\ bulb}{exit\ sign} \times \frac{30W}{bulb} \times \frac{24hrs}{day} \times \frac{365\ days}{year} \times \frac{1kW}{1000W} = 6307\ kWh \times \frac{\$0.08}{kWh} = \$505$$

Total Annual Cost: $108 + $24 + $505 = ~$640

Installation and Annual Cost for LED:
Installation cost (labor and parts) per sign:
--1 hr for labor ($18/hr) for installation
--$50 for miscellaneous parts needed for installation

$$12\ exit\ signs \times \frac{\$68}{exit\ sign} = \$816$$

Cost of Electricity

$$12\ exit\ signs \times \frac{1.03W}{exit\ sign} \times \frac{24hrs}{day} \times \frac{365\ days}{year} \times \frac{1kW}{1000W} = 108kWh \times \frac{\$0.08}{kWh} = \$9.00$$

Annual kWh Savings
= 6307 kWh-108 kWh = **6200kWh**

Annual Cost Savings: $640-$9 = $630

Payback Period
Initial costs divided by annual savings

$$\frac{\$816}{\$630} = 1.3\ years$$

Implementation Status: **Implemented** (adapted from report by Kurt Palu 2010)
The incandescent exit signs have been replaced with LED signs.

Key Barriers/Benefits: Energy and cost savings were well documented. The project was simple. The implementation costs were small and well documented and the payback period was relatively short. The organization saves on operating costs, energy consumption, and related environmental impact on an ongoing basis.

Appendix 3
Greenhouse Gas Reductions Explanation and Calculations

Relevance of Greenhouse Gas Emission Estimates

This issue is an increasingly important one for business decision makers as it relates to regulations, stakeholder interests and day-to-day business operations and energy use. There are several important dimensions of analysis for any pollution prevention opportunity. One is certainly direct environmental impact (e.g. reductions in solid or hazardous waste, water use, air pollution, or energy use). Another important dimension is cost. Yet another is the intangible (not quantifiable) impact, such as reduced liability, increased worker safety/satisfaction, or improved corporate image. A final important dimension is indirectly estimating the impact on greenhouse gas (GHG) emissions that can be achieved by implementing any given pollution prevention opportunity.

GHGs include a number of different gases such as carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons and water vapor. These gases contribute to the "greenhouse effect" in the Earth's atmosphere. While GHGs make the planet warm enough to be habitable, an excessive amount of these gases is believed to be building up in the atmosphere and causing the average global temperature to rise, leading to climate change and instability. A significant spike in GHG concentrations in the atmosphere has occurred since the industrial revolution, pointing to the man-made nature of this change. This is why a new emphasis, and discussion of possible regulations, has been placed on reducing GHG emissions in all parts of our society, including government, business and industry.

The most widely recognized unit for measuring GHG emissions is carbon dioxide equivalent (CO2e). Each of the GHGs has a different capacity to heat the earth's atmosphere, called its global warming potential (GWP). Carbon dioxide (CO2) has a GWP of 1, so in order to standardize reporting, when GHG emissions are calculated, they are reported as equivalent to a given volume of CO2.

Array of Calculation Tools

Reductions in GHG emissions can be estimated using a variety of calculation tools and computer models. The direct environmental/cost benefits estimated or realized are used as quantified input for these calculations, therefore the resulting GHG emission reduction estimates are considered indirect benefits. Some commonly used tools are listed below:

--Nationally recognized conversion factors from the U.S. Department of Energy and the American Water Works Association: these are used to estimate GHG emissions for electricity, natural gas, and water use. For example, kilowatt-hours (kWh) of electricity used can be converted to GHG emissions using a factor of 1.404 pounds CO2 e per kWh.

--EPA's WAste Reduction Model (WARM): this tool is used to determine GHG emissions related to solid waste. This online calculator uses a life-cycle approach to determine the change in GHG emissions caused by alternative end-of-life waste management decisions or disposal methods for a number of different kinds of wastes. For example, using the weight of a solid waste diverted from a landfill and recycled, an approximate reduction in GHG can be calculated. WARM is periodically updated and new material types are added by the EPA as new information from climate change research becomes available.

--Economic Input Output Life Cycle Assessment (EIO-LCA): this model used to estimate GHG reductions has been developed by researchers at Carnegie Mellon University. This model provides a useful approximation of GHG reductions through the full life-cycle production of a material or chemical, based on the cost savings from reductions in use. For example, if a business reduces its purchase of lights by $50,000, the EIO-LCA estimates the GHG emissions to produce the lights through the mining, manufacturing, packaging and delivery (to list a few) steps in the process of getting the lights to the end user.

--Recycled Content (ReCon) Tool: EPA created the ReCon Tool to help companies and individuals estimate life-cycle greenhouse gas (GHG) emissions and energy impacts from purchasing and/or manufacturing materials with varying degrees of post-consumer recycled content.

--Pollution Prevention (P2) Greenhouse Gas (GHG) Calculator: designed by U.S. EPA in conjunction with a panel of professionals from the P2 community with state and local governments, business facilities, grantees, and project managers in mind. The tool was reviewed in national webinars and conferences reaching over 600 participants and reworked to be more robust and user friendly. The tool is available in an Excel format and finalized as of November 2011. U.S. EPA will periodically update the tool as new information and data sources become available. It is designed to help calculate GHG emissions reductions in metric tons of carbon dioxide equivalent (MTCO2e) from electricity conservation, green energy, fuel and chemical substitutions, water conservation, and improved materials and process management in the chemical manufacturing sector.

Selecting the Most Appropriate Tool(s):

When using one of these models to estimate GHG emission reductions for a client, always provide an explanation of which model was used, why it is most relevant for the issue at hand, what assumptions were applied, and the importance of reducing GHG emissions as a business and global sustainability strategy.

A summary sentence stating the amount of GHG reduction should be included with each recommendation, e.g. "Using more energy efficient light bulbs will save 200,000 kWh/year and reduce GHG emissions by over 190 $MTCO_2e$/year. A detailed appendix should be developed which shows how the GHG emission reductions were calculated. An example of a tool appropriate for lighting source reduction is listed in the example Appendix below.

Example Appendix of Greenhouse Gas Calculations

Recommendation 1: Turn Off Lamp Fixtures During Daytime Hours

Using EPA P2 GHG Calculator (http://www.p2.org/category/general-resources/p2-data-calculators/) extracting data specific for Nebraska

Known Value: 4000 kWh/year saved

Calculations:

4,000 kWh/year X 2.104 lb CO_2E/kWh X 1 $MTCO_2E$/2,204.6 lb ≈ 3.8 $MTCO_2E$

Sources:

- U.S. EPA, Clean Energy. "eGRID 2007 Version 1.1." February 2009. Downloadable ZIP file: eGRID20071_1year05_aggregation.xls, tab NRL05 and US05. (http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html#download)

- US EPA, Downloadable Document: "Unit Conversions, Emissions Factors, and Other Reference Data, 2004." Table I, Page 1. (http://www.epa.gov/climatechange/emissions/downloads/emissionsfactorsbrochure2004.pdf)

Recommendation 2: Replace T12 bulbs with T8 bulbs
Using EPA P2 GHG Calculator (http://www.p2.org/category/general-resources/p2-data-calculators/)

Known Value: 77,000 kWh/year saved

Calculations:
77,000 kWh/year X 2.104 lb CO_2E/kWh X 1 $MTCO_2E$/2,204.6 lb ≈ 69 $MTCO_2E$

Sources:
(a) Source 1: U.S. EPA, Clean Energy "eGRID 2010 Version 1.1" May 2011
(b) Source 2: U.S. EPA, Downloadable Document "Unit Conversions, Emissions Factors, and Other Reference Data, 2004" Table I, Page I

Tips for Making the Business Case for Change

Tip # 1: Writing an Executive Summary
An executive summary is a brief overview of a report designed to give readers a quick preview of its contents. Its purpose is to consolidate the principal points of a document in one place. After reading the summary, your audience should understand the main points you are making and your evidence for those points without having to read every part of your report in full. It is called an executive summary because the audience is usually someone who makes funding, personnel, or policy decisions and needs information quickly and efficiently in order to make decisions and respond appropriately.

Guidelines:
An executive summary should communicate independently of the report. It should stand on its own as a complete document.

It should explain why you wrote the report, emphasize your conclusions or recommendations, and include only the essential or most significant information to support those conclusions.

Use subtitles, bullets, tables, selective bolding or other types of organizational structure to add clarity to your summary

It should be concise—about 10% of the length of the full report.

It should be organized according to the sequence of information presented in the full report. Don't introduce any new information that is not in your report.

To help with organizing the executive summary, after you have written the full report, find key words; words that enumerate (first, next, finally); words that express causation (therefore, consequently); words that signal essentials (basically, central, leading, principal, major); and contrast (however, similarly, less likely).

Read the completed summary with fresh eyes. Check spelling, grammar, punctuation, details, and content. Ask someone else to read it.

Tip #2: Technical Writing Tips:

Use these tips as a **checklist** as you prepare your report.

— **Proof reading.** Write your report, let it sit, then proof read it for grammar, jargon, clarity, multiple meanings, and technical correctness before submittal. Re-read the report from the recipient's point of view. Reading the report aloud may help.

— **Figures and tables.** Refer to each figure and table in the text prior to inserting it. Always place the figure or table in the report soon after you have referred to it. Include a title and number for all figures and tables, capitalizing the title when referring to a specific table or figure, e.g., "All of the wastes generated by the shop are listed in Table 1

— **Transitions.** Provide brief transition sentences between sections of the report and before a bulleted list to explain what the list consists of and how it is organized.

— **Parallel construction.** Use parallel construction in all numbered or bulleted lists. For example, all items should be a complete sentence or none should be; or all items might begin with an active verb, e.g., "use," "change," "remove" or a noun, like this list.

— **Format.** A general format/outline has been suggested, although this may need to be modified to address a client's requests. Generally you should:
  - Move from generalities to specifics, in each section and across the report as a whole.
  - Use page numbers.
  - Keep section headings with the narrative that follows at page breaks.
  - Rarely split a table across two pages.

— **Abbreviations.** On first use, spell the term out completely, followed by the abbreviation in parentheses. For example, "Volatile Organic Compounds (VOCs) are another waste that could be minimized." Subsequently, just the abbreviation is sufficient unless it is used at the beginning of a sentence. Never start a sentence with an abbreviation or a numeral.

— **Professional tone.**
  - Avoid slang, informal terminology (inexpensive vs. cheap), or imprecise (there, that, it) language.
  - Be careful how you word suggestions. Avoid making recommendations outside of your area and level of expertise in source reduction and waste minimization.
  - Use tact and be positive in your conclusions. Remember a reader likes to be complimented, but can see through phoniness.
  - Be careful to confirm your information if you state it as a fact; or cite your source, e.g., "According to Mr. Jones, Plant Engineer, . ." or state that the information is a potential based on xyz assumptions.

— **Common errors.**
  - i.e. vs. e.g.: i.e. means "that is" or "in other words," and e.g. means "for example."
  - compliment vs. complement: a compliment is a nice comment, and a complement is a part of a whole
  - how many vs. how much: how many can be counted, and how much is uncountable, e.g., how many bottles of water vs. how much water.
  - policies vs. procedures vs. practices: policies are formal written positions or statements about some issue; procedures are written directives aimed at accomplishing a task or complying with a policy; practices are typically informal steps people take, which may or may not follow written policies and procedures

Tip #3: General Recommendations

General recommendations are made to help a company establish the culture and infrastructure needed to establish and sustain a commitment to source reduction and sustainability. Examples of commonly made general recommendations include:

1. A pollution prevention policy statement should be generated and periodically updated by management to formally reflect management's commitment to incorporating pollution prevention in the company's operations. Some examples of formal policy statements follow:

> *This company is committed to continued excellence, leadership, and stewardship in protecting the environment. Environmental policy is a primary management responsibility, as well as the responsibility of every employee.*
>
> *The corporate objective is to reduce waste and achieve minimal adverse impact on the air, water, and land through excellence in environmental control.*
>
> *Minimizing or eliminating the generation of hazardous waste is a prime consideration in process design and plant operations and is viewed by management as having a priority as high as safety, yield, and loss prevention.*

2. To further implement the corporate pollution prevention policy, one or more "cause champions" should be selected to lead the pollution prevention program and overcome the resistance present when changes are made to existing operations. These "cause champions" may include a project manager, an environmental coordinator, or anyone else dedicated to implementing the pollution prevention ideal and company policy. These individuals must be given authority by management to carry out the policy.

3. Input from employees should be considered, encouraged, and valued. Since the employees must deal with the waste, they may have insight into how a specific pollution prevention opportunity may be implemented. Many companies offer incentives to employees who suggest innovations to minimize or reduce waste generation.

4. Goals should be established to help implement and track the progress of the corporate pollution prevention policy. Specific, quantitative goals should be set that are acceptable to those willing to work to achieve them, flexible to changing requirements, and achievable with a practical level of effort. To document the progress of the pollution prevention goals, a waste accounting system should be used.