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Informal Report

**Potential Impact on National Energy Use and Carbon Emissions
of an Energy Management Course**

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Abstract

This report reviews a draft training program planned for the International Union of Operating Engineers and uses it as a general model in terms of its possible goals. Using information contained within the energy evaluation and reporting structure of the US government and the buildings industry, an approach is formed for evaluating of this training program as it is applied to commercial buildings. This approach uses the estimated impact such a training program would have on energy use and carbon emissions if it were to be applied on a broad or national basis. Additional information regarding approaches commercial sector site energy evaluations is provided.

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Introduction

The importance and ultimate impact of any Energy Conservation Plan on a buildings energy performance into the future is based on how well trained the energy managers are and the level of enthusiasm they and the organization have on the issues of Energy Conservation . These issues include audits to identify and measure energy flows, the planning of energy conservation projects, and the correct economic presentation of energy conservation projects to management. Ultimately this presentation will have its effect in terms of the approval by upper management of economically viable energy conservation projects.

This introduction is contains a overview of some of the industry positions regarding energy conservation and how an effective energy audit plan can be set up. Appendix B contains additional information regarding heating and cooling loads within commercial buildings and the estimated End-Use split between building types. In addition, an itemized list of general primary and applied energy conservation measures is included in Appendix C. This latter information is largely extracted from the draft Energy Conservation Course Outline for the International Union of Operating Engineers and included in Ref.[5].

Some things to keep in mind when planning an Energy Management Program from the basic energy audit through to the ultimate implementation of energy conservation projects are paraphrased from Ref.[3].

Energy Upgrades - Fictions and Facts

Fiction (1) Paybacks on energy-efficient upgrades are too slow!

Fact The recovery of investments can be recovered in as little as two years and the investments keep contributing to the bottom line year after year in terms of costs and productivity.

Fiction (2) Single-technology upgrades offer the best returns.

Fact The a whole building approach to electrical product upgrades yields the most positive returns. Projects with quick paybacks can offset the longer paybacks of others.

Fiction (3) You're better off waiting!

Fact Any energy efficiency savings now may outstrip savings due to deregulation in the future. Savings lost in the meantime will be lost forever and energy conservation will always save money.

Fiction (4) Most buildings are already energy efficient.

Fact The majority of buildings were built before 1980 and there is a high probability that energy conservation opportunities exist. The person charged with building a facility is often not the person charged with operating it.

Fiction (5) Electrical product upgrades require trade-offs in other areas.

Fact An electrical upgrade may well have effects on comfort, ambience, and product quality as well as energy conservation.

Fiction (6) Energy projects are only worthwhile if rebates are available.

Fact Some energy projects have sufficient savings to justify them without rebates. Rebates have dried up but utilities still remain flexible. Performance contracting is a way to get projects underway without cash outlay.

Fiction (7) Energy-efficient technologies are not proven.

Fact The evidence of the many agencies who track this as well as manufacturers who offer free audits counters this notion. There are many new technologies are in daily use and saving energy in buildings.

Fiction (8) Potential savings are not significant to the organization.

Fact Energy conservation savings can be large. The potential exists for upwards of a dollar per square foot in annual energy costs and saving money in a competitive environment is positive.

Fiction (9) Companies have to fund the cost of upgrades themselves.

Fact Many efficiency projects can be funded through utilities; the management, implementation, using energy service corporations through cost recovery via savings, and through securing energy-efficiency loans at favorable rates.

Fiction (10) Savings projections are not reliable.

Fact Establishing a good baseline performance database and keeping to planned energy conservation measures are key to evaluating the accuracy of savings.

Energy Master Planning

(1) Understanding Load Profiling - Facility executives need to familiarize themselves with their facilities' electrical load profiles which are essentially patterns of energy usage over time (minutes to years).

(2) Selecting a Rate Structure - The load profile will determine the leverage a facility can exert negotiating a contract with a provider. Prevalent rate structures may include time-of-day or real-time.

(3) Shaping Load Profiles - Replacing or shifting the use of inefficient building systems. Once this is done, further consideration can be made to power generation, electrical load shifting, or fuel shifting.

(4) Using an Energy Management System (EMS) - An EMS can monitor electrical usage and minimize electrical demand.

Energy Upgrades - Optimize Energy Use in Seven Steps

- (1) Find where energy is being used** - Gather all the information for the past two or three years on energy consumption and costs.
- (2) Develop an energy plan** - Develop an implementation plan through the screening of project benefits versus project budgets of in-house, maintenance, operational, and workplace improvements.
- (3) Bring in the experts** - Focus on what you do best and leave the rest to the experts in energy optimization.
- (4) Evaluate the upgrade and funding options** - The range of options range from straight financing of upgrades to utility ownership of the energy system.
- (5) Manage the project** - Regardless of the option choice keep the employees and upper management informed through frequent meetings and progress reports.
- (6) Evaluate and report the results** - Provide for progress and monitoring reports for the verification of energy savings.
- (7) Examine the energy supply options** - Study the subject and constantly shop for an appropriate energy provider.

The Building Envelope - Ten Steps to Efficiency

- (1) Establish an energy budget** - Control of the energy use of a building starts with an understanding of the energy consumption of all uses usually in BTUs per square foot per year.
- (2) Optimize the building insulation** - In most regions more insulation is better but this not always true where building cooling is required. Models exist for optimizing buildings interior, site and local weather conditions.
- (3) Optimize building glazing** - Evaluate the R-value, visible light transmittance, and shading coefficient. Building orientation and sunshading can enter the equation. Options include multi-glazed, coated glazing, and windows with interior films.
- (4) Consider daylighting** - The application of architecturally pleasing daylighting can lead to energy conservation through reduced lighting and cooling loads.
- (5) Incorporate exterior shading and sun control** - The use of these strategies can dramatically reduce heat gain resulting in energy savings and the downsizing of basic equipment and it's cost.

(6) Evaluate the impact of interior shading - This can result in reductions in heat gain through the use of such things as shutters, films, draperies, and blinds.

(7) Minimize air infiltration - Infiltrations effect can raise overall loads and add to the amount of fan energy required to ventilate or pressurize a building.

(8) Minimize thermal bridges - Unintentional or uncontrolled thermal short circuits can alter the building envelope conductivity.

(9) Use of thermal mass - The optimized use of the dynamic effects of thermal mass and insulation geometry can be used to reduce heating and cooling loads in buildings.

(10) Explore renewable energy options - In the future the cost of these options may drop below the cost of fossil fuel with the advent of new technologies and tax credits.

In summary, any audit plan has to start with as complete an understanding as possible of the energy flows in all applications and the possible options available to optimize their use. The applications include the fuel source energy stream flows (Central Plant), the character of their flow paths (Distribution), the site utilization of these energy flows (Process or HVAC), and their ultimate disposal as waste energy (Waste). An understanding of these flows and their paths can help to target Energy Management Opportunities (EMO) and then translate these to Energy Conservation Measures (ECM).

In all of the above areas it is important to ensure that any existing instrumentation is working and calibrated. Where reference to historical records is used the auditor needs to assure that the records are accurate. Additional instrumentation may be needed to gather the information needed to complete the audit. See the Appendix C for some explicit Primary and Applied energy conservation measures or ECM's.

Energy Intensities of US Commercial Buildings

To get at the total scope of energy use in the commercial sector and provide some breakdown among the various building types an evaluation of recent government reports was conducted. The contents of the following table was derived from the Total Energy End-Use Intensities contained in Table 7.4.1 Ref [1] and Total Floorspace for Principal Building Activities in Table 32 of Ref [2]. Table 1(a) was formed on a national basis for each building type in terms of its reported Floor Space and Energy Intensity. The last column in this table is the product of these two and represents the Energy End-Use of each building type in quads and its percentage of the whole commercial sector.

**Table 1(a) Floor Space, Energy Intensity by End-Use Energy of
US Commercial Buildings**

Item	Building Type	Floor Space (10 ⁶ sq.ft.)	Energy Intensity (10 ³ Btu/sq.ft.)	Energy End-Use (10 ¹⁵ Btu) Quads (%)
1	Office	10478	97.2	1.02 (19.2)
2	Mercantile and Service	12728	76.4	0.97 (18.3)
3	Education	7740	79.3	0.61 (11.5)
4	Health Care	2333	240.4	0.56 (10.6)
5	Lodging	3618	127.3	0.46 (8.7)
6	Public Assembly	3948	113.7	0.45 (8.5)
7	Food Service	1353	245.5	0.33 (6.2)
8	Warehouse and Storage	8481	38.3	0.32 (6)
9	Other (a)	1004	172.2	0.17 (3.2)
10	Food Sales	642	213.5	0.14 (2.6)
11	Public Order and Safety	1271	97.2	0.12 (2.3)
12	Religious Worship	2792	37.4	0.1 (1.9)
13	Vacant	2384	21.5	0.05 (0.9)
	Total	58772		5.3 (100)

Notes:

(a) Includes mixed uses, hangars, crematoriums, laboratories, and others.

The final total of 5.3 quads shown in the above table does not take into account the categories of "Other" and "Miscellaneous" energy usage as they are defined in Table 1.3.3 of Ref. [1]. Table 1.3.3 defines these categories as including commercial service gas equipment, emergency electric generators, cogenerators, natural gas-driven pumps, natural gas lighting, automated teller machines, telecommunications equipment, medical equipment, some commercial manufacturing, and other commercial energy. It seems reasonable to neglect these items from consideration as

they are very site specific and cannot be used to contribute to a general energy conservation plan. When these items are neglected from Table 1.3.3 the total "Site" energy is 5.72 quads. This shows an error of about 7.3 % and implies that the Energy Intensity and End-Use split shown in Table 1(a) is probably quite good.

**Table 1(b) Floor Space, End-Use Energy by Energy Intensity of
US Commercial Buildings**

Item	Building Type	Floor Space (10 ⁶ sq.ft.)	Energy Intensity (10 ³ Btu/sq.ft.)	Energy End-Use (10 ¹⁵ Btu) Quads (%)
1	Food Service	1353	245.5	0.33 (6.2)
2	Health Care	2333	240.4	0.56 (10.6)
3	Food Sales	642	213.5	0.14 (2.6)
4	Other (a)	1004	172.2	0.17 (3.2)
5	Lodging	3618	127.3	0.46 (8.7)
6	Public Assembly	3948	113.7	0.45 (8.5)
7	Office	10478	97.2	1.02 (19.2)
8	Public Order and Safety	1271	97.2	0.12 (2.3)
9	Education	7740	79.3	0.61 (11.5)
10	Mercantile and Service	12728	76.4	0.97 (18.3)
11	Warehouse and Storage	8481	38.3	0.32 (6)
12	Religious Worship	2792	37.4	0.1 (1.9)
13	Vacant	2384	21.5	0.05 (0.9)
	Total	58772		5.3 (100)

Notes:

(a) Includes mixed uses, hangars, crematoriums, laboratories, and others.

One of the conclusions which can be drawn from the above table is that a certain methods exist for ranking energy conservation efforts in the Commercial sector. These rankings can be applied either in terms of Energy End-Use or Energy Intensity. In terms of priorities in Energy End-Use, as can be seen in Table 1(a), items 1 through 13 comprise about 100% of the energy used in the commercial sector.

The same items contained in Table 1(a) were ranked in terms of Energy Intensity. This ranking results in a different priority ordering for the building use items as shown in Table 1(b).

Another useful piece of information was the projected fuel split (energy sources) between and the total of site and primary electric for each End-Use. Here again, government reporting was used and tabulated in Table 2.

**Table 2 All Commercial Buildings, Energy End-Use Splits, by
Fuel Type (quads)**

End-Use	Nat. Gas	Fuel Oil	Other Fuels	Ren. En.	Site Elec.	Prim. Elec.	Total Elec.
Space Heating	1.58	0.37	0.11	-	0.16	0.53	0.69
Space Cooling	0.02	-	-	-	0.34	1.08	1.42
Ventilation	-	-	-	-	0.17	0.53	0.7
Water Heating	0.75	0.07	-	0.02	0.09	0.29	0.38
Lighting	-	-	-	-	1.22	3.9	5.12
Refrigeration	-	-	-	-	0.18	0.58	0.76
Cooking	0.23	-	-	-	0.02	0.07	0.09
Office Equipment	-	-	-	-	0.4	1.3	1.34
Total	2.58	0.44	0.11	0.02	2.58	8.27	13.99

The above table was generated using the Total End-Use Energy Split for each fuel shown in Table 1.3.3 of Ref. [1] and providing a total of the Electric End-Use. The final total shown in the above table does not take into account the categories of "Other" and "Miscellaneous" energy usage as they are defined in Table 1.3.3 of Ref. [1] for the reasons discussed above.

**Table 3 Commercial Energy End-Use Splits, by
Fuel (quads) and Building Type**

Building Type	Nat. Gas	Fuel Oil	Other Fuels	Renw. En.	Site Elec.	Prim. Elec.
Office	0.495	0.034	0.021	0.004	0.495	1.59
Mercantile and Service	0.47	0.08	0.02	0.004	0.472	1.52
Education	0.297	0.051	0.013	0.002	0.297	0.953
Health Care	0.273	0.047	0.012	0.002	0.273	0.876
Lodging	0.224	0.038	0.01	0.002	0.224	0.719
Public Assembly	0.219	0.037	0.009	0.002	0.219	0.703
Food Service	0.16	0.027	0.007	0.001	0.16	0.514
Warehouse and Storage	0.155	0.026	0.007	0.001	0.155	0.498
Food Sales	0.067	0.011	0.003	0.001	0.067	0.215
Vacant	0.023	0.004	0.001	0.000	0.023	0.074
Religious Worship	0.049	0.008	0.002	0.000	0.049	0.157
Public Order and Safety	0.059	0.01	0.003	0.000	0.059	0.189
Other (a)	0.083	0.014	0.004	0.001	0.083	0.266
Total	2.58	0.44	0.11	0.02	2.58	8.27

In order to estimate fuel energy split between Building Types, the End-Use Energy percentages shown in the last column of Table 1(a) were multiplied by the Total End-Use Energy Split for each fuel shown in Table 1.3.3 of Ref. [1]. The result was then applied against each Building Type and shown in Table 3.

The next step in this investigation was aimed at developing some means of assessing the future accomplishment of energy conservation projects in the commercial sector as a result of a broad training course in the area of energy conservation.

Figures 1 and 2 were derived from Figures 52 and 53 secured from Ref.[2] using website <http://www.eia.doe.gov/emeu/cbecs/char95/conserve.html>. The changes in conservation in terms of Percent of Floor Space effected were projected to the year 2020 assuming an estimated constant linear change rate as measured in 1995. The basis for this assumption is that the Operating Engineers training course does nothing more than continue the enthusiasm towards energy conservation in the commercial sector at the same rate exhibited in 1995. The results are believed to yield a conservative view of the penetration of conservation measures. This "penetration" is a measure of the management approval of energy conservation projects applied to the business at hand. Table 4 shows this projected "penetration" through the year 2010 using Figures 1 and 2.

Figure 1 Building Shell Conservation Trends

Figure 2 Building Lighting Conservation Trends

Table 4 Penetration Estimates of Energy Conservation Projects Through the Year 2010

Project	Penetration by % Points	Penetration by Floorspace
Envelope (average)	17 (13 neglecting Shading)	9991
Roof and Ceiling Insulation	12	7053
Wall Insulation	17	9991
Shading	34 (Accomplished 2003*)	19982
Multiple Glazing	13	7640
Coated Glazing	10	5877
Lighting (average)	16	9404
Reflectors	25	14693
Dimmers	15	8816
Time Clock	14	8228
Natural Lighting	21	12342
Occupancy	17	9991
Other	4	2351

Figure 3 Projected Growth of Energy Consumption in the Commercial Sector

At the same time, there is a projection of growth in Commercial Primary Energy Consumption. This has been taken from Ref. [1], Table 1.3.1, and is shown as a graph in Figure 3. The figure shows this growth by fuel type against time. In the following section, further analysis is presented to determine the potential savings through energy conservation and the potential of headway against this projected growth.

Table 5 Assumed Efficiency of Various Types of Commercial Equipment

Heating Equipment	Stock Eff., COP, or EER	New Eff., COP, or EER	Energy (1) End-Use %
Heat Pumps	EER=12	EER=12	8
Furnaces	Eff.=75%[a]	Eff.=80%[a]	16
Individual Space Heaters	Eff.=75%[b]	Eff.=80%[b]	23
District Heat	Eff.=72%[c]	Eff.=81%[d]	5
Boilers	Eff.=77%[e]	Eff.=82%[e]	19
Packaged Heating Units	Eff.=80%[f]	Eff.=85%[f]	20
Other	Eff.=98%[g]	Eff.=98%[g]	9
Cooling Equipment			
Res. Type Central Air Conditioners	EER=10[h]	EER=12[h]	13
Heat Pumps	EER=12[i]	EER=12[i]	10
Individual Air Conditioners	EER=8[j]	EER=10[j]	19
District Chilled Water	COP=2.1[k]	COP=2.9[l]	3
Central Chillers	COP=2.3[m]	COP=3[m]	16
Packaged Air Conditioning Units	COP=2.3[n]	COP=3[n]	34
Swamp Coolers	ϵ_{te} =60%[o]	ϵ_{te} =80%[o]	4
Other	EER=8[p]	EER=10[p]	1

Notes:

(1) Derived from Ref.[2], Table 34 - The overlapping equipment applications were summed and percentages of each equipment were taken as a fraction of the total End-Use energy for Heating and Cooling respectively.

[a] Average of each, Stock and New furnaces contained in Table 1-1.7

[b] Assumed the same as [a]

[c] Assumed 80% eff. at the central plant with 10% transmission losses.

[d] Assumed 85% eff. At the central plant with 5% transmission losses.

[e] Average of each, Stock and New boilers contained in Table 1-1.7

[f] Estimated values of eff. For Packaged Units, Stock and New

[g] Assumed as an electric usage and assigned values contained in Table 1-1.7

[h] Based on EER of past and currently available central residential units

[i] Based on values for heat pumps shown in Table 1-1.7

[j] Based on EER of past and currently available individual residential units

[k] Assumed COP=2.3 at the central plant with 10% transmission losses.

[l] Assumed COP=3 at the central plant with 5% transmission losses

[m] Average of each, Stock and New chillers contained in Table 1-1.7

[n] Assumed the same as [m]

[o] Estimated from ASHRAE Systems and Equipment Handbook, Chapter 19

[p] Assumed the same as [j]

Additional information on estimated building loads and equipment efficiencies and figures of merit was needed. Some of this information is used in following section to evaluate potential energy conservation efforts over the next 10 years. Table 5 was assembled from information contained in Tables 34 and 36 of Ref. [2]. The second and third columns in Table 5 show an assumed change in equipment efficiency resulting from an upgrade. Ref. [2] shows an overlap of equipment types when based on floor space. Instead, the last column of Table 5 was formed

using the amount of energy used by heating and cooling equipment as a percent of the total energy used in each application. See note (1) above.

Table 6 Commercial Buildings Equipment Efficiencies

Equipment Type	Efficiency Parameter	Stock Efficiency	New Efficiency	Best Efficiency
Chillers				
Reciprocating	COP	2.5	3.2	3.0
Centrifugal	COP	4.6	5.9	7.3
Gas-Fired Absorption	COP	1.0	1.0	NA
Gas-Fired Engine Driven	COP	1.0	2.0	NA
Rooftop AC	COP	2.1	2.5	3.4
Rooftop Heat Pump	EER	12	12	15
Boilers				
Gas-Fired	Therm. Eff.	75%	80%	90%
Oil-Fired	Therm. Eff.	78%	83%	87%
Electric	Therm. Eff.	98%	98%	98%
Furnaces				
Gas-Fired	AFUE	75%	77%	92%
Oil-Fired	AFUE	75%	83% (a)	87%
Water Heater				
Gas-Fired	Therm. Eff.	65%	78%	96%
Oil-Fired	Therm. Eff.	65% (b)	78% (b)	87% (b)
Electric Resistance	Therm. Eff.	75%	95%	98%
Gas-Fired Instantaneous	Therm. Eff.	75%	80%	90%
Oil-Fired Instantaneous	Therm. Eff.	75%(b)	80%(b)	87%(b)
Cooking (c)				
Gas	Therm. Eff.	25%	50%	65%
Electric	Therm. Eff.	50%	70%	80%
Other Electric				
Ventilation (d)	Motor Eff.	68%	88%	NA
Lighting (e)	Lum. Efficacy	15%	75%	NA
Refrigeration (f)	COP	1.5 (est.)	2.0	2.3
Office Equipment (g)	Elec. Eff.	60% (avg.)	80% (avg.)	80%

Notes:

(a) 1996 Consumers Directory of Certified Efficiency Ratings, average of the range for high capacity water heaters and Table 5.10.6 in Ref. [1].

(b) Assumed efficiency based on the performance of similar gas-fired equipment and the current flue gas temperature limitations of oil-fired equipment

(c) Ref. [1], Table 5.10.6

(d) ASHRAE Systems and Equipment Handbook, Chapter 39, Figures 1 and 4

(e) Ref. [1], Table 5.9.7

(f) Ref. [1], Table 5.10.4

(g) Ref. [1], Table 5.10.7

NA - Not Available

Table 6 was extracted largely Ref. [1], Table 5.6.5 and shows some of the Commercial Equipment Efficiencies as projected from stock through new to best-available. This information is further augmented with inputs taken from other tables in Ref. [1] as noted and some added information relating to Oil-Fired equipment. The table provides a guide to assigning reasonable efficiency improvements which can be achieved through servicing or replacement.

Energy Analysis

The three areas where assumptions were made for this analysis are:

- 1) The "savings" - interpreted first as the percent savings resulting from conservation and the combined effect of conservation and equipment efficiency improvement.
- 2) The impact of the "savings" of item (1) as a percentage fraction of the total load.. Some of the equipment described in Table 5 and Table 6 overlap in meeting the load.
- 3) The "penetration" - interpreted as the percent of management approval of energy conservation projects.

Starting with the last item, an estimate of item (3) above can be made from Table 4. Neglecting the penetration of "Shading" under Envelope, the average of the remaining four items is 13 percentage points. This is taken to mean that about 13% of the energy conservation projects relating to heating will be instituted over the next 10 years. This includes Space Heating and Water Heating.

In terms of Space Cooling, Refrigeration, Lighting, Ventilation, and Office Equipment, the use was predominantly electric energy and mirrored the approach to lighting conservation. In Table 4 the average of the six items under Lighting was 16 percentage points. This was taken to mean that about 16% of the projects related to electric use would be instituted over the next 10 years.

The various types of equipment, described in Tables 5 and 6, overlapped in addressing the heating and cooling load of the buildings. In order to get at a split of the load which is shown in the last column of Table 5, the total areas addressed by the various equipment types, was

summed and the percentage taken of each equipment type. This was assigned to each as a percentage fraction of the total load and assigned as item (2)

In terms of item (1) above the amount of savings was calculated using the combined effect of energy "use" conservation (load reduction) and equipment efficiency improvement. Thus the combined effect would be higher than the "use" reduction alone. For one item of equipment, say optimized boilers with a stock efficiency 76% and a new efficiency of 81%, affected by building envelope changes resulting in a 30% drop in load, the projected fuel savings would be:

$$\text{Site Fuel Savings} = (1 - (1 - \text{Load Reduction})(\eta_{\text{Old}})/(\eta_{\text{New}}))$$

where η = Efficiency,

$$\text{Thus, Site Fuel Savings} = (1 - (1 - 0.3)(0.76)/(0.81)) = 0.343 \text{ or } 34.3\%$$

In terms of ventilation, a similar scenario can be drawn. The ventilation load through the use of strategic controls may be reduced by about 10%. The fans are electrically driven and through the use of improved electric motors could raise the electrical efficiency from 68% to an estimated 88%. The site electric savings would then be:

$$\text{Site Electric Savings} = (1 - (1 - 0.1)(0.68)/(0.88)) = 0.305 \text{ or } 30.5\%$$

A spreadsheet was assembled using the assumptions similar to those above and the assumed equipment efficiency improvements shown in Table 6. This spreadsheet (hcsave.wb2, see Appendix A) provides for site usages of natural gas, fuel oil, renewables, electricity, and the primary source electricity with the required multiplier of 3.21. In summary, the spreadsheet showed that the combined savings due to energy conservation with equipment efficiency improvements yielded a site energy usage savings of 0.374 quads and a primary electric savings of 0.682 quads. This resulted in about 16.5 Million metric tons in carbon emission savings when site energy and primary electric were totaled. A detailed breakdown of these calculated results is summarized in Table 7 and the details regarding the spreadsheet calculations are discussed in Appendix A.

**Table 7 All Commercial Buildings, Energy Savings, by Fuel Type (quads)
(Assuming a combined impact of conservation and equipment savings)**

End-Use	Nat. Gas	Fuel Oil	Other Fuels	Ren. En.	Site Elec.	Prim. Elec.	Total Elec.
Space Heating	0.069	0.016	0.005	-	0.007	0.023	0.03
Space Cooling	0.001	-	-	-	0.024	0.062	0.086
Ventilation	-	-	-	-	0.008	0.027	0.035
Water Heating	0.041	0.004	-	0.001	0.005	0.017	0.022
Lighting	-	-	-	-	0.16	0.514	0.182
Refrigeration	-	-	-	-	0.009	0.03	0.039
Cooking	0.02	-	-	-	0.001	0.004	0.005
Office Equipment	-	-	-	-	0.002	0.007	0.009
Total	0.131	0.02	0.005	0.001	0.216	0.684	0.9
Energy to Carbon	14.4	19.75	17 (a)		15.67	15.67	
Carbon Savings (10 ⁶ metric tons)	1.886	0.395	0.085		3.385	10.718	

Notes:

(a) Average value of Energy to Carbon factor for Natural Gas and Fuel Oil

Another spreadsheet (savings potential.wb3, see Appendix A) was formed using the calculations defined in Ref. [4]. The details of this spreadsheet calculation are shown in Appendix A.

The one exception taken in this spreadsheet was the given Energy to Carbon Factor of 15.67 for electric use in Ref. [4]. The given factor is only applicable to site electric use. In actuality, in terms of total electric energy and carbon impact, this factor should be multiplied by 3.21 to reflect the primary source and then summed with the site use to develop a factor of 65.97. Using this factor, the spreadsheet calculation resulted in a calculated potential site energy savings of 0.247 quads with a primary electric savings of 0.604 quads. The resulting carbon emission reduction was projected at 13.3 Million metric tons.

Summary

Using reference source information, the commercial sector was broken down in terms of current energy usage, projected yearly savings of various projects, and expected "penetration" over 10 years (2000 to 2010), based on percentage of total floor space. A comparison of the two methods was made through the use of spreadsheet calculations. One such calculation was based on the combined effect of load reduction on building energy uses and equipment improvement. Here an assumption was made for the estimated energy reductions from various individual energy conservation improvements in envelope, equipment, lighting, and utilization. This information, together with estimates of equipment efficiency improvements and penetration in the form of management acceptance of energy conservation projects, was used in one spreadsheet to

calculate the effect of an energy conservation program on energy uses. The calculated finding shows a reduction of total energy use of 1.056 quads and a resulting carbon emission reduction of about 16.5 Million metric tons. In a second spreadsheet, assembled largely from Ref. [4], the energy use, as well as carbon emissions, were projected as a function of applied energy conservation measures to individual items and ignored any combined effect. In this latter spreadsheet the reduction in total energy was projected as 0.851 quads with a reduction of carbon emissions of about 13.3 Million metric tons. See Appendix A for a detailed discussion of the assumptions used in the spreadsheets.

Conclusions

Over the next 10 to 20 years the potential benefits of reasonable energy conservation efforts in the commercial sector on a national scale can result in enormous improvements in both savings in total energy and carbon emissions. The implementation of a comprehensive training program for a professional approach to this subject can result in individuals who will not only have the basic necessary knowledge as tools, but who can extend these tools to fulfill their own specific site needs for energy conservation.

In one calculation, using the combined effect of load reduction and equipment improvement, the finding was a reduction of site energy use of 0.374 quads with a reduction in primary electric of 0.682 quads yielding a total of 1.056 quads nationally. The resulting carbon emission of this total was calculated as about 16.5 Million metric tons. In a second calculation, assembled largely from Ref. [4], the energy use as well as carbon emissions were projected as a function of applied energy conservation measures to individual items. In this latter spreadsheet the reduction in site energy was projected as a lower number than the previous, 0.247 quads with a comparable 0.604 quads of primary electric yielding a total of 0.851 quads. The reduction of carbon emissions for this total was projected at about 13.3 Million metric tons.

The above calculations result in figures for energy and carbon savings which are not far apart. The difference between them is probably due to different viewpoints and the credits taken for energy savings. It is interesting to note, using Figure 3, that the growth in total energy use of the national commercial sector over the same time period is projected at about 1.25 quads or about 1.25 to 1.6 times what an energy conservation program could achieve if its goal is set to track with past accomplishments. That is to say that even a conservative effort in energy conservation can keep pace with the projected growth in energy usage. In this endeavor, an accelerated effort in energy conservation should be able to keep pace with and even exceed the future growth of energy usage in the commercial sector.

References

- [1] Kelso, J., D&R International, 1999 BTS Core Databook
- [2] Commercial Building Characteristics, 1995 Census, website - <http://www.eia.doe.gov/emeu/cbecs/cb951a.html>
- [3] Editorials, Building Operating Management and Maintenance Solutions magazines, website- <http://www.facilitiesnet.com>
- [4] Guide for Evaluation of Energy Savings Potential of Office of Building Technology, State and Community Programs, Section X - Appendix D, February 26, 1999
- [5] Energy Conservation Course Outline (DRAFT) for the International Union of Operating Engineers, 1998

Appendix A

Detailed Spreadsheet Calculations

The spreadsheets are best explained using some of the previous tables to show where the various assumed numbers came from. The calculations are straight forward in both spread sheets. The Primary Electric Energy was derived as Site Electric multiplied by the factor of 3.21

The first spreadsheet (hcsave.wb2) uses the same calculations shown in the text under the Analysis section to calculate the estimated national reduction in Natural Gas, Fuel Oil, Other Fuels, and Site Electric with the combined effects of load reduction and equipment efficiency improvement. The cell called "Reduction" or "Red. Use" (Reduced Use) was assigned a decimal fraction identifying the assumed reduction in the energy category. The reduction assigned to each of Space Heating, Space Cooling, and Water Heating was 0.3. Cooking and Electric use were each assigned reductions of 0.1

The cell called "Penet." (Penetration) was assigned a decimal fraction for the assumed management approval of energy conservation projects. Space Heating and Water Heating were each assigned 0.13 which was the average in Table 4. Space Cooling, Cooking, and Electric use were each assigned 0.16, again the average shown in Table 4.

Table A-1 Assumed Efficiency of Equipment and Site Energy Split for Space Conditioning

Heating Equipment	Comment	Stock Eff., COP, or EER	New Eff., COP, or EER	Energy (1) End-Use %
Heat Pumps	As in Table 5	EER=12	EER=12	8
Furnaces and Boilers	Average of both in Table 5	Eff.=75%	Eff.=80%	35 (a)
Individual Space Heaters	As in Table 5	Eff.=75%	Eff.=80%	23
District Heat	As in Table 5	Eff.=72%	Eff.=81%	5
Packaged Heating Units	As in Table 5	Eff.=80%	Eff.=85%	20
Other	As in Table 5	Eff.=98%	Eff.=98%	9
Cooling Equipment				
Res. Type Central Air Conditioners	As in Table 5	EER=10	EER=12	13
Heat Pumps	As in Table 5	EER=12	EER=12	10
Individual Air Conditioners	As in Table 5	EER=8	EER=10	19
District Chilled Water	As in Table 5	COP=2.1	COP=2.9	3
Central Chillers	As in Table 5	COP=2.3	COP=3	16
Packaged Air Conditioning Units	As in Table 5	COP=2.3	COP=3	34
Swamp Coolers	As in Table 5	ϵ_{te} =60%	ϵ_{te} =80%	4
Other	As in Table 5	EER=8	EER=10	1

Note: (a) Total energy load seen by furnaces and boilers

Tables 5 and 6 show the various pieces of equipment involved with the explanation of assumed items appearing in Tables A-1 and A-2. The assigned energy sources are identified in Table 6 by references and used in the spreadsheet.

Table A-2 Assumed Efficiency of Equipment for Other Energy Uses

Equipment Type	Comments	Stock Eff., COP, or EER	New Eff., COP, or EER	Best Efficiency
Water Heater				
Gas-Fired	As in Table 6	65%	78%	96%
Oil-Fired	As in Table 6	65%	78%	87%
Electric Resistance	As In Table 6	75%	95%	98%
Cooking				
Gas	As in Table 6	25%	50%	65%
Electric	As in Table 6	50%	70%	80%
Other Electric				
Ventilation	As in Table 6	68%	88%	NA
Lighting	As in Table 6	15%	75%	NA
Refrigeration	As in Table 6	1.5 (est.)	2.0	2.3
Office Equipment	As in Table 6	60% (avg.)	80% (avg.)	80%

The Energy to Carbon factors were taken largely from Table E in Ref. [4]. The one exception was the use of an average value for Natural Gas and Fuel Oil as noted in Table 7.

The second spreadsheet (savings potential.wb3) was formed around the procedure outlined in Ref [4] which utilizes a simple multiplication of expected Energy Savings, a National Energy Consumption factor, and Maximum Penetration, to calculate a National Total Energy Savings.

The estimated Energy Savings in percent was derived for each type of equipment. This, as is the source for the assumed savings is shown in Table A-3. The last column of the table shows the savings as:

$$\text{Percent Savings} = \frac{\text{New Efficiency} - \text{Stock Efficiency}}{\text{New Efficiency}} (100)$$

In the first part of the spreadsheet, The National Energy Consumption factors were used as they appear against usage type in Table C of Ref. [4].

Table A-3 Assumed Efficiency of Equipment for Commercial Buildings

Equipment Type	Comments	Stock Eff.,COP	New Eff., COP	Savings %
Chillers				
Reciprocating	As in Table 6	2.5	3.2	22
Centrifugal	As in Table 6	4.6	5.9	22
Rooftop AC	As in Table 6	2.1	2.5	16
Boilers				
Gas-Fired	As in Table 6	75%	80%	6.3
Oil-Fired	As in Table 6	78%	83%	6
Furnaces				
Gas-Fired	As in Table 6	75%	77%	2.6
Oil-Fired	As in Table 6	75%	83% (a)	9.6
Water Heater				
Gas-Fired	As in Table 6	65%	78%	16.7
Oil-Fired	As in Table 6	65%	78%	16.7
Electric Resistance	As in Table 6	75%	95%	21
Cooking				
Gas	As in Table 6	25%	50%	50
Electric	As in Table 6	50%	70%	28.6
Other Electric				
Ventilation	As in Table 6	68%	88%	22.7
Lighting	As in Table 6	15%	75%	80
Refrigeration	As in Table 6	1.5 (est.)	2.0	25
Office Equipment	As in Table 6	60% (avg.)	80% (avg.)	25

In the second part of the spreadsheet, the calculation has to do with building envelope conservation. The assumed total savings for all aspects of the envelope improvement was 30%. This was divided up as follows:

Component	Savings %
(1) Walls	10
(2) Roofs	5
(3) Windows (Conduction)	9
(4) Windows (Solar)	-5
(5) Foundations	3
(6) Infiltration	8

This division of potential savings is based roughly on same ratio of division as the National Energy Consumption factors shown in Table D of Ref. [4].

The penetration for Heating Equipment, Water Heating, and Envelope was assigned as 13% and all the others (Cooling Equipment, Refrigeration, Lighting, Ventilation, Office Equipment, and Cooking) assigned as 16%

In this spreadsheet the Energy to Carbon factors were taken from largely from Table E of Ref. [4]. The one exception, as discussed earlier and repeated here, was the given Energy to Carbon factor of 15.67 for electric use in Ref. [4]. The given factor is only applicable to site electric use. In actuality, in terms of total electric energy and carbon impact, this factor should be multiplied by 3.21 to reflect the primary source and then summed with the site use to develop a factor of 65.97.

Each of the spreadsheets are shown on the following pages.

Space Heating and Cooling, Ventilation, Water Heating, Lighting, Ref., Cooking, Office Eq., Energy Savings (quads)										
Roof and Walls and Simultaneous Equipment Improvemen					Reduct.	0.3		Penet.	0.13	
Quattro	hcsave.wb2					Nat.Gas	Fuel Oil	Other	Site Elec.	Prim.Elec
					Tot.Eng.	1.58	0.37	0.11	0.16	0.5136
Space Heating	Stock Eff.	New Eff.	Site Eng.		Conserv.	0.06162	0.01443	0.00429	0.00624	0.02003
	COP.EE	COP.EE	Split		Percent	0.71171	0.16667	0.04955	0.07207	
Heat Pumps	12	12	0.08			0.00493	0.00115	0.00034	0.0005	0.0016
Furn. & Boilers	0.76	0.81	0.35			0.02467	0.00578	0.00172	0.0025	0.00802
Individ. Heaters	0.75	0.8	0.23			0.01624	0.0038	0.00113	0.00164	0.00528
District Heating	0.72	0.81	0.05			0.00388	0.00091	0.00027	0.00039	0.00126
Packaged Units	0.8	0.85	0.2			0.01402	0.00328	0.00098	0.00142	0.00456
Other		0.98	0.98	0.09		0.00555	0.0013	0.00039	0.00056	0.0018
Tot. Eng.	2.22									
Tot. Env.	0.08658	SH Site	0.09735		SH Sim.	0.06928	0.01622	0.00482	0.00702	0.02252
New Tot.	2.12265									
Roof and Walls and Simultaneous Equipment Improvemen					Reduct.	0.3		Penet.	0.16	
						Nat.Gas	Fuel Oil	Other	Site Elec.	Prim.Elec
					Energy	0.02	0	0	0.34	1.0914
Space Cooling	Stock Eff.	New Eff.	Site Eng.		Conserv.	0.00096	0	0	0.01632	0.05239
	COP.EE	COP.EE	Split		Percent	0.05556	0	0	0.94444	
Res. Type Cent. AC	10	12	0.13			0.00017	0	0	0.00295	0.00946
Heat Pumps	12	12	0.1			9.6E-05	0	0	0.00163	0.00524
Individ. AC	8	10	0.19			0.00027	0	0	0.00455	0.0146
District Chilled Wate	2.1	2.9	0.03			4.7E-05	0	0	0.0008	0.00258
Central Chillers	2.3	3	0.16			0.00024	0	0	0.00403	0.01295
Pack. AC Units	2.3	3	0.34			0.0005	0	0	0.00857	0.02751
Swamp Coolers	0.6	0.8	0.04			6.1E-05	0	0	0.00103	0.00332
Other		8	10	0.01		1.4E-05	0	0	0.00024	0.00077
Tot. Eng.	0.36									
Tot. Env.	0.01728	SC Site	0.02521		SC Sim.	0.0014	0	0	0.02381	0.06172
New Tot.	0.33479									
Water Heating					Red.Use	0.3		Penet.	0.13	
						Nat.Gas	Fuel Oil	Renew.	Site Elec.	Prim.Elec
	Stock Eff.	New Eff.			Energy	0.75	0.07	0.02	0.09	0.2889
					Conserv.	0.02925	0.00273	0.00078	0.00351	0.01127
Fossil	0.65	0.78								
Electric	0.75	0.95			WH Sim.	0.04063	0.00379	0.00108	0.00523	0.0168
Tab.5.10.6										
Tot. Eng.	0.93									
Tot. WH	0.03627	WH Site	0.05073							
New Tot.	0.87927									
Cooking					Red.Use	0.1		Penet.	0.16	
						Nat.Gas	Fuel Oil	Renew.	Site Elec.	Prim.Elec
	Stock Eff.	New Eff.			Energy	0.23	0	0	0.02	0.0642
					Conserv.	0.00368	0	0	0.00032	0.00103
Nat. Gas	0.25	0.5								
Electric	0.5	0.7			Ckg Sim.	0.02024	0	0	0.00114	0.00367
Tab.5.10.7										
Tot. Eng.	0.25									
Tot. Ckg.	0.004	CK Site	0.02138							
New Tot.	0.22862									
Electric					Red.Use	0.1		Penet.	0.16	
						Nat.Gas	Fuel Oil	Renew.	Site Elec.	Prim.Elec
	Stock Eff.	New Eff.			Vent.	0	0	0	0.17	0.5457
					Light	0	0	0	1.22	3.9162
Ventilation	0.68	0.88	ASHRAE	Ref.		0	0	0	0.18	0.5778
Lighting	0.15	0.75	Tab.5.9.7	Office Eq.		0	0	0	0.04	0.1284
Refrigeration	1.5	2	Tab.5.10.4							
Office Equipment	0.6	0.8	Tab.5.10.	Vent.Con		0	0	0	0.00272	0.00873
				Light Con		0	0	0	0.01952	0.06266
Tot. Eng.	1.61			Ref. Con.		0	0	0	0.00288	0.00924
Tot. Svg	0.02576	EL Site	0.17979	Off. Con		0	0	0	0.00064	0.00205
New Tot.	1.43021									
					Vent.Sim	0	0	0	0.00828	0.02659
					Light Si	0	0	0	0.16006	0.51381
					Ref. Sim	0	0	0	0.00936	0.03005
					Off. Sim.	0	0	0	0.00208	0.00668
Site EnergyTot.	0.37446					0.13155	0.02002	0.00591	0.21699	0.68183
Primary Elec.Tot.	0.68183									
Energy Tot.	1.05629									

Evaluation of National Energy and Carbon Savings Potential (Comm. Equipment)					07/07/99	
Quattro: savings potential.wb3						
Type	Energy savings over new technology (%)	National energy consumption for end-use	Maximum potential market penetration (%)	National Total Energy Savings (Quads)	Energy to carbon factor	National Total Carbon Savings (10 ⁶ METRIC TONS)
Heating Equipment						
Gas Furnaces	2.6	0.83	13	0.0029054	14.4	0.04039776
Oil Furnaces	9.6	0.11	13	0.0013728	19.75	0.0271128
Gas Boilers	6.3	0.32	13	0.0025208	14.4	0.03773952
Oil Boilers	6	0.09	13	0.000702	19.75	0.0138645
Electric Heat Pumps	0	0.1	13	0	65.9707	0
Electric Space Heaters	0	0.17	13	0	65.9707	0
Other Electric	0	0.11	13	0	65.9707	0
Other Gas	0	0.67	13	0	14.4	0
Total Space Heating		2.4		0.007501		0.11911458
Cooling Equipment						
Centrifugal Chillers	22	0.29	16	0.010208	65.9707	0.67342891
Reciprocating Chillers	22	0.32	16	0.011264	65.9707	0.74309396
Absorption Chillers	0	0.02	16	0	65.9707	0
Rooftop A/C or Unitary A/C	16	1.03	16	0.026368	65.9707	1.73951542
Total Space Cooling		1.66		0.04784		3.15603829
Water Heating						
Electric	21	0.55	13	0.015015	65.9707	0.99055006
Gas	16.7	0.45	13	0.0097695	14.4	0.1406808
Oil	16.7	0.09	13	0.0019539	19.75	0.03858952
Other Fuels		0.01	13	0		
Total Water Heating		1.1		0.0267384		1.16982039
Refrigeration						
Supermarket		0.33		0	65.9707	0
Walk-in		0.18		0	65.9707	0
Vending Machines		0.13		0	65.9707	0
Beverage Merchandisers		0.05		0	65.9707	0
Reach-in	25	0.12	16	0.0048	65.9707	0.31665936
Ice Machines		0.1		0	65.9707	0
Total Refrigeration		0.91		0.0048		0.31665936
Lighting						
Incandescent	80	0.49	16	0.06272	65.9707	4.1376823
Fluorescent		2.5	16	0	65.9707	0
HID		0.74	16	0	65.9707	0
Total Lighting		3.73		0.06272		4.1376823
Ventilation						
Ventilation	22.7	0.54	16	0.0196128	65.9707	1.29387014
Office Equipment						
Office Equipment	25	0.84	16	0.0336	65.9707	2.21661552
Laundry						
Clothes Washer		0.054		0	65.9707	0
Clothes Dryer (gas)		0.122		0	14.4	0
Clothes Dryer (electric)		0.014		0	65.9707	0
Total Laundry		0.19		0		0
Cooking						
Electric	28.6	0.1	16	0.004576	65.9707	0.30188192
Gas	50	0.18	16	0.0144	14.4	0.20736
Total Cooking		0.28		0.018976		0.50924192
Grand Totals				0.2217882		12.9190425

Evaluation of National Energy and Carbon Savings Potential (Comm. Envelope)					07/07/99	
Quattro: savings potential.wb3 Heating						
	Energy savings over new technology (%)	National energy consumption for end-use category	Maximum potential market penetration (%)	National Total Energy Savings (Quads)	Energy to carbon factor	National Total Carbon Savings (Kg/MMBtu)
B.1 Current Building Stock						
Component						
Walls	10	0.6	13	0.0078	15.19	0.118482
Roofs	5	0.33	13	0.002145	15.19	0.03258255
Windows (net)		0.25		0	15.19	0
Conduction	9	0.6	13	0.00702	15.19	0.1066338
Solar	-5	-0.35	13	0.002275	15.19	0.03455725
Foundations	3	0.2	13	0.00078	15.19	0.0118482
Infiltration	8	0.54	13	0.005616	15.19	0.08530704
Envelope Subtotal	30	1.92		0.025636		0.38941084
Internal Loads		NA				
Total	30			0.025636		0.38941084

(10⁶ METRIC TONS)

Appendix B

Building Energy Use

Table B-1 was extracted from Ref. [1], Table 1.3.9. It shows some Commercial Building loads as a percentage of the whole building energy load and is included here as information only.

Table B-1 Aggregate Commercial Building Component Loads

Component	Heating (%)	Cooling (%)
Roof	12	1
Walls	21	-
Foundation	11	-
Infiltration	18	-
Ventilation	15	-
Windows (conduction)	22	-
Windows (solar gain)	-	32
Lights	-	42
Electrical Equip.	-	17
Non-Electrical Equip.	-	1
People	-	7
Net Load	100	100

Using Table 1.3.3, the following Tables B-2 to Table B-14, show the split for each End-Use (Space Heating, Space Cooling, etc.) assuming that all the Building Types use the applied energy in the same way. These tables are provided here as additional information and show how total Commercial Energy according to Ref. [2] can be split and projected within the various Building Types.

Table B-2 Office Building Energy End-Use Splits, by Fuel Type (quads)

End-Use	Nat. Gas	Fuel Oil	Other Fuels	Renw. En.	Site Elec.	Prim. Elec.
Space Heating	0.303	0.071	0.021	-	0.031	0.1
Space Cooling	0.004	-	-	-	0.065	0.209
Ventilation	-	-	-	-	0.033	0.105
Water Heating	0.144	0.013	-	0.004	0.017	0.055
Lighting	-	-	-	-	0.234	0.75
Refrigeration	-	-	-	-	0.035	0.111
Cooking	0.044	-	-	-	0.004	0.012
Office Equipment	-	-	-	-	0.077	0.246
Total	0.495	0.084	0.021	0.004	0.495	1.59

Table B-3 Mercantile/Service Building Energy End-Use Splits, by Fuel Type (quads)

End-Use	Nat. Gas	Fuel Oil	Other Fuels	Renw. En.	Site Elec.	Prim. Elec.
Space Heating	0.288	0.067	0.02	-	0.029	0.094
Space Cooling	0.004	-	-	-	0.062	0.2
Ventilation	-	-	-	-	0.031	0.1
Water Heating	0.137	0.013	-	0.004	0.016	0.053
Lighting	-	-	-	-	0.223	0.717
Refrigeration	-	-	-	-	0.033	0.106
Cooking	0.042	-	-	-	0.004	0.012
Office Equipment	-	-	-	-	0.073	0.235
Total	0.047	0.08	0.02	0.004	0.472	1.52

Table B-4 Education Building Energy End-Use Splits, by Fuel Type (quads)

End-Use	Nat. Gas	Fuel Oil	Other Fuels	Renw. En.	Site Elec.	Prim. Elec.
Space Heating	0.182	0.043	0.013	-	0.018	0.059
Space Cooling	0.002	-	-	-	0.039	0.126
Ventilation	-	-	-	-	0.02	0.063
Water Heating	0.86	0.008	-	0.002	0.01	0.033
Lighting	-	-	-	-	0.14	0.451
Refrigeration	-	-	-	-	0.021	0.067
Cooking	0.026	-	-	-	0.002	0.007
Office Equipment	-	-	-	-	0.046	0.148
Total	0.297	0.051	0.013		0.297	0.953

Table B-5 Health Care Building Energy End-Use Splits, by Fuel Type (quads)

End-Use	Nat. Gas	Fuel Oil	Other Fuels	Renw. En.	Site Elec.	Prim. Elec.
Space Heating	0.167	0.04	0.012	-	0.017	0.054
Space Cooling	0.002	0.007	-	-	0.036	0.116
Ventilation	-	-	-	-	0.018	0.058
Water Heating	0.079		-	0.002	0.01	0.031
Lighting	-	-	-	-	0.129	0.414
Refrigeration	-	-	-	-	0.019	0.061
Cooking	0.024	-	-	-	0.002	0.007
Office Equipment	-	-	-	-	0.042	0.136
Total	0.273	0.047	0.012	0.002	0.273	0.876

Table B-6 Lodging Building Energy End-Use Splits, by Fuel Type (quads)

End-Use	Nat. Gas	Fuel Oil	Other Fuels	Renw. En.	Site Elec.	Prim. Elec.
Space Heating	0.137	0.032	0.01	-	0.014	0.045
Space Cooling	0.002	-	-	-	0.03	0.095
Ventilation	-	-	-	-	0.015	0.047
Water Heating	0.065	0.006	-	0.002	0.008	0.025
Lighting	-	-	-	-	0.106	0.34
Refrigeration	-	-	-	-	0.016	0.05
Cooking	0.02	-	-	-	0.002	0.006
Office Equipment	-	-	-	-	0.035	0.111
Total	0.224	0.038	0.01	0.002	0.224	0.719

Table B-7 Public Assembly Building Energy End-Use Splits, by Fuel Type (quads)

End-Use	Nat. Gas	Fuel Oil	Other Fuels	Renw. En.	Site Elec.	Prim. Elec.
Space Heating	0.134	0.031	0.009	-	0.014	0.044
Space Cooling	0.002	-	-	-	0.029	0.093
Ventilation	-	-	-	-	0.014	0.046
Water Heating	0.064	0.006	-	0.002	0.008	0.025
Lighting	-	-	-	-	0.104	0.332
Refrigeration	-	-	-	-	0.015	0.049
Cooking	0.02	-	-	-	0.002	0.005
Office Equipment	-	-	-	-	0.034	0.109
Total	0.219	0.037	0.009	0.002	0.219	0.703

Table B-8 Food Service Building Energy End-Use Splits, by Fuel Type (quads)

End-Use	Nat. Gas	Fuel Oil	Other Fuels	Renw. En.	Site Elec.	Prim. Elec.
Space Heating	0.098	0.023	.007	-	0.01	0.032
Space Cooling	0.001	-	-	-	0.021	0.068
Ventilation	-	-	-	-	0.011	0.034
Water Heating	0.047	0.004	-	0.001	0.006	0.018
Lighting	-	-	-	-	0.076	0.243
Refrigeration	-	-	-	-	0.011	0.036
Cooking	0.014	-	-	-	0.001	0.004
Office Equipment	-	-	-	-	0.025	0.08
Total	0.16	0.27	0.007	0.001	0.16	0.514

Table B-9 Warehouse/Storage Building Energy End-Use Splits, by Fuel Type (quads)

End-Use	Nat. Gas	Fuel Oil	Other Fuels	Renw. En.	Site Elec.	Prim. Elec.
Space Heating	0.095	0.022	0.007	-	0.01	0.031
Space Cooling	0.001	-	-	-	0.02	0.066
Ventilation	-	-	-	-	0.01	0.033
Water Heating	0.045	0.004	-	0.001	0.005	0.017
Lighting	-	-	-	-	0.073	0.235
Refrigeration	-	-	-	-	0.011	0.035
Cooking	0.014	-	-	-	0.001	0.004
Office Equipment	-	-	-	-	0.024	0.077
Total	0.155	0.026	0.007	0.001	0.155	0.498

Table B-10 Food Sales Building Energy End-Use Splits, by Fuel Type (quads)

End-Use	Nat. Gas	Fuel Oil	Other Fuels	Renw. En.	Site Elec.	Prim. Elec.
Space Heating	0.041	0.009	0.003	-	0.004	0.013
Space Cooling	0.001	-	-	-	0.009	0.029
Ventilation	-	-	-	-	0.004	0.014
Water Heating	0.019	0.002	-	0	0.002	0.008
Lighting	-	-	-	-	0.032	0.102
Refrigeration	-	-	-	-	0.005	0.015
Cooking	0.006	-	-	-	0.001	0.002
Office Equipment	-	-	-	-	0.01	0.033
Total	0.067	0.011	0.003	0	0.067	0.215

Table B-11 Vacant Building Energy End-Use Splits, by Fuel Type (quads)

End-Use	Nat. Gas	Fuel Oil	Other Fuels	Renw. En.	Site Elec.	Prim. Elec.
Space Heating	0.014	0.003	0.001	-	0.001	0.005
Space Cooling	0	-	-	-	0.003	0.01
Ventilation	-	-	-	-	0.002	0.005
Water Heating	0.007	0.001	-	0	0.001	0.003
Lighting	-	-	-	-	0.011	0.035
Refrigeration	-	-	-	-	0.002	0.005
Cooking	0.002	-	-	-	0	0.001
Office Equipment	-	-	-	-	0.004	0.011
Total	0.023	0.004	0.001	0	0.023	.074

Table B-12 Religious Worship Building Energy End-Use Splits, by Fuel Type (quads)

End-Use	Nat. Gas	Fuel Oil	Other Fuels	Renw. En.	Site Elec.	Prim. Elec.
Space Heating	0.03	0.007	0.002	-	0.003	0.01
Space Cooling	0	-	-	-	0.006	0.021
Ventilation	-	-	-	-	0.003	0.01
Water Heating	0.014	0.001	-	0	0.002	0.005
Lighting	-	-	-	-	0.023	0.074
Refrigeration	-	-	-	-	0.003	0.011
Cooking	0.004	-	-	-	0	0.001
Office Equipment	-	-	-	-	0.008	0.024
Total	0.049	0.008	0.002	0	0.049	0.157

Table B-13 Public Order/Safety Building Energy End-Use Splits, by Fuel Type (quads)

End-Use	Nat. Gas	Fuel Oil	Other Fuels	Renw. En.	Site Elec.	Prim. Elec.
Space Heating	0.036	0.008	0.003	-	0.004	0.012
Space Cooling	0	-	-	-	0.008	0.025
Ventilation	-	-	-	-	0.004	0.012
Water Heating	0.017	0.002	-	0	0.002	0.007
Lighting	-	-	-	-	0.028	0.09
Refrigeration	-	-	-	-	0.004	0.013
Cooking	0.005	-	-	-	0	0.001
Office Equipment	-	-	-	-	0.009	0.029
Total	0.059	0.01	0.003	0	0.059	0.189

Table B-14 Other Building Energy End-Use Splits, by Fuel Type (quads)

End-Use	Nat. Gas	Fuel Oil	Other Fuels	Renw. En.	Site Elec.	Prim. Elec.
Space Heating	0.051	0.012	0.004	-	0.005	0.017
Space Cooling	0.001	-	-	-	0.011	0.035
Ventilation	-	-	-	-	0.005	0.018
Water Heating	0.024	0.002	-	0.001	0.003	0.009
Lighting	-	-	-	-	0.039	0.126
Refrigeration	-	-	-	-	0.006	0.019
Cooking	0.007	-	-	-	0.001	0.002
Office Equipment	-	-	-	-	0.013	0.041
Total	0.083	0.014	0.004		0.083	0.266

Appendix C

Energy Conservation Check List

The scope of the Energy Management Opportunities (EMO) become understandable when the following items are as fully documented as possible for each area:

1. Electric energy (usage and demand based)
2. Fuel usage (Gas, oil, recovered waste, etc.)
3. Water usage (blowdown, cooling, wash, etc.)
4. Production or other rates (periodic, seasonal, project, etc.)

The following Primary (low first cost) and Applied (first cost intensive) ECM's from Ref. [5] can be used as suggestive of the type needed. The list may have to be altered as specific site needs are addressed. This as well as the basic approach provided in the above training program contains additions from the author and as well as industry sources. Although the headings of Primary and Applied, many of the items have general applicability and can form the structure of an Energy Conservation Check List. Because of the diverse nature of commercial usages none of these can be overlooked as items that may need the specific attention of the energy auditor. As such they may be applicable to the main areas defined above.

Primary Building Envelope

1. Repair door and window caulking and weather-stripping.
2. Repair broken glass.
3. Repair mechanisms, tracks, latches, cams.
4. Adjust door closing mechanisms.
5. Refit windows and doors.

Applied Building Envelope

1. Install double glazing.
2. Install automatic door closing mechanisms.
3. Install tight closing air dampers.
4. Install heat absorbing or reflective film.
5. Install weather-stripping-caulk windows and joints.
6. Insulate walls.
7. Insulate attic or roof.
8. Add insulation to ceilings.

Primary Domestic Hot Water

1. Repair leaks.
2. Reduce quantity of water used.
3. Lower hot water temperature setting.
4. Check and tune efficiency of equipment.

5. Raise chilled water setting on water fountains.
6. Repair insulation of piping and water storage tanks.

Applied Domestic Hot Water

1. Install shower and faucet restrictors.
2. Install timer on circulation pump.
3. Install summer boiler.
4. Decentralize water heaters.
5. Install timer to de-energize night heating.
6. Install hot water temperature controls.
7. Recover waste-heat to heat local hot water.
8. Install local hot water temperature booster.
9. Insulate hot water storage tank.
10. Insulate hot water circulating lines.

Primary Process Water

1. Repair leaks and reduce spillage
2. Reduce quantity of water used.
3. Raise or lower water temperature setting.

Applied Process Water

1. Install timer on usage.
2. Install heat or cool recovery.
3. Decentralize water heaters or chillers.
4. Install water temperature controls.
5. Insulate water storage tank.
6. Insulate water circulating lines.

Primary Heating and Cooling

1. Lower or raise indoor thermostats.
2. Lock thermostats.
3. Adjust supply temperature.
4. Install night setback/setup thermostats.
5. Restrict heating and cooling in unoccupied or unused areas.
6. Check operation of manual and automatic controls.
7. Reduce heating/cooling in garages, loading docks, platform, storage areas.
8. Lower or raise indoor thermostats.
9. Clean radiators, air registers, filters, ducts.
10. Reduce air leakage in HVAC ducts.
11. Insulate connecting ducts and pipes.
12. Check operation of manual and automatic controls.
13. Reduce heating/cooling in garages, loading docks, platform, storage areas.

Applied Heating and Cooling

1. Install flue damper
2. Preheat boiler water
3. Preheat combustion air.
4. Replace burner with more efficient type.
5. Add controls to permit boiler isolation (increase loading).
6. Install flue gas analyzer.
7. Install controls to modify water temperatures with load.
8. Replace inefficient air conditioners.
9. Install temperature controls.
10. Install time clocks for automatic control.
11. Install economizer controls.
12. Replace existing boiler with more efficient type.
13. Install heat pump.
14. Install destratification fan.
15. Install energy management system and control strategies (ie; resets, optimization).
16. Install valves to permit shutoff to unoccupied or unutilized zones.
17. Insulate bare piping and fittings.
18. Insulate boiler.
19. Install tempor-proof boxes on thermostats.
20. Relocate improperly placed thermostats.
21. Install valves to permit shutoff of unoccupied or unutilized areas.
22. Downsize motors.
23. Install high-efficiency motors.
24. Install variable speed drives.

Primary Ventilation

1. Consider shut down of system in unoccupied zones.
2. Check operation of manual and automatic controls.
3. Reduce ventilation rates.
4. Inspect outside air dampers.
5. Balance air intake and exhaust rates.
6. Improve filter maintenance.
7. Consider the maintaining positive interior pressure.
8. Inspect all central systems and controls.

Applied Ventilation

1. Install controls of ventilation/exhaust in unoccupied or unutilized areas.
2. Recover heat from exhaust air.
3. Where safety issues are understood wire exhaust fans to lighting circuit.
4. Reduce fan speed.
5. Install time clocks for exhaust fans.
6. Reduce outside and exhaust air.

7. Install outside air control on unit ventilators.
8. Install variable air volume system.
9. Install high-efficiency motors.
10. Install variable speed drives.

Primary Lighting

1. Reduce illumination levels.
2. Maximize use of daylight.
3. Reduce or eliminate evening cleaning.
4. Utilize task lighting.

Applied Lighting

1. Install HID lamps to replace incandescent.
2. Install fluorescent lamps to replace incandescent.
3. Install energy efficient lamps.
4. Install energy efficient ballasts.
5. Provide local switching for lighting.
6. Install photocell controls.
7. Reduce number of fixtures.