State of Wisconsin Public Service Commission of Wisconsin

Focus on Energy Evaluation

Business Programs: Deemed Savings Parameter Development

Final Report: November 13, 2009

Evaluation Contractor: PA Consulting Group Inc.

Prepared by: Tammy Kuiken, John Dendy, Ryan Barry, and
Miriam Goldberg, KEMA, Inc.

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The power is within you.

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Appendices

1. EXECUTIVE SUMMARY

This report represents one of two deliverables associated with the Deemed Savings Parameter Development task outlined in the Business Programs Detailed Evaluation Plan[1] (DEP) for calendar year 2009. The second deliverable is a Deemed Savings Manual that provides an overview of the calculations and assumptions for every deemed savings measure. The manual will be submitted for Public Service Commission of Wisconsin (PSCW) and Focus comment following the Commission's approval of the deemed savings values. The DEP includes another deemed savings task that consists of a typical deemed savings review with new deemed savings measure proposals. The other deemed savings review will be affected by this report but is not considered in the course of this analysis.

The Focus on Energy program has transitioned from prescriptive energy savings estimates that are evaluated post-installation to deemed energy savings estimates that are evaluated pre-installation for a significant portion of program energy savings. The new deemed savings measures and initial estimates are proposed by the program, reviewed by the evaluation team, and finalized through joint consensus. This is the same deemed savings process that KEMA and Focus have been participating in for several years. The resulting estimates do not receive a gross savings adjustment on a per-unit basis; only the non-deemed portion of the savings calculation is reviewed during the impact evaluation. Determining the correct savings estimate for deemed measures is crucial to determining the accuracy of the overall program savings estimate.

KEMA performed a review of the WISeerts database to find the deemed savings measures that contribute the most toward program and sector energy savings. We examined the list and identified the measures that would benefit from additional or updated reviews. We also identified a few parameters that are used for a number of deemed measures and had limited source information. We then performed a comprehensive review of each measure and parameter that included a review of the calculation method, a literature review, conversations with manufacturers and service providers, and application of general engineering practice. In this report, we recommend changes to the deemed savings values or parameters based on our review.

1.1 OVERVIEW OF APPROACH

1.1.1 Measure and parameter selection

KEMA conducted a WISeerts database analysis, identified measures to review, and presented a list of recommended measures and parameters to the program in a June 5, 2009, memo. The program provided comments and feedback on the proposed list and it was approved by the PSCW.

The most important criteria used to select measures for review was the contribution to program savings. The greatest improvement in overall program savings accuracy can be

[1] Miriam Goldberg, J. Ryan Barry, and Tammy Kuiken, KEMA, Inc. *State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation Calendar Year 2009 Detailed Evaluation Plan: Business Programs.* April 16, 2009.

achieved more cost-effectively by addressing the measures that contribute most to those savings. Therefore, KEMA began our analysis by determining energy savings by measure. We then examined measure count and the other selection criteria to determine whether these criteria would suggest other measures to include.

Our analysis was based on the WISeerts database as downloaded on May 4, 2009, and included all measures entered to that date. We asked the program to identify any additional new measures that would make a significant contribution to program savings going forward. The program felt that the historical analysis was sufficient and did not suggest any additional measures. Therefore, our recommendations were based solely on program history, not upon any forecast of future program activity or savings.

A. SELECTING MEASURES AND PARAMETERS FOR CONSIDERATION

To calculate savings by measure, we limited the WISeerts data set by removing custom and hybrid measures, leaving only the prescriptive measures. Among the prescriptive measures are some that are currently deemed but were not deemed at some point in the database period. Those measures were entered under a different Tech Code. We wanted a complete picture of the savings associated with the technology, not just the savings that occurred since the measures became deemed. Therefore, we did not limit the data set by removing the Tech Codes associated with the non-deemed life of the measure; instead, we combined the energy savings from the non-deemed portion of the database with the deemed portion.

Using this data set, overall kWh and therm savings were calculated by Tech Code and ranked accordingly. KEMA selected the top 20 kWh and top 10 therm measures for further examination. Many of the measures selected were similar to other measures either within or outside of the top groups. Measures that use the same calculation method or assumptions can be grouped into a single “measure bin” and can be reviewed concurrently without adding very much cost to the task. So, like measures were combined into measure bins, savings were calculated for each bin, and the measure bins were re-ranked accordingly. For kWh savings, the resulting 10 measure bins contain the 37 measures with the most savings. For therm savings, the resulting six measure bins represent the 13 measures with the most savings.

KEMA also looked at measures that contribute the most to sector-level savings, measures that are popular based on measure count, measures whose savings are not easily quantified, and measures deemed early in the deemed savings process. This additional analysis did not lead to the identification of new measures or measure bins to include for consideration in this review.

Finally, KEMA looked at parameters that are used in a variety of measure calculations. Certain parameters apply to multiple technologies and thereby significantly affect program savings. We determined that the parameters with the most significant effect on savings estimates are lighting operating hours and lighting coincidence factor. Therefore, we recommended that lighting hours and coincidence factors be evaluated to improve the accuracy of the lighting savings estimates.

B. RECOMMENDED MEASURES AND PARAMETERS FOR REVIEW

Based on the above analysis, KEMA recommended nine measure bins and two parameters for review. The measure bins with the greatest savings were chosen, with the following adjustments:

- Lighting hours and coincidence factor were included for review.
- The top five kWh deemed measure bins were selected.
- The top three therm measure bins were selected.

The measure bins and parameters recommended for evaluation are presented in Table 1-1. This list was approved by the PSCW.

Table 1-1. Parameters and Measure Bins Recommended for Review

Measure Bin Description	Tech Code	Measure Description
Lighting Hours	N/A	Lighting hours assumptions for all sectors
Lighting Coincidence Factors	N/A	Lighting coincidence factor assumptions for all sectors
T8 or T5HO replacing HID	2.5170	T8 4 lamp or T5HO 2 lamp Replacing 250-399 Watts HID
	2.5180	T8 6 lamp or T5HO 4 lamp Replacing 400-999 Watts HID
	2.5182	T8 8 lamp or T5HO 6 lamp Replacing 400-999 Watts HID
	2.5185	T8 or T5HO <= 500W, Replacing >=1000 W HID
	2.5186	T8 or T5HO <= 800W, Replacing >=1000 W HID
CFL < 30W replacing incandescent	2.0300	CFL <= 30 Watts - Replaces Incandescent
Occupancy Sensors on High Bay Fluorescents	2.5192	Occupancy sensor for high bay fluorescent fixtures, per fixture controlled
T8 replacing T12	2.0810	T8 4L-4ft High Performance - Replaces T12 2L-8ft
	2.0811	T8 4L-4ft High Performance Replacing T12HO/VHO 2L-8 ft
CFL Floods	2.0307	CFL Reflector Flood Lamps - Replaces incandescent reflector flood lamps
HE Ventilation Fans	4.0736	Ventilation Fans, High Efficiency - 36"
	4.0742	Ventilation Fans, High Efficiency - 42"
	4.0748	Ventilation Fans, High Efficiency - 48"
	4.0750	Ventilation Fans, High Efficiency - 50"
	4.0751	Ventilation Fans, High Efficiency - 51"
	4.0752	Ventilation Fans, High Efficiency - 52"
	4.0754	Ventilation Fans, High Efficiency - 54"
	4.0755	Ventilation Fans, High Efficiency - 55"
	4.0760	Ventilation Fans, High Efficiency - 60"
Boiler Tune-ups	1.1300	Boiler Tune-up - Service Buy Down
Steam Traps, Low Pressure HVAC	4.1000	Repair leaking steam trap, building space conditioning system
Boiler Controls	1.0710	Boiler oxygen trim controls, per output hp
	1.0711	Linkageless Boiler Control, per output hp

1.1.2 Measure reviews

KEMA reviewed each measure in Table 1-1 and summarized the results of our review in Section 4. Each technology review contains the following four sub-sections:

- **Introduction.** The first sub-section is an introduction to the measure which includes a group, category, and technical definition, a list of qualifying equipment, the date the measure was last deemed/reviewed, and the name of the KEMA employee that conducted this review. The existing deemed savings values and an explanation of how energy is saved are also included in the introduction.
- **Current Savings Methodology.** The second sub-section outlines the current deemed savings methodology and the parameter assumptions that feed into the calculation. The savings calculation is listed and the variable names are identified along with the current parameter assumptions. The calculation is followed by a more complete definition of each variable. The last part identifies the source material and thought process that went into determining the current deemed savings values and assumptions.
- **Literature Review.** The third sub-section summarizes the sources that KEMA found during our literature review for each technology. This section only includes the sources that were used in developing the new proposal. Each source is identified and explained and the pertinent information is listed.
- **Proposed Savings Methodology.** The fourth sub-section outlines KEMA's proposed deemed savings values. Each variable in the calculation equation is addressed and the source material from the literature review is analyzed and used to create new measure assumptions. The new assumptions are assembled into a section that is essentially a repeat of the current savings methodology but uses the proposed assumptions and, if applicable, calculation methods. The proposed deemed savings are listed at the end of the section.

We have also assembled some calculation spreadsheets that were used to determine the proposed deemed savings. The spreadsheets will be distributed with this report.

1.2 RECOMMENDATIONS

1.2.1 Proposed deemed savings values

The following tables contain proposed updates to deemed savings values resulting from the DSPD analysis. KEMA recommends these deemed savings estimates be adopted in January 2010 along with the deemed savings measures that are currently being reviewed as part of the deemed savings review task. The proposed lighting hours of use and coincidence factor values are shown in Table 1-2.[2] The current lighting hours of use and coincidence factor values are shown in Table 1-3.

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[2] These hours of use and coincidence factors are recommended for almost all lighting measures. Hours of use for CFLs in Agricultural buildings are one exception, as presented in Table 1-10.

Table 1-2. Proposed Deemed Parameters, Lighting Hours and Coincidence Factor

Building Use	Hours	CF
Food Sales	5,544	92%
Food Service	4,482	84%
Health Care	3,677	78%
Hotel/Motel	3,356	35%
Office	3,526	77%
Public Assembly	2,729	67%
Public Services	3,425	64%
Retail	4,226	84%
Warehouse	3,464	79%
School	2,302	52%
College	3,900	68%
Dormitory	986	7%
Industrial	4,745	77%
Agricultural	4,698	67%
Other	3,672	67%

Table 1-3. Existing Deemed Parameters, Lighting Hours, and Coincidence Factor

Sector	Hours	CF
Agriculture	4,368	90%
Commercial	3,680	90%
Industrial	4,576	90%
Schools & Government	3,230	71%

The PSC may decide that the proposed building use definition cannot be implemented at this time. Appendix A contains an alternative, sector-level review of lighting hours and coincidence factor. If the building use definition is rejected at this time, KEMA recommends using the values in Appendix A.

The proposed deemed values by building use for replacing 8 foot T12 fluorescent lighting fixtures with T8 fixtures are shown in Table 1-4. Alternative, sector-level savings can be found in Appendix B. The alternative savings use the hours and coincidence factors suggested in Appendix A. The current savings for these measures are shown in Table 1-5.

Table 1-4. Proposed Deemed Savings Values by Measure, T8 Replacing 8' T12

Building Use	Hours	CF	Proposed Deemed Savings 2.0810.170 kW	2.0810.170 kWh	2.0811.170 kW	2.0811.170 kWh
Food Sales	5,544	92%	0.0214	129	0.1095	661
Food Service	4,482	84%	0.0196	104	0.1001	534
Health Care	3,677	78%	0.0182	86	0.0931	438
Hotel/Motel	3,356	35%	0.0081	78	0.0416	400
Office	3,526	77%	0.0178	82	0.0912	420
Public Assembly	2,729	67%	0.0155	64	0.0794	325
Public Services	3,425	64%	0.0148	80	0.0757	408
Retail	4,226	84%	0.0197	99	0.1006	503
Warehouse	3,464	79%	0.0184	81	0.0941	413
School	2,302	52%	0.0122	54	0.0625	274
College	3,900	68%	0.0159	91	0.0810	465
Dorms	986	7%	0.0016	23	0.0083	117
Industrial	4,745	77%	0.0180	111	0.0918	565
Agricultural	4,698	67%	0.0156	110	0.0797	560
Other	3,672	67%	0.0155	86	0.0794	438

Table 1-5. Current Deemed Savings Values, T8 Replacing 8' T12

Tech Code	Measure Description	Current Deemed Savings Ag kW	Ag kWh	Com kW	Com kWh	Ind kW	Ind kWh	S-G kW	S-G kWh
2.0810.170	T8 4L-4ft High Performance Replacing T12 2L-8 ft	0.0234	114	0.0234	96	0.0234	119	0.0185	83
2.0811.170	T8 4L-4ft High Performance Replacing T12HO/VHO 2L-8 ft	0.1008	489	0.1008	412	0.1008	513	0.0795	358

The proposed deemed savings by building use for replacing high intensity discharge lighting with fluorescent lighting are shown in Table 1-6. Alternative, sector-level savings can be found in Appendix C. The alternative savings use the hours and coincidence factors suggested in Appendix A. The current savings for these measures are shown in Table 1-7.

Table 1-6. Proposed Deemed Savings by Measure, T8 or T5 Replacing HID

Building Use	2.5170.170		2.5180.170		2.5182.170		2.5185.170		2.5186.170	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Food Sales	0.1388	837	0.2265	1,366	0.0952	574	0.6592	3,975	0.5016	3,025
Food Service	0.1269	677	0.2070	1,104	0.0870	464	0.6025	3,214	0.4584	2,445
Health Care	0.1180	555	0.1925	906	0.0809	381	0.5604	2,636	0.4264	2,006
Hotel/Motel	0.0528	507	0.0861	827	0.0362	347	0.2505	2,406	0.1906	1,831
Office	0.1156	532	0.1886	869	0.0793	365	0.5489	2,528	0.4177	1,923
Public Assembly	0.1006	412	0.1641	672	0.0690	283	0.4776	1,956	0.3634	1,489
Public Services	0.0959	517	0.1564	844	0.0657	355	0.4552	2,456	0.3464	1,869
Retail	0.1275	638	0.2081	1,041	0.0875	438	0.6055	3,030	0.4608	2,305
Warehouse	0.1192	523	0.1945	853	0.0818	359	0.5661	2,484	0.4308	1,890
School	0.0792	347	0.1292	567	0.0543	238	0.3760	1,650	0.2861	1,256
College	0.1026	589	0.1675	961	0.0704	404	0.4875	2,796	0.3710	2,128
Dormitory	0.0106	149	0.0172	243	0.0072	102	0.0502	707	0.0382	538
Industrial	0.1163	716	0.1898	1,169	0.0798	491	0.5523	3,402	0.4203	2,589
Agricultural	0.1010	709	0.1648	1,157	0.0693	486	0.4797	3,368	0.3650	2,563
Other	0.1006	554	0.1641	905	0.0690	380	0.4776	2,633	0.3634	2,003

Table 1-7. Current Deemed Savings Values, T8 or T5 Replacing HID

Tech Code	Measure Description	Agriculture		Commercial		Industrial		Schools-Government	
		kW	kWh	kW	kWh	kW	kWh	kW	kWh
2.5170.170	T8 4 lamp or T5HO 2 lamp Replacing 250-399 W HID	0.1345	653	0.1345	550	0.1345	684	0.1061	478
2.5180.170	T8 6 lamp or T5HO 4 lamp Replacing 400-999 W HID	0.2120	1,029	0.2120	867	0.2120	1,078	0.1672	754
2.5182.170	T8 8 lamp or T5HO 6 lamp Replacing 400-999 W HID	0.1437	697	0.1437	587	0.1437	731	0.1133	511
2.5185.170	T8/T5HO <= 500 Watts Replacing >=1000 W HID	0.5589	2,713	0.5589	2,285	0.5589	2,842	0.4409	1,987
2.5186.170	T8 or T5HO <= 800W, Replacing >=1000 W HID	0.4244	2,060	0.4244	1,735	0.4244	2,158	0.3348	1,509

The proposed deemed values for high bay occupancy sensors are shown in Table 1-8. Alternative, sector-level savings can be found in Appendix D. The alternative savings use the hours and coincidence factors suggested in Appendix A. The existing deemed savings values are found in Table 1-9.

Table 1-8. Proposed Deemed Savings, High Bay Occupancy Sensors

Building Type	Hours	kWh Savings by Space Type					
		Gymnasium	Industrial	Retail	Warehouse	Public Assembly	Other
Food Sales	5,544	517	591	197	701	618	525
Food Service	4,482	418	478	159	567	499	424
Health Care	3,677	343	392	131	465	410	348
Hotel/Motel	3,356	313	358	119	424	374	318
Office	3,526	329	376	125	446	393	334
Public Assembly	2,729	254	291	97	345	304	258
Public Services	3,425	319	365	122	433	382	324
Retail	4,226	394	451	150	534	471	400
Warehouse	3,464	323	370	123	438	386	328
School	2,302	215	246	82	291	256	218
College	3,900	364	416	139	493	434	369
Dormitory	986	92	105	35	125	110	93
Industrial	4,745	442	506	169	600	529	449
Agriculture	4,698	438	501	167	594	523	445
Other	3,672	342	392	131	464	409	348
	Percent Off	39%	45%	15%	53%	47%	40%
	Coincidence Factor	15%	18%	6%	18%	12%	14%
	kW Savings	**0.034**	**0.043**	**0.014**	**0.043**	**0.028**	**0.032**

Table 1-9. Existing Deemed Savings, High Bay Occupancy Sensors

Tech. Code	Measure Description	Watt-age	CF	Agriculture		Commercial		Industrial		Schools-Government	
				kW	kWh	kW	kWh	kW	kWh	kW	kWh
2.5192.085	Occupancy sensor for high bay fluorescent fixtures, per fixture controlled	247	0%	0.00	5.5438	0.00	4.6706	0.00	5.8078	0.00	2.8204
			Percent Off	62.5%		62.5%		62.5%		43.0%	
			Hours of Use	4,368		3,680		4,576		3,230	

The proposed deemed values for CFLs are shown in Table 1-10. Alternative, sector-level savings can be found in Appendix E. The alternative savings use the hours and coincidence factors suggested in Appendix A. The existing deemed savings values are found in Table 1-11.

Table 1-10. Proposed Deemed Savings, CFLs

Building Use	Hours	CF	Savings by Measure: CFL <32 W kW	CFL <32 W kWh	CFL Reflector Flood kW	CFL Reflector Flood kWh
Food Sales	5,544	92%	0.0512	3098	0.0449	271
Food Service	4,482	84%	0.0468	250	0.0410	219
Health Care	3,677	78%	0.0435	205	0.0382	180
Hotel/Motel	3,356	35%	0.0195	187	0.0171	164
Office	3,526	77%	0.0426	196	0.0374	172
Public Assembly	2,729	67%	0.0371	152	0.0325	133
Public Services	3,425	64%	0.0354	191	0.0310	167
Retail	4,226	84%	0.0470	235	0.0412	206
Warehouse	3,464	79%	0.0440	193	0.0386	169
School	2,302	52%	0.0292	128	0.02456	112
College	3,900	68%	0.0379	217	0.0332	190
Dormitory	986	7%	0.0039	55	0.0034	48
Industrial	4,745	77%	0.0429	264	0.0376	232
Agricultural	2,450	67%	0.0373	136	0.0327	120
Other	3,672	67%	0.0371	205	0.0325	179

Table 1-11. Existing Deemed Savings, CFLs

Tech Code	Measure Description	Delta Watts: Ag.	Com.	Ind.	S&G	Agriculture kW	Agriculture kWh	Commercial kW	Commercial kWh	Industrial kW	Industrial kWh	Schools-Government kW	Schools-Government kWh
2.0300.1650	CFL <= 32W, replacing incandescent <=100W	57.0	56.0	53.0	53.0	0.051	199	0.050	178	0.048	323	0.038	171
		New Watts		Old Watts									
2.0307.1650	CFL reflector flood lamps <=30W replacing incandescent reflector flood lamps <=100W	20.0		75.0		0.05	131	0.05	173	0.05	336	0.039	178
					Coincidence Factor	90%		90%		90%		71%	
					Hours of Use	3,490		3,130		6,100		3,230	

The existing and proposed deemed values for Agriculture ventilation fans are shown in Table 1-12.[3]

[3] The measure descriptions have been changed at the request of the program to distinguish them from new measures for circulation fans.

Table 1-12. Existing and Proposed Deemed Savings, Ag Exhaust Fans

Tech Code	Measure Description	Current Deemed Savings		Proposed Deemed Savings	
		kW	kWh/yr	kW	kWh/yr
4.0736.150	Agricultural Exhaust Fan, High Efficiency - 36"	0.322	1,094	0.206	700
4.0742.150	Agricultural Exhaust Fan, High Efficiency - 42"	0.396	1,483	0.240	815
4.0748.150	Agricultural Exhaust Fan, High Efficiency - 48"	0.470	1,872	0.274	930
4.0750.150	Agricultural Exhaust Fan, High Efficiency - 50"	0.664	2,553	0.305	1,037
4.0751.150	Agricultural Exhaust Fan, High Efficiency - 51"	0.664	2,553	0.305	1,037
4.0752.150	Agricultural Exhaust Fan, High Efficiency - 52"	0.664	2,553	0.305	1,037
4.0754.150	Agricultural Exhaust Fan, High Efficiency - 54"	0.664	2,553	0.305	1,037
4.0755.150	Agricultural Exhaust Fan, High Efficiency - 55"	0.664	2,553	0.305	1,037
4.0760.150	Agricultural Exhaust Fan, High Efficiency - 60"	0.664	2,553	0.305	1,037
4.0772.150	Agricultural Exhaust Fan, High Efficiency - 72"	0.664	2,553	0.305	1,037

The existing and proposed deemed savings values for natural gas measures are shown in Table 1-13.

Table 1-13. Existing and Proposed Deemed Savings, Natural Gas Measures

Tech Code	Measure Description	Current Deemed Savings (per year)	Proposed Deemed Savings (per year)
4.1000.390	Repair leaking steam trap, building space conditioning system	718	910
1.1300.430	Boiler Tune-up - service buy-down, per MBh	0.679	0.356
1.0711.085	Linkageless Boiler Control, per hp	27	25
1.0710.085	Boiler Oxygen Trim Controls, per hp	13	11.3

KEMA looked at each measure to determine our confidence that the estimated deemed savings would be realized. Table 1-14 summarizes our degree of confidence in each of the measure bins reviewed.

Table 1-14. Confidence that Deemed Savings Will Be Realized

Measure Description	Confidence Savings Will Be Realized		
	High	Medium	Low
Lighting Hours of Use and Coincidence Factor	X		
T8 replacing 8 foot T12HO or T12VHO	X		
High bay fluorescent fixture replacing HID	X		
Occupancy sensor for high bay fluorescent fixtures		X	
CFL replacing incandescent		X	
High efficiency Ag ventilation fans		X	
Leaking steam trap			X
Boiler tune-up	X		
Linkageless boiler controls	X		
Oxygen trim boiler controls	X		

1.2.2 Further research

We recommend that the following future research be performed.

- **Lighting Hours of Use and Coincidence Factor.** The Agriculture sector hours of use and coincidence factor values are based on a review of only six projects installed during the 18MCP.[4] Since there are no secondary sources that provide values for agriculture, it may be up to Focus on Energy to strengthen the parameter estimates through program data collection and tracking or primary research. By requiring and tracking lighting use profiles for projects in the Agriculture sector, the program could increase the sample size used to determine lighting hours and CF and thereby increase the accuracy of the savings estimate. A metering study of Agriculture sector lighting use would provide a more accurate estimate but also increase the cost.

  The hours of use value for Colleges is based on one source and is the least supported value outside of the Agriculture sector. The hours of use and CF values for Dormitories are also based on single sources, as provided by Focus Residential Programs. The program may also decide to track lighting use profiles for projects in colleges and dormitories to further strengthen these estimates.

- **Interactive Factor.** The program may want to consider including an Interactive Factor in lighting savings estimates to account for savings resulting from reducing the cooling load on buildings in which lighting projects are completed. We cannot formally recommend including an Interactive Factor in the lighting savings equation at this time for a number of reasons. First, we must know the percentage of buildings that are air conditioned before applying the interactive factor. That data is not currently available. Second, the Interactive Factor is weather dependent, so primary metered sources for Interactive Factor would have to be adjusted for Wisconsin's climate. Finally, only one primary source is available for Interactive Factor, so the current research does not provide strong support for the values that should be used. Since including an interactive factor may yield a more accurate savings estimate, we recommend further research into this matter.

- **T8 Replacing T12 Fluorescents.** The parameter estimates for the 8-foot T12 replacement measures are straightforward and accurately obtained but improvements can always be made. One way to increase confidence in the old and new wattage estimates is to better track both the ballast factors of the installed fixtures and a basic description of what was removed in WISeerts. Ballast factors are normally available on invoices and/or cut sheets, but removed fixtures are not often described. This would allow a larger sample of installed projects to be reviewed, and would provide direct data on which to base energy savings estimates.

- **High Bay Fluorescent Installations.** The parameter estimates for the high bay fluorescent installations are straightforward and accurately obtained but improvements can always be made. One way to increase confidence in the old and new wattage estimates is to better track in WISeerts data for installed fixtures (fixture

[4] Hours of use for CFLs in the Agriculture sector are calculated by a different method and are discussed below.

type, number of lamps, and ballast factor) and a basic description of what was removed. Ballast factors are normally available on invoices and/or cut sheets, but removed fixtures are not often described. This would allow a larger sample of installed projects to be reviewed, and would provide direct data on which to base energy savings estimates.

The current and proposed calculation for this measure assumes that the operating hours of the fixtures remain constant before and after the fluorescent fixture installation. This is likely not the case, as HID lights require an extensive warm-up period which often causes operators to turn the lights on early in the operating period and only turn them off when they are guaranteed to no longer be needed. Fluorescent lights can be turned on and off at will and are more likely to be operated only when necessary. We were unable to find any sources that specifically addressed this issue. Therefore, we recommend that a pre- and post- installation metering study be conducted to improve the estimates for hours of use and coincidence factor for high bay applications.

- **High Bay Fluorescent Occupancy Sensors.** One way to increase confidence in the estimate of the fixture wattage controlled is to record data for the fixture (number of lamps, fixture type, and ballast factor) in WISeerts as part of the occupancy sensor measure. This data is not currently available, as invoices do not often indicate which fixtures are controlled by which occupancy sensors.

  Due to the lack of significant study data available in the industry, values for percent off, hours of use, and coincidence factor could be improved through a metering study of customer installations. This would be a simple study to execute and should include metering data from high bay fluorescent fixtures that are controlled by occupancy sensors as well as those that are not.

- **CFLs.** The wattage estimates for all building uses and the hours of use for the Agricultural building use are based on data from surveys with Focus on Energy participants. This is a telephone survey that collects customer-reported data. While it has been suggested in a number of studies that customers do not consistently over or under-report wattages or hours of use, the estimates that they provide are not necessarily accurate. One way to improve the wattage estimate is to collect this data on the application and to record it in the tracking database. This would allow for a very large sample and more accurate data. For the hours of use and coincidence factor estimates, the quality of the data could be improved by conducting a metering study of the various types of CFLs in the non-residential sector. The study results would increase the accuracy of the parameter estimates using the building type definition, and provide CFL-specific data for the non-Agriculture building types. The study should meter pre- and post- installation operating hours and coincidence factor.

- **Ag Ventilation Fans.** There are many relevant agricultural ventilation fan sources to inform the deemed savings. However, there were also several assumptions that were made with limited information.

  While the estimates for annual runtime hours are probably conservative, future research could improve accuracy. The research could involve collecting detailed information from participating Ag ventilation projects or fielding a metering study of fan operating run times.

  The accuracy of the transition rate from smaller to larger fans is difficult to gauge. Future research should be conducted on the proportion of projects that include a size transition and how it compares to the market as a whole.

  Poorly maintained fans will get soiled and their effectiveness will be reduced. With limited market data, it is difficult to assess the potential impacts that soiling and poor maintenance will have. Further research should address this issue.

- **Leaking Steam Traps.** The sources described in the review are based on theoretical estimates of leakage rates, assumed operating hours, and expert opinions on market prevalence of steam system pressures and trap types and sizes. We were unable to find empirical research demonstrating savings due to steam trap repairs in an HVAC system. A study that examined the actual realized savings throughout the state of Wisconsin would provide a more accurate statement of expected savings.

- **Boiler Tune-Up.** Two of the sources described in the review are based on empirical research to determine actual savings due to boiler tune-ups. These studies were not performed in a climate identical to Wisconsin's and actual savings in Wisconsin could vary somewhat. However, we do not believe that any improvements in accuracy would be substantial. The climate in one study was warmer than Wisconsin's while the climate for the other study was colder. Regardless, performing research in Wisconsin on boiler combustion efficiency may provide improved accuracy since the types and efficiencies of boilers in the population could differ from the two empirical studies.

- **Boiler Controls.** The sources described in the review are based on unsupported assumptions for operating hours and boiler load factors. We believe these assumptions are conservative but they should be confirmed through a study of participants. A study of this type would provide additional data for both linkageless control and oxygen trim control savings estimates. The study would try to determine the percentage of boilers in Wisconsin that are dedicated to HVAC loads, the percentage of boilers in Wisconsin that are dedicated to process loads, and the percentage of boilers in Wisconsin that provide heat to both HVAC and process loads. The study would also look at the annual operating hours and load factors associated with each group. In addition, the study could attempt to directly calculate savings attributed to linkageless controls based on a billing analysis.

2. INTRODUCTION

This report represents one of two deliverables associated with the Deemed Savings Parameter Development task outlined in the Business Programs Detailed Evaluation Plan[5] (DEP) for calendar year 2009. The second deliverable is a Deemed Savings Manual that provides an overview of the calculations and assumptions for every deemed savings measure. The manual will be submitted for Public Service Commission of Wisconsin (PSCW) and Focus comment following the Commission's approval of the deemed savings values. The DEP includes another deemed savings task that consists of a typical deemed savings review with new deemed savings measure proposals. The other deemed savings review will be affected by this report but is not considered in the course of this analysis.

The Focus on Energy program has transitioned from prescriptive energy savings estimates that are evaluated post-installation to deemed energy savings estimates that are evaluated pre-installation for a significant portion of program energy savings. The new deemed savings measures and initial estimates are proposed by the program, reviewed by the evaluation team, and finalized through joint consensus. This is the same deemed savings process that KEMA and Focus have been participating in for several years. The resulting estimates do not receive a gross savings adjustment on a per-unit basis; only the non-deemed portion of the savings calculation is reviewed during the impact evaluation. Determining the correct savings estimate for deemed measures is crucial to determining the accuracy of the overall program savings estimate.

In the standard deemed savings process, measures are evaluated on a nearly equal basis; that is, the current review process does not formally prioritize measures based on their expected contribution to program savings or high participation levels. The evaluation team reviews all proposals provided by the program. Going forward, the evaluation team could prioritize measures and give them greater attention if the program indicates which measures are expected to account for larger fractions of savings in the future. When prescriptive measures were evaluated post-installation, the measures that contributed more to program savings were selected at a greater rate than others, resulting in more evaluation dollars being spent to address energy savings estimates where they mattered most. Now that deemed measures are evaluated pre-installation, the contribution to program savings is no longer a factor in the allocation of the limited evaluation budget.

2.1 OVERVIEW OF APPROACH

KEMA performed a review of the WISeerts database to find the deemed savings measures that contribute the most toward program and sector energy savings. We examined the list and identified the measures that would benefit from additional or updated reviews. We also identified a few parameters that are used for a number of deemed measures and had limited source information. We then performed a comprehensive review of each measure and parameter that included a review of the calculation method, a literature review, conversations with manufacturers and service providers, and application of general engineering practice. In

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[5] Miriam Goldberg, J. Ryan Barry, and Tammy Kuiken, KEMA, Inc. *State of Wisconsin Public Service Commission of Wisconsin, Focus on Energy Evaluation Calendar Year 2009 Detailed Evaluation Plan: Business Programs.* April 16, 2009.

this report, we recommend changes to the deemed savings values or parameters based on our review.

2.2 OVERVIEW OF REPORT

The next section provides a detailed overview of the measure selection process. Section 4 contains a summary of each measure or parameter review with corresponding recommendations. Section 5 summarizes the recommendations from each review in Section 4. We also encourage you to review the five Excel spreadsheets[6] that were released in conjunction with this report.

[6] (1) “DSPD CY09 Deeming Boiler Controls”
(2) “DSPD CY09 Deeming HVAC Barn Ventilation Fans”
(3) “DSPD CY09 Deeming HVAC Boiler Service Buydown”
(4) “DSPD CY09 Deeming HVAC Steam Traps”
(5) “DSPD CY09 Deeming Lighting Measures”

3. MEASURE AND PARAMETER SELECTION

This section outlines the process used to select measures and parameters for the deemed savings parameter development review. It also reports on the measures that were selected.

The first step in the process was to determine which measures or parameters to review. This was done with input from the Focus on Energy program staff. KEMA conducted a WISeerts database analysis, identified measures to review, and presented a list of recommended measures and parameters to the program in a June 5, 2009, memo. The program provided comments and feedback on the proposed list and it was approved by the PSCW.

According to the DEP, the following may be evaluated under the DSPD task:

- Measures that contribute the most to overall program energy savings
- Measures that are installed in large quantities
- Measures that were deemed early in the process and may benefit from recently released secondary source data
- Popular measures (those with high numbers of installed units) for which savings are not easily quantified
- Parameters that are used in a variety of measure calculations and therefore have a significant effect on the energy savings estimates for a number of measures or technologies.

The most important of these criteria is the contribution to program savings. The greatest improvement in overall program savings accuracy can be achieved more cost-effectively by addressing the measures that contribute most to those savings. Therefore, KEMA began our analysis by determining energy savings by measure. We then examined measure count and the other selection criteria to determine whether these criteria would suggest other measures to include.

Our analysis was based on the WISeerts database as downloaded on May 4, 2009, and included all measures entered to that date. We asked the program to identify measures that would make a significant contribution to program savings going forward. The program felt that the historical analysis was sufficient and did not suggest any additional measures. Therefore, our recommendations were based solely on program history, not upon any forecast of future program activity or savings.

3.1 MEASURE SAVINGS

To calculate savings by measure, we limited the WISeerts data set by removing custom and hybrid measures, leaving only the prescriptive measures. Among the prescriptive measures are some that are currently deemed but were not deemed at some point in the database period. Those measures were entered under a different Tech Code. We wanted a complete picture of the savings associated with the technology, not just the savings that occurred since the measures became deemed. Therefore, we did not limit the data set by removing the Tech Codes associated with the non-deemed life of the measure; instead, we combined the energy savings from the non-deemed portion of the database with the deemed portion.

Using this data set, overall kWh and therm savings were calculated by Tech Code and ranked accordingly. The results are reported in Table 3-1 and Table 3-2.The top twenty measures are reported for kWh. For therms, the savings associated with each measure decreased quickly after the first few measures, so only the top ten are reported.

Table 3-1. Measures with Greatest kWh Savings

Rank	Tech Code	Measure Description	Savings (kWh)
1	2.5181	T8 6 lamp or T5HO 4 lamp Replacing 400-999 Watts HID - INCLUDES $30 BONUS	74,964,518
2	2.5180	T8 6 lamp or T5HO 4 lamp Replacing 400-999 Watts HID	59,182,561
3	2.0300	CFL <= 30 Watts - Replaces Incandescent	34,963,759
4	2.5182	T8 8 lamp or T5HO 6 lamp Replacing 400-999 Watts HID	8,647,940
5	2.5185	T8 or T5HO <= 500W, Replacing >=1000 W HID	8,111,800
6	2.0811	T8 4L-4ft High Performance Replacing T12HO/VHO 2L-8 ft	7,622,894
7	2.5191	Occupancy Sensors or Multi-level Switching - Add to a retrofit project where high bay fluorescent replaces HID (Old Form Only)	6,547,842
8	2.0307	CFL Reflector Flood Lamps - Replaces incandescent reflector flood lamps (installed before May 1, 2008)	5,973,514
9	2.5170	T8 4 lamp or T5HO 2 lamp Replacing 250-399 Watts HID	4,786,844
10	2.0301	CFL High Wattage 31-115 Watts - Replaces Incandescent	3,409,535
11	4.1810	Air Cooled Chiller System Tune Up - Service Buydown, System <= 500 tons (expired May 1, 2008)	3,318,816
12	2.5183	T8 8 lamp or T5HO 6 lamp Replacing 400-999 Watts HID - INCLUDES $20 BONUS	3,266,862
13	2.5192	Occupancy sensor for high bay fluorescent fixtures, per fixture controlled	2,904,325
14	3.1410	ECM (electronically commutated) motor replacing shaded-pole motor in refrig/freezer case	2,872,008
15	4.1813	Water Cooled Chiller System Tune Up - Service Buydown, System > 500 tons (expired May 1, 2008)	2,870,760
16	4.0752	Ventilation Fans, High Efficiency - 52" (installed before May 1, 2008)	2,832,435
17	4.5000	Guest Room Energy Management Controls - Electric heat PTAC Systems Only (installed before May 1 2008)	2,472,987
18	3.1199	Anti-sweat heater controls, on freezer case with standard door	2,348,400
19	2.0507	Occupancy Sensors - Ceiling Mount <= 500 Watts	2,139,942
20	3.1200	Cooler Door Anti-Sweat Heater Controls (Prescriptive) (installed before May 1, 2008)	1,866,005

Table 3-2. Measures with Greatest Therm Savings

Rank	Tech Code	Measure Description	Savings (therms)
1	1.1301	Boiler Tune-up - Service Buy Down - COUPON	3,264,914
2	1.1300	Boiler Tune-up - Service Buy Down (service performed before May 1, 2008)	2,597,327
3	4.1000	Repair leaking steam trap, building space conditioning system	1,357,511
4	1.1400	Steam Trap - Service Buy Down (expired May 1 2008)	301,093
5	1.0711	Linkageless Boiler Control, per output hp	156,851
6	1.0710	Boiler oxygen trim controls, per output hp	71,688
7	1.1408	Repair leaking steam trap, 50-125 psig steam - PROMOTION (Industrial Only)	37,800
8	1.2791	Boiler, hot water, high efficiency modulating, for space heating (AFUE >= 90%)(175 - 300 MBh input)	32,927
9	4.0410	Infrared Heating Units, High or Low Intensity - Existing Building	28,834
10	1.1416	Repair leaking steam trap, 126-225 psig steam (Industrial Only)	27,100

Many of the measures in Table 3-1 and Table 3-2 are similar to other measures either within or outside of these top groups. Measures that use the same calculation method or assumptions can be grouped into a single “measure bin” and be reviewed concurrently without adding very much cost to the task. So, like measures were combined into measure bins, savings were calculated for each bin, and the measure bins were re-ranked accordingly.

For kWh savings, the resulting ten measure bins contain the 37 measures with the most savings.

Table 3-3. Measure Bin kWh Savings

Measure Group Description	Tech Code	Measure Description	Measure Savings	Measure Bin Savings	Percent of Program Savings
T8 or T5HO replacing HID	2.5181	T8 6 lamp or T5HO 4 lamp Replacing 400-999 Watts HID - INCLUDES $30 BONUS	74,964,518	159,901,810	33%
	2.5180	T8 6 lamp or T5HO 4 lamp Replacing 400-999 Watts HID	59,182,561		
	2.5182	T8 8 lamp or T5HO 6 lamp Replacing 400-999 Watts HID	8,647,940		
	2.5185	T8 or T5HO <= 500W, Replacing >=1000 W HID	8,111,800		
	2.5170	T8 4 lamp or T5HO 2 lamp Replacing 250-399 Watts HID	4,786,844		
	2.5183	T8 8 lamp or T5HO 6 lamp Replacing 400-999 Watts HID - INCLUDES $20 BONUS	3,266,862		
	2.5186	T8 or T5HO <= 800W, Replacing >=1000 W HID	941,285		
CFL < 30W replacing incandescent	2.0300	CFL <= 30 Watts - Replaces Incandescent	34,963,759	34,963,759	7%
T8 replacing T12	2.0811	T8 4L-4ft High Performance Replacing T12HO/VHO 2L-8 ft	7,622,894	10,110,357	2%
	2.0810	T8 4L-4ft High Performance - Replaces T12 2L-8ft	491,569		
	2.0812	T8 2L-4ft High Performance HBF Replacing T12HO 1L-8 ft	819,284		
	2.0813	T8 2L-4ft High Performance Tandem Replacing T12HO/VHO 2L-8 ft	12,978		
	2.1062	BOUNTY - T8 1L replacing T12	478,469		
	2.1063	BOUNTY - T8 2L replacing T12	264,209		
	2.1064	BOUNTY - T8 3L replacing T12	128,830		
	2.1065	BOUNTY - T8 4L replacing T12 4ft	292,124		
Lighting Controls on High Bay Fluorescents	2.5191	Occupancy Sensors or Multi-level Switching - Add to a retrofit proj. where high bay fluorescent replaces HID (Old Form Only)	6,547,842	9,452,167	2%
	2.5192	Occupancy sensor for high bay fluorescent fixtures, per fixture controlled	2,904,325		

Measure Group Description	Tech Code	Measure Description	Measure Savings	Measure Bin Savings	Percent of Program Savings
Chiller Tune Ups	4.1810	Chiller System Tune Up, Air Cooled - Service buydown, System <=500 tons	3,318,816	8,072,466	2%
	4.1813	Chiller System Tune Up, Water Cooled - service buydown, System >500 Tons (Old Form Only)	2,870,760		
	4.1811	Chiller System Tune Up, Air Cooled - Service buydown, System >500 tons (Old Form Only)	967,500		
	4.1812	Chiller System Tune Up, Water Cooled - service buydown, System <=500 tons	915,390		
CFL Floods	2.0307	CFL Reflector Flood Lamps - Replaces incandescent reflector flood lamps (installed before May 1 2008)	5,973,514	5,973,514	1%
HE Ventilation Fans	4.0752	Ventilation Fans, High Efficiency - 52" (installed before May 1 2008)	2,832,435	5,111,852	1%
	4.0736	Ventilation Fans, High Efficiency - 36" (installed before May 1 2008)	123,801		
	4.0748	Ventilation Fans, High Efficiency - 48" (installed before May 1 2008)	622,440		
	4.0750	Ventilation Fans, High Efficiency - 50" (installed before May 1 2008)	953,778		
	4.0754	Ventilation Fans, High Efficiency - 54" (installed before May 1 2008)	533,444		
	4.0755	Ventilation Fans, High Efficiency - 55" (Ag Only)	20,424		
	4.0772	Ventilation Fans, High Efficiency - 72" (Ag Only)	25,530		
Anti-sweat heater controls	3.1199	Anti-sweat heater controls, on freezer case with standard door	2,348,400	4,465,957	1%
	3.1200	Anti-sweat heater controls, on refrigerated case with standard door	1,866,005		
	3.1197	Anti-sweat heater controls, on freezer case with low-heat door	224,667		
	3.1198	Anti-sweat heater controls, on freezer case with no-heat door	1,725		
	3.1201	Anti-sweat heater controls, on refrigerated case with low-heat or no-heat doors	25,160		
High Wattage CFL replacing incandescent	2.0301	CFL High Wattage 31-115 Watts - Replaces Incandescent	3,409,535	3,409,535	1%
ECM replacing shaded pole in refrigerated case	3.1410	ECM (electronically commutated) motor replacing shaded-pole motor in refrig/freezer case	2,872,008	2,872,008	1%

Some non-deemed prescriptive measures appear in the above list because all of the prescriptive tech codes were included in the analysis, not just deemed codes. Non-deemed measures were not ultimately recommended for review.

Therm Savings. For therm savings, the resulting six measure bins represent the 13 measures with the most savings.

Table 3-4. Measure Bin Therm Savings

Measure Bin Description	Tech Code	Measure Description	Measure Savings (therm)	Measure Bin Savings	Percent of Program Savings
Boiler Tune-ups	1.1301	Boiler Tune-up - Service Buy Down - COUPON	3,264,914	5,862,242	26%
	1.1300	Boiler Tune-up - Service Buy Down (service performed before May 1, 2008)	2,597,327		
Steam Traps, Low Pressure, HVAC	4.1000	Repair leaking steam trap, building space conditioning system	1,357,511	1,658,604	7%
	1.1400	Steam Trap - Service Buy Down (expired May 1 2008)	301,093		
Boiler Controls	1.0711	Linkageless Boiler Control, per output hp	156,851	228,538	1%
	1.0710	Boiler oxygen trim controls, per output hp	71,688		
Steam Traps, Industrial	1.1408	Repair leaking steam trap, 50-125 psig steam - PROMOTION (Industrial Only)	37,800	87,068	0.4%
	1.1409	Repair leaking steam trap, 126-225 psig steam - PROMOTION (Industrial Only)	1,084		
	1.1412	Repair leaking steam trap, <50 psig steam (Industrial Only)	18,816		
	1.1414	Repair leaking steam trap, 50-125 psig steam (Industrial Only)	2,268		
	1.1416	Repair leaking steam trap, 126-225 psig steam (Industrial Only)	27,100		
Infrared Heaters	4.0410	Infrared Heating Units, High or Low Intensity - Existing Building	28,834	45,800	0.2%
	4.041	Infrared Heating Units, High or Low Intensity - New Construction	16,966		
Boilers, HE Modulating	1.2791	Boiler, hot water, high efficiency modulating, for space heating (AFUE >= 90%)(175 - 300 MBh input)	32,927	41,747	0.2%
	1.2790	Boiler, hot water, high efficiency modulating, for space heating (AFUE >= 90%)(<175 MBh input)	8,820		

The next step in measure selection was to limit the above lists to ensure that each reviewed measure received adequate attention. We examined criteria other than measure group savings to see if that analysis would inform our decision about which of the above measures to eliminate from consideration.

3.2 SAVINGS BY SECTOR

Using only the overall program savings analysis, it would have been possible to exclude measures that are very important to a particular sector that do not rank in the top tier in overall program savings. To see if this were the case, measure savings were broken out and analyzed by sector.

We found only one measure that appeared in the top five in savings (by kWh or therms) for a particular sector that did not appear in the overall savings analysis. That measure is the Energy Efficient Livestock Waterer measure in the Agriculture sector. The measure accounted for 1,744,500 kWh, or 4 percent of Agriculture sector savings. We did not recommend this measure to be included in the measure reviews based on the fact that the measure is prescriptive but not deemed and it has relatively low savings compared to other measures in the program.

3.3 OTHER CONSIDERATIONS

3.3.1 Measure count

If a measure with high unit count contained a relatively small error in its savings estimate, the overall error could quickly propagate and significantly affect overall savings. Therefore, measures were ranked according to the total number of units installed to see if there were measures with high unit count that do not appear in the analysis by measure savings. Table 3-5 shows the measures with the greatest number of units installed.

Table 3-5. Measures with Greatest Number of Installed Units

Rank	Tech Code	Measure Description
1	2.0300	CFL <= 30 Watts - Replaces Incandescent
2	2.5181	T8 6 lamp or T5HO 4 lamp Replacing 400-999 Watts HID - INCLUDES $30 BONUS
3	2.0852	T8 Low Watt Relamp - 28 Watts
4	2.5180	T8 6 lamp or T5HO 4 lamp Replacing 400-999 Watts HID
5	2.0851	T8 Low Watt Relamp - 25 Watts
6	2.0307	CFL Reflector Flood Lamps - Replaces incandescent reflector flood lamps (installed before May 1 2008)
7	2.0870	T8 2L-4 ft Hi Lumen Lamp with Low BF
8	2.1062	BOUNTY - T8 1L replacing T12
9	2.0811	T8 4L-4ft High Performance Replacing T12HO/VHO 2L-8 ft
10	2.5191	Occupancy Sensors or Multi-level Switching - Add to a retrofit proj. where high bay fluorescent replaces HID (Old Form Only)

Two measures in this list of ten do not appear in the measure lists based on savings. These are “T8 Low Watt Relamp – 25 W,” ranked third in count, and “T8 2L-4ft Hi Lumen Lamp with Low BF, ranked seventh in count. Savings were calculated for these measures, and they were found to rank twenty-third and twenty-second in overall savings.

We then combined these measures into measure bins with like measures and determined the bin energy savings. The measure bins were found to have savings that would have placed them near the bottom of the savings list in Table 3-3; therefore, they were not recommended for inclusion in the review.

3.3.2 Measures deemed early in the process

Several measures that were deemed early in the deemed savings process were found to already appear on the existing lists based on measure savings, including low wattage CFLs. We reviewed other measures that were deemed early in the deeming process, including commercial and ENERGY STAR refrigeration among others. These measures ranked low in overall savings, and therefore did not provide additional candidates for review.

3.3.3 Popular measures that are not easily quantified

Several measures installed in high number for which savings are not easily quantified were also found on the existing lists based on measure savings, including steam traps and boiler controls. A review of other measures that are popular and not easily quantified did not provide additional candidates for review.

3.3.4 Parameters that are used in a variety of measure calculations

Certain parameters apply to multiple technologies and thereby significantly affect program savings. Factors that determine how important a parameter is to program savings estimates include how many measures the parameter applies to, how significant the overall savings of those measures is, and how much uncertainty there is regarding the parameter value or values. We determined that the parameters with the most significant affect on savings estimates are lighting operating hours and lighting coincidence factor.

Lighting kWh savings use a simple calculation based on the difference in wattage between the baseline and installed equipment and the lighting operating hours. Lighting kW savings use the same difference in wattage and a coincidence factor. Since lighting wattage estimates are well documented and consistent, lighting operating hours and lighting coincidence factor are the major sources of uncertainty for lighting savings calculations.

These parameters also apply to many of the high-savings measure bins. Six of the top ten kWh saving measure bins contain lighting measures, accounting for 45 percent of program savings. Lighting operating hours and coincidence factors are assumed to be constant across most lighting measures within each sector, so reviewing these assumptions will affect many of the per-unit lighting measure savings. Therefore, we recommended that lighting hours and coincidence factors be evaluated by sector to improve the accuracy of the lighting savings estimates.

3.4 RECOMMENDED MEASURES FOR REVIEW

Based on the above analysis, KEMA recommended nine measure bins and two parameters for review. The recommendations were based primarily on the measure bin savings presented in Table 3-3 and Table 3-4. The measure bins with the greatest savings were chosen, with the following adjustments:

- Lighting hours and coincidence factor by sector were included for review.
- The top five kWh measure bins were selected, excluding Chiller Tune-ups which are not deemed.
- The top three therm measure bins were selected.
- Any measures that are not currently deemed were removed from the measure bins.
- Ventilation fan measures that did not appear in the analysis because they have had no associated savings were added to that measure bin.

The measure bins and parameters recommended for evaluation are presented in Table 3-6. This list was approved by the PSCW.

Table 3-6. Parameters and Measure Bins Recommended for Review

Measure Bin Description	Tech Code	Measure Description
Lighting Hours	N/A	Lighting hours assumptions for all sectors
Lighting Coincidence Factors	N/A	Lighting coincidence factor assumptions for all sectors
T8 or T5HO replacing HID	2.5170	T8 4 lamp or T5HO 2 lamp Replacing 250-399 Watts HID
	2.5180	T8 6 lamp or T5HO 4 lamp Replacing 400-999 Watts HID
	2.5182	T8 8 lamp or T5HO 6 lamp Replacing 400-999 Watts HID
	2.5185	T8 or T5HO <= 500W, Replacing >=1000 W HID
	2.5186	T8 or T5HO <= 800W, Replacing >=1000 W HID
CFL < 30W replacing incandescent	2.0300	CFL <= 30 Watts - Replaces Incandescent
Occupancy Sensors on High Bay Fluorescents	2.5192	Occupancy sensor for high bay fluorescent fixtures, per fixture controlled
T8 replacing T12	2.0810	T8 4L-4ft High Performance - Replaces T12 2L-8ft
	2.0811	T8 4L-4ft High Performance Replacing T12HO/VHO 2L-8 ft
CFL Floods	2.0307	CFL Reflector Flood Lamps - Replaces incandescent reflector flood lamps
HE Ventilation Fans	4.0736	Ventilation Fans, High Efficiency - 36"
	4.0742	Ventilation Fans, High Efficiency - 42"
	4.0748	Ventilation Fans, High Efficiency - 48"
	4.0750	Ventilation Fans, High Efficiency - 50"
	4.0751	Ventilation Fans, High Efficiency - 51"
	4.0752	Ventilation Fans, High Efficiency - 52"
	4.0754	Ventilation Fans, High Efficiency - 54"
	4.0755	Ventilation Fans, High Efficiency - 55"
	4.0760	Ventilation Fans, High Efficiency - 60"
Boiler Tune-ups	1.1300	Boiler Tune-up - Service Buy Down
Steam Traps, Low Pressure HVAC	4.1000	Repair leaking steam trap, building space conditioning system
Boiler Controls	1.0710	Boiler oxygen trim controls, per output hp
	1.0711	Linkageless Boiler Control, per output hp

Note that in this analysis, Boiler Controls is listed as one measure bin, populated by Boiler Oxygen Trim Controls and Linkageless Boiler Controls. In this report, these technologies are reviewed as separate measures rather than as a group. Conversely, low watt CFLs and CFL Floods are separate in our analysis above, but are evaluated together in the report.

In case the budget had allowed for review of additional measures, KEMA presented a list of secondary measures for review, and asked the program to prioritize that list. The program did so, with Industrial (high-pressure) Steam Traps, High Wattage CFLs, and T8 Relamp appearing at the top of the list. The budget did not allow for review of these measures but the list may be valuable when considering future reviews. The measures groups presented in Table 3-6 are reviewed in Section 4 of this report.

4. REVIEWS

This section contains the literature review and recommendations for the technologies chosen in Section 3 and listed in Table 3-6 on the previous page. The lighting measures are addressed first, followed by the Agriculture sector ventilation fans and the natural gas measures.

Each technology review contains the following four sub-sections:

- **Introduction.** The first sub-section is an introduction to the measure which includes a group, category, and technical definition, a list of qualifying equipment, the date the measure was last deemed/reviewed, and the name of the KEMA employee that conducted this review. The existing deemed savings values and an explanation of how energy is saved are also included in the introduction.
- **Current Savings Methodology.** The second sub-section outlines the current deemed savings methodology and the parameter assumptions that feed into the calculation. The savings calculation is listed and the variable names are identified along with the current parameter assumptions. The calculation is followed by a more complete definition of each variable. The last part identifies the source material and thought process that went into determining the current deemed savings values and assumptions.
- **Literature Review.** The third sub-section summarizes the sources that KEMA found during our literature review for each technology. This section only includes the sources that were used in developing the new proposal. Each source is identified and explained and the pertinent information is listed.
- **Proposed Savings Methodology.** The fourth sub-section outlines KEMA's proposed deemed savings values. Each variable in the calculation equation is addressed and the source material from the literature review is analyzed and used to create new measure assumptions. The new assumptions are assembled into a section that is essentially a repeat of the current savings methodology but uses the proposed assumptions and, if applicable, calculation methods. The proposed deemed savings are listed at the end of the section.

We have also assembled five calculation spreadsheets that were used to determine the proposed deemed savings.[7] The spreadsheets will be distributed with this report.

[7] (1) "DSPD CY09 Deeming Boiler Controls"
(2) "DSPD CY09 Deeming HVAC Barn Ventilation Fans"
(3) "DSPD CY09 Deeming HVAC Boiler Service Buydown"
(4) "DSPD CY09 Deeming HVAC Steam Traps"
(5) "DSPD CY09 Deeming Lighting Measures"

4.1 LIGHTING HOURS OF USE AND COINCIDENCE FACTORS

Group: Lighting

Category: N/A

Technology Description: Lighting hours of use and coincidence factor (CF) values for all lighting measures.[8]

Qualifying Equipment: N/A

Date Deeming Last Modified: Pre-2006 (exact date unclear)

Summarized by: Jeremiah Robinson

4.1.1 Existing deemed savings basis and estimates

Lighting hours of use and coincidence factor are not, in and of themselves, an energy savings measure. However, they are parameters which are used to calculate deemed savings for all lighting measures except low-wattage CFLs. Each sector has its own value for hours of use and coincidence factor.

A. DEFINITIONS AND EXISTING VALUES

Hours of Use, Hours. Hours of Use refers to the average annual operating hours of the light fixture and is measured in hours/year. The current values are shown in Table 4-1.

Coincidence Factor, CF. Coincidence Factor refers to the average percentage of total system wattage that is operating during the peak period and is measured in percent. The peak period is defined as 1 pm to 4 pm, Monday through Friday, June through August. The values are shown in Table 4-1.

Table 4-1. Existing Deemed Lighting Operating Hours and Coincidence Factors

Sector	Hours	CF
Agriculture	4,368	90%
Commercial	3,680	90%
Industrial	4,576	90%
Schools & Government	3,230	71%

[8] The recommended hours of use value for CFLs in the Agriculture Sector is not covered in this section of the report; that value is developed in Section 4.5.

B. DISCUSSION OF EXISTING VALUES

i. Hours of Use

The existing values for hours of use have been used in prescriptive and deemed estimates for a number of years. The origin of the existing hours of use is unknown and no source can be found either by personnel at Focus on Energy or in documentation maintained by KEMA.

The logic behind the hours for use for each sector is as follows:

- Agriculture sector hours are based on 12 hours per day, 7 days per week (4,368 hr/yr)
- Commercial sector hours are based on the average of eight different industries per the statewide database. (3,680 hr/yr)
- Industrial sector hours are based on 16 hours per day, 5.5 days per week (4,576 hr/yr)
- Schools and Government sector hours are based on 12 hours per day, 5 days per week, 12 months per year (3,120 hr/yr).

ii. Coincidence Factor

It is not clear when the values currently used for coincidence factor first came to be used. However, the justification for the 90 percent factor used for Agriculture, Commercial, and Industrial was presented in March 2005 in the CFL deemed savings calculations. This report claims that the data was based on a suggestion by the Edison Electric Institute (EEI). We have not been able to track down this source, and the single value of 90 percent across different sectors suggests that it was not a thoroughly researched value.

We could not find the source of the 71 percent value used for the Schools & Government sector. The 2005 CFL deemed savings document suggests a value of 63 percent, which was abandoned at some indeterminate point in time.

4.1.2 Literature review

Here we present the findings of various sources related to lighting hours of use and coincidence factors. Data from the various studies are categorized in many different ways. This data is presented in this review as it was presented in the various sources. In the final recommendations, a weighting scheme will be suggested and used to combine the data and apply it to the Focus on Energy program.

It should be noted that no sources were found for agricultural lighting hours of use or coincidence factor. This will be addressed below in Section 4.1.3a.iv.

A. PG&E 1996 EVALUATION [9]

The *Evaluation of Pacific Gas & Electric Company's 1996 Commercial Energy Efficiency Incentives Program: Lighting Technologies* was performed by Quantum Consulting in 1998. It studied lighting hours and coincidence factors in the California commercial sector, and included a billing analysis of 413,035 sites, 1,270 telephone surveys, and 351 engineering reviews over the course of two years. Though it is an older study, it is included here because it was large and comprehensive. Table 4-2 shows the CF and hours of use values determined by this study.

Table 4-2. PG&E 1996 Hours & CF Values

Building Use	Hours	CF
College/University	3,900	68%
School	2,150	42%
Office	4,000	81%
Retail	4,450	88%
Grocery	5,800	81%
Restaurant	4,600	68%
Health Care/Hospital	4,400	74%
Hotel/Motel	5,500	67%
Warehouse	3,550	84%
Personal Service	4,100	79%
Community Service	2,700	48%
Miscellaneous	4,500	76%

The table shows that the building use with the highest operating hours is grocery stores with 5,800 hours/year. The lowest hours of use belongs to schools, with 2,150 hours/year. It is apparent that coincidence factor does not seem to correspond to hours of use in this study, which is due to the fact that the sectors with the most hours of use may not be the most heavily used in the afternoon summer peak hours. For instance, Restaurants have a 68 percent CF while Retail has an 88 percent CF even though the hours of use for Restaurants is higher than for Retail.

The peak demand period used in the PG&E 1996 Evaluation is defined as 12–6 pm, Monday though Friday, May through October.

B. DEPARTMENT OF ENERGY STUDY [10]

The *U.S. Lighting Market Characterization – Volume 1: National Lighting Inventory and Energy Consumption Estimate* was performed by Navigant Consulting in 2002. It was an attempt at a comprehensive cataloging of installed lighting throughout the U.S, and consisted of telephone surveys of 5,430 commercial and 17,877 industrial buildings. It includes data on

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[9] Quantum Consulting. *Evaluation Of Pacific Gas & Electric Company's 1996 Commercial Energy Efficiency Incentives Program: Lighting Technologies.* March 1, 1998.

[10] Navigant Consulting. *U.S. Lighting Market Characterization – Volume 1: National Lighting Inventory and Energy Consumption Estimate*. September 2002.

the square-footage and installed lighting wattage in the various building types, and hours of use weighted both by building type and lamp type.

Table 4-3 shows the hours of use and sector weighting for commercial buildings and Table 4-4 shows the hours of use and sector weighting for industrial buildings. The column labeled "% Ltg. Usage" in these tables refers to the percentage of total national lighting kWh by building type within the commercial and industrial sectors. So, for example, referring to Table 4-3, offices use 20.6 percent of the total national kWh used by commercial buildings, according to this study.

It should be noted that in this study, "commercial" includes both government and education buildings.

Table 4-3. DOE Study Commercial Hours of Use

Building Use	Hours	% Ltg. Usage
Vacant	3,577	3.9%
Office/ Professional	3,760	20.6%
Laboratory	5,074	1.0%
Warehouse (non-refrigerated)	3,541	11.8%
Food sales	5,256	2.9%
Public order/safety	3,504	1.0%
Health Care (outpatient)	3,395	2.0%
Warehouse (refrigerated)	3,869	1.0%
Religious Worship	1,825	2.0%
Public Assembly	2,665	3.9%
Food Service	4,599	2.9%
Health Care (inpatient)	5,840	4.9%
Skilled Nursing	4,380	1.0%
Hotel/Motel/Dorm	3,687	4.9%
Strip Shopping	4,052	7.8%
Enclosed Retail	5,001	2.9%
Retail (excluding enclosed)	3,723	8.8%
Service (excluding food)	3,431	4.9%
Other	3,723	1.0%
Education	2,774	10.8%

The table shows that Office/Professional is the largest commercial building use with 20.6 percent of total commercial lighting kWh usage. Inpatient Health Care has the highest hours of use with 5,840 hours/year and Religious Worship the lowest with 1,825 hours/year.

Table 4-4. DOE Study Industrial Hours of Use

Building Use	Hours	% Ltg. Usage
Food and Kindred Products	5,913	8.1%
Tobacco Products	5,001	0.0%
Textile Mill Products	4,928	8.1%
Apparel and Other Textile Products	3,687	2.0%
Lumber and Wood Products	5,731	4.0%
Furniture and Fixtures	3,942	3.0%

Building Use	Hours	% Ltg. Usage
Paper and Allied Products	5,913	4.0%
Printing and Publishing	5,329	3.0%
Chemicals and Allied Products	5,293	10.1%
Petroleum and Coal Products	5,293	1.0%
Rubber and Miscellaneous Plastics	5,512	6.1%
Leather and Leather Products	4,417	0.0%
Stone, Clay, and Glass Products	5,402	4.0%
Primary Metal Industries	5,731	6.1%
Fabricated Metal Products	4,125	8.1%
Industrial Machinery and Equipment	5,183	7.1%
Electronic and Other Electric Equipment	4,526	4.0%
Transportation Equipment	6,059	12.1%
Instruments and Related Products	3,650	7.1%
Miscellaneous Manufacturing Industries	2,920	2.0%

The table shows that transportation is the largest industrial building use with 12.1 percent of total industrial lighting kWh usage, and also has the highest hours of use at 6,059 hours/year.

C. NEW ENGLAND SCHOOLS STUDY [11]

The *CT & MA Utilities 2004–2005 Lighting Hours of Use for School Buildings Baseline Study* was performed by RLW Analytics. It was a direct metering study done on school buildings in New England, and involved installing 600 lighting loggers in schools during 2006. This study did not include data from universities or any other building use. Therefore, data from this study will inform only the final recommended values for the Schools & Government sector buildings. Table 4-5 shows the hours of use and CF values for lighting in schools.

[11] RLW Analytics. *CT & MA Utilities 2004-2005 Lighting Hours of Use for School Buildings Baseline Study*. September 7, 2006.

Table 4-5. RLW School Hours of Use Study Values

Space	Hours	CF
Auditorium	1,667	35%
Cafeteria	2,196	32%
Classroom	1,844	16%
Gymnasium	2,076	33%
Hallway	3,129	58%
Kitchen	1,625	16%
Library	2,087	27%
Locker Room	2,198	84%
Mechanical Room	940	28%
Office	2,236	35%
Other	1,826	16%
Restroom	2,380	43%
Storage Closet	800	26%
Teacher Lounge	1,879	21%

The table shows that, in schools, hallways show the highest hours of use with 3,129 hours/year. Locker Rooms show the highest coincidence factor with 84 percent.

The peak demand period for the New England Schools Study is defined as 3–5 pm, Monday through Friday, June through September.

D. NEW ENGLAND COINCIDENCE FACTOR STUDY [12]

The *New England Coincidence Factor Study* was performed by RLW Analytics. It was a direct metering study that involved the installation of 1,415 meters throughout New England on buildings in 10 different building use categories. Table 4-6 shows the coincidence factor results of this study.

Table 4-6. RLW Coincidence Factor Study Values

Building Use	CF
Grocery	95%
Manufacturing	73%
Medical (Hospital)	77%
Office	75%
Other	54%
Restaurant	81%
Retail	82%
University/College	68%
Warehouse	78%
School	63%

[12] RLW Analytics. *Coincidence Factor Study - Residential and Commercial Industrial Lighting Measures*. Spring 2007.

Here we see that grocery stores have the highest coincidence factor with 95 percent and schools the second-lowest coincidence factor at 63 percent. There is also a catchall building use for "Other" with a low CF value.

The peak demand period for the New England Coincidence Factor study is defined as 1–5 pm, Monday through Friday, June through August.

E. PG&E RIGHTLIGHTS PROGRAM EVALUATION[13]

The *Evaluation of the 2004–2005 RightLights Program* is an impact evaluation done of a California program by Quantec in 2006. The RightLights program is a commercial and industrial lighting rebate program. The impact evaluation included telephone surveys with 100 program participants and 75 non-participants supplemented by 136 site visits for measure verification, a participant billing analysis, and the installation of 184 meters at 60 participant sites. Table 4-7 shows a summary of metered hours of use determined through this impact evaluation.

Table 4-7. PG&E RightLights Program 2004–2005 Evaluation Values

Building Use	Hours
Process Industrial	3,547
Grocery	4,636
Office	2,558
Restaurant	4,278
Retail	1,621

Here we see that Grocery has the highest hours of use with 4,636 hours/year and Retail the lowest with 1,621 hours/year.

F. SDG&E TIME OF USE STUDY[14]

The *SDG&E 2004-05 Express Efficiency Lighting Program Time of Use Study* is a metering study done by RLW Analytics in 2007. It included the installation of 431 meters on fluorescent and metal halide fixtures at 122 customer sites in southern California[15]. Table 4-8 shows a summary of the results of this study.

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[13] Quantec. *Evaluation of the 2004–2005 RightLights Program*. April 21, 2006.

[14] RLW Analytics. *SDG&E 2004–05 Express Efficiency Lighting Program Time of Use Study.* February 15, 2007.

[15] The report also included 281 meters installed on CFLs. The fluorescent and metal halide values are presented here, since the lighting hours and coincidence factors in question do not currently apply to CFL measures.

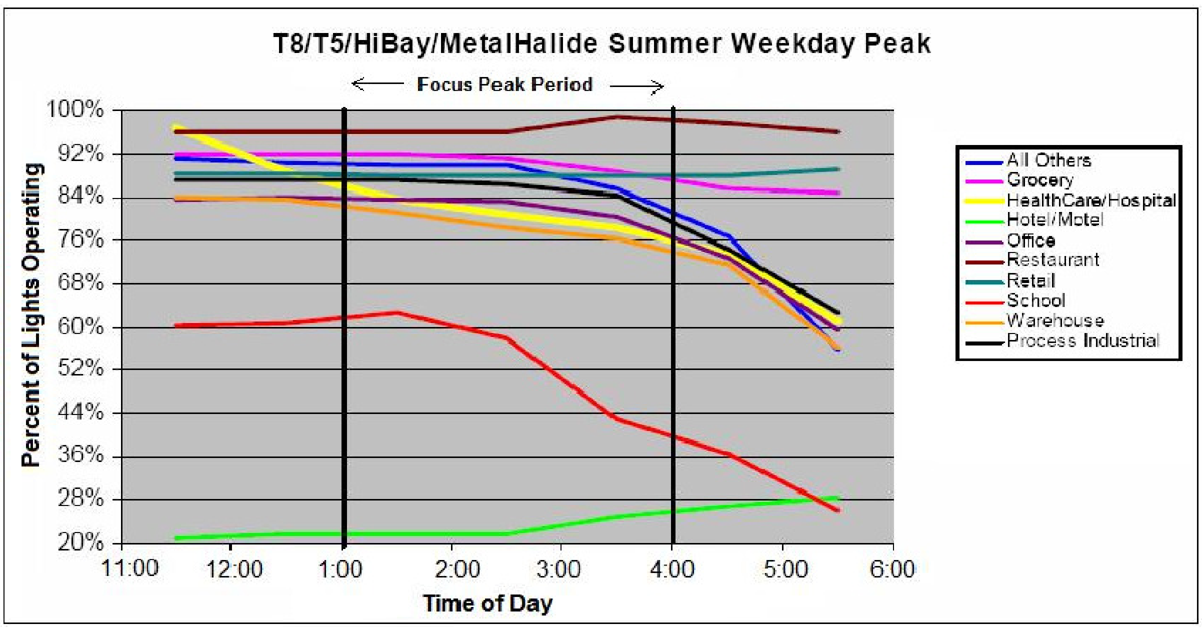
Table 4-8. SDG&E 2004–2005 Hours of Use

Building Use	Hours	CF
Grocery	6,390	90%
Health Care	2,689	82%
Hotel	2,307	23%
Office	3,792	78%
Process	5,512	85%
Restaurant	4,450	96%
Retail	5,435	88%
School	1,795	53%
Warehouse	3,211	79%
Others	3,667	88%

The table shows that grocery stores have the highest hours of use at 6,390 hours/year and schools the lowest with 1,795 hours/year.

Coincidence factors were reported for the peak demand period of 11–6 pm, Monday through Friday, May through September. However, they were also reported graphically by time of day as shown in Figure 4-1. This allowed the values for the Focus peak hours of 1 to 4 pm to be read from the graph and averaged to yield the values reported in Table 4-8. Therefore, the coincident factor values in Table 4-8 represent a peak period of 1–4 pm, Monday through Friday, May through September.

Figure 4-1. SDG&E 2004–2005 Peak Demand Period Graph



G. SDG&E HOURS OF OPERATION STUDY [16]

The *Small Business Super Saver Program Hours of Operation Study* was a metering study done by KEMA Services, Inc. in 2006. It was similar to the study above, except in that it did not look at coincidence factor and included other technologies. The study involved installing 150 meters at 60 small businesses and institutions in southern California. Table 4-9 shows a summary of the lighting results of this study.

Table 4-9. SDG&E 2006 Study Values

Building Use	Hours
Assembly	2,961
Grocery	5,058
Healthcare	2,504
Office	2,698
Process	2,895
Restaurant	4,305
Retail	3,640
School	2,795
Warehouse	3,250
All Other	2,804

The table shows that Grocery had the highest hours of use at 5,058 hours/year and Health Care the lowest at 2,504 hours/year.

4.1.3 Proposed deemed savings basis and estimates

A. DEVELOPMENT OF PROPOSED VALUES

The studies cited above divide results into different building use types that do not directly correspond to Focus on Energy sectors. Building uses are much more specific, such as "Grocery" or "College," rather than general sectors like "Commercial" or "Schools & Government." The exception to this rule is the Industrial sector, which is often listed as "Industrial" or "Process." There are no values reported in the cited studies for agricultural buildings.

Focus appears to be the only program that deems lighting savings by sectors rather than by building type. Dividing lighting parameters into more categories based on building type provides the opportunity to use study data as it is reported, rather than introducing unsupported assumptions about which building types correspond to which sectors. This provides the opportunity to increase the accuracy of program savings estimates. For this reason, we recommend that Focus deem lighting hours based on building type/use rather than by sector.

[16] KEMA Services, Inc. *Small Business Super Saver Program Hours of Operation Study*. September 2006.

i. Building Type Divisions

The cited studies break hours of use or coincidence factor into as few as five and as many as 20 categories. Five categories appear to be too few, as they do not include many prevalent building types. Twenty categories appear to be too many, introducing significant complexity, perhaps without increasing accuracy to the same degree.

Most studies divide buildings into ten to twelve categories. To check whether ten to twelve is a reasonable number, we first considered the DOE study that provides the percent of total national lighting use by twenty commercial building types. These values are reported in Table 4-3. Within the twenty building types are many that are similar. For example, there are values for two kinds of warehouse, two types of health care, and three types of retail buildings. There are also building types that account for only one percent of total lighting use (laboratories, for example), and a value for vacant buildings.

Table 4-10 shows the DOE data with like categories combined and with vacant buildings and those with a low percentage of national lighting use removed.

Table 4-10. DOE Building Categories Combined and Limited

Building Use	% Ltg. Usage
Office/ Professional	20.6%
Warehouse	12.8%
Food sales	2.9%
Health Care	6.9%
Public Assembly	5.9%
Food Service	2.9%
Hotel/Motel/Dorm	4.9%
Retail	19.5%
Service (excluding food)	4.9%
Education	10.8%
Total	**92.2%**

Note that these ten categories account for more than 92 percent of commercial lighting use as reported by the DOE. Therefore, buildings in these ten categories account for a great majority of commercial lighting use.[17]

These categories do not encompass all building types that are important to Focus on Energy and are presented here to determine the approximate number of building categories that are necessary to represent a high percentage of commercial building lighting use. The categories presented only include commercial buildings and a single value for education. Industrial and agricultural building types are absent. There is also no specific value for colleges or universities, a building type that is significant in the Focus program.

Another consideration in determining building type categories is the number of sources available for each building type. If a particular category does not have enough source data to generate an accurate parameter value, it may not make sense to include it.

[17] Note that in the DOE analysis, education is included in the commercial category.

Table 4-11 adds categories for “College,” “Industrial,” “Agricultural,” and “Other” to the list in Table 4-10 and presents the number of sources cited for hours of use and coincidence factor for each building type.

Table 4-11. Building Categories with Number of Sources

Building Use	Number of Citations	
	Hours	CF
Food Sales	5	3
Food Service	5	3
Health Care	4	3
Hotel/Motel	3	2
Office	5	3
Public Assembly	2	0
Public Services (non-food)	2	1
Retail	5	3
Warehouse	4	3
School	5	4
College	1	2
Industrial	4	2
Agricultural	0	0
Other	4	3

The cited studies provide at least two sources for each parameter for most building types. Again, there are no sources for agricultural buildings, but the category is very important to the program and must be included. Also, there is no source for coincidence factor for Public Assembly buildings and only one source for College hours of use and Public Services coincidence factor.

Because all these building types are prevalent and important to the program, and because there are sources for hours of use or CF for each (besides Agriculture and Public Assembly), we recommend that they remain separate categories and not be subsumed under “Other.” We therefore recommend that hours of use and coincidence factor be deemed according to the building types presented in Table 4-11 above.[18]

ii. Hours of Use

In the current deeming method, hours of use refers to the average annual hours that light fixtures operate in each sector. In the proposed deeming method, it refers to the average annual hours that light fixtures operate by building type.

These building types may occur in any sector, but most of the division occurs in the Commercial and Schools and Government sectors. There is typically only one value reported for Industrial buildings. Agricultural buildings are not dealt with in this analysis because we could not identify any sources that report values for agricultural buildings. Agricultural buildings are addressed in Section 4.1.3a.iv.

[18] A category for Dormitories has subsequently been added so that all lighting measures, including CFLs, can use consistent building use definitions.

There are six studies cited that provide hours of use values for one or more building types. These sources are not equal in value to the Focus program. Each has a different sample size and some are based on surveys, while others are based on metering. A larger sample size or number of data points translates into greater accuracy.

Surveys often result in inaccurate self-reported values, which may lead one to disregard surveys entirely. However, many surveys can be completed at a similar cost as relatively few metering installations, so survey studies tend to contain more data points. The size of these studies makes them important even though the values tend to be less accurate than metering. In order to use all the cited studies and to assign them value based on their size and data collection method, we have developed a weighting system to average the hours of use in the cited studies.

Two of the studies are based on surveys; they are PG&E 1996 and DOE. The other four studies are based on metering. Some of these four also include surveys but the values reported from the studies are the metered values. In order to compare studies based on metering with those based on surveys, we must determine the relative weight or value of a metered sample as compared to a survey sample.

Unfortunately, there is no standard rule of thumb to suggest the worth of a survey compared to a metered data point. In order to include the large PG&E and DOE surveys in our weighting analysis, we propose to weight them at ten percent of a metered study with the same number of data points. To put this more simply, a meter is worth ten surveys in this analysis. Putting a value on this relationship is somewhat arbitrary, but it is necessary, and it reflects the reality that metering is much more reliable than self-reports.

Table 4-12 shows the number of meters or surveys used in each cited study. When applicable, the number of surveys is then divided by 10 to yield the value in the “meter equivalent sample size” column, with the number of meters from the other studies transferred to that row. The “weight” row represents the percent of the total sample size contributed by each study.

Table 4-12. Hours of Use Study Weighting by Sample Size

Study	Meters	Surveys	Meter Equivalent Sample Size	Weight
PG&E 1996	0	1,270	127	6%
DOE	0	5,430	543	27%
RLW Schools	600	0	600	29%
PG&E RightLights	184	0	184	9%
SDG&E TOU	431	0	431	21%
SDG&E 2006	150	0	150	7%
Total	**1,365**	**6,700**	**2,035**	**100%**

If all building types had values reported for all six sources, the weights above would be the relative weight of each survey, across all building types. However, none does. Each building type has values from between one and five sources. So, the weights presented above act as relative weights between the applicable sources by building type.

Table 4-13 shows the hours of use values cited for each study for each building type, the weighting factors determined using the method described above, and the resulting weighted average Hours of Use by building type.

Table 4-13. Hours of Use Values and Weighted Averages

Building Use	PG&E 1996	DOE	RLW Schools	PG&E RightLights	SDG&E TOU	SDG&E 2006	Weighted Average
Food Sales	5,800	5,256	-	4,636	6,390	5,058	5,544
Food Service	4,600	4,599	-	4,278	4,450	4,305	4,482
Health Care	4,400	4,617	-	-	2,689	2,504	3,677
Hotel/Motel	5,500	3,687	-	-	2,307	-	3,356
Office	4,000	3,760	-	2,558	3,792	2,698	3,526
Public Assembly	-	2,665	-	-	-	2,961	2,729
Public Services (non-food)	3,400	3,431	-	-	-	-	3,425
Retail	4,450	4,258	-	1,621	5,435	3,640	4,226
Warehouse	3,550	3,705	-	-	3,211	3,250	3,464
School	2,150	2,774	2,147	-	1,795	2,795	2,302
College	3,900	-	-	-	-	-	3,900
Industrial	-	5,054	-	3,547	5,512	2,895	4,745
Other	4,500	3,723	-	-	3,667	2,804	3,672
Weight	6%	27%	29%	9%	21%	7%	100%

All building categories have at least two sources except for “College” with only one citation based on surveys. However, we would expect the value for college buildings to be greater than that for schools, and on the order of that for offices, and it is. Therefore, the College estimate appears reasonable. Under this analysis, the College category would also include dormitories. However, dorms are used more like residences than like other building types addressed by these measures. Therefore, we have included a discussion of dorms in Section 4.1.3a.v below.

Based on the above analysis, we recommend that the weighted averages in Table 4-13 be the deemed hours of use for lighting measures for all building types besides dormitories and agricultural buildings.

iii. Coincidence Factor

In the current deeming method, coincidence factor refers to the average percentage of total system wattage that is operating during the peak demand period, and is deemed for each sector. A value of 90 percent was used for the Commercial, Industrial, and Agriculture sectors and 71 percent was used for the Schools & Government sector. Sources for these values are not available or have been lost. In the proposed deeming method, the definition of coincidence factor is the same, but coincidence factor values are based on building type rather than sector.

There are four sources that provide coincidence factor values for at least one building type, with most providing values for approximately ten building types. Again, not all of these surveys are of equal value to the program. The same considerations for sampling method (survey or meter) and sample size discussed for hours of use above apply to coincidence factors as well. These factors are dealt with in the same way for coincidence factor as they are for hours of use. A meter is considered to be worth ten surveys, and sample sizes are weighted accordingly.

However, in addition to these factors, another very important consideration is the peak period used by each study. Each study cited uses a different definition for peak period. Since coincidence factor is defined as the percent of total system wattage on during the peak period, when the peak period occurs may have a significant effect on the coincidence factor value for that study. Thus, a weighting system was developed to include both sample size and the degree to which the peak periods for each study overlap with the Focus peak period.

All cited studies define peak period in the summer, Monday through Friday, mostly in the afternoon. This is consistent with the program's definition. However, the months and hours included is different for each. The peak months and hours for each cited study are presented in Table 4-14 below.[19]

Table 4-14. Coincidence Factor Study Weighting by Sample Size and Peak Period Overlap

	PG&E 1996	RLW Schools	RLW CF	SDG&E Time of Use	Focus	Total
Peak Months	May-Oct	Jun-Sept	Jun-Aug	May-Sept	Jun-Aug	
Peak Hours	12 - 6 pm	3 - 5 pm	1 - 5 pm	1 - 4 pm	1 - 4 pm	
Total Peak Hours	1,104	244	368	459	276	
Hours In Focus Peak	276	92	276	276	276	
Percent in Focus Peak	25%	38%	75%	60%	100%	
Peak Period Weighting Factor	13%	19%	38%	30%	-	100%
Sample Size	127	600	1,415	431	-	-
Sample Size Weighting Factor	5%	23%	55%	17%	-	100%
Overall Weighting Factor	9%	21%	46%	24%	-	100%

The total peak hours for each program were calculated, as were the number of these hours that are contained in the Focus peak period. A ratio of the former to the latter is reported in the "Percent in Focus Peak" row in the above table. Each of these "Percent in Focus Peak" values was divided by the sum of the percentages to yield Peak Period Weighting Factors that sum to 100 percent.

Then, Sample Size Weighting Factors were developed using the method described for hours of use. The two weighting factors, Peak Period and Sample Size, were given equal importance and averaged to yield the Overall Weighting Factor of each study. For each building type, these act as relative weights of the values reported by each study for that building type.

The CF values reported by each study by building type are reported in Table 4-15 along with their relative weights and the resulting weighted average.

[19] The hours reported here for the SDG&E Time of Use study are not the actual peak period hours used by that program. Instead, they are the hours that the CF values presented in this report are based on, as interpolated from a graph in the report.

Table 4-15. Coincidence Factor Values and Weighted Averages

Building Use	PG&E 1996	RLW Schools	RLW CF	SDG&E Time of Use	Weighted Average
Food Sales	81%	-	95%	90%	92%
Food Service	68%	-	81%	96%	84%
Health Care	74%	-	77%	82%	78%
Hotel/Motel	67%	-	-	23%	35%
Office	81%	-	75%	78%	77%
Public Assembly	-	-	-	-	67%
Public Services (non-food)	64%	-	-	-	64%
Retail	88%	-	82%	88%	84%
Warehouse	84%	-	78%	79%	79%
School	42%	33%	63%	53%	52%
College	68%	-	68%	-	68%
Industrial	-	-	73%	85%	77%
Other	76%	-	54%	88%	67%
Weighting Factor	**9%**	**21%**	**46%**	**24%**	**100%**

Since there is no coincidence factor value cited for Public Assembly buildings, the value for “Other” has been assigned. Note also that there is only one cited value for Public Services (non-food) buildings, so that one value is the “weighted average” value even though no actual weighting has occurred.

Based on the above analysis, we recommend that the weighted average coincidence factor values be the deemed coincidence factors by building type for all buildings that are not agricultural or dormitories

iv. The Agricultural Sector

After a thorough but unsuccessful search for studies on lighting usage in the Agriculture sector, we decided to examine the existing engineering reviews that were performed on installed projects during Focus on Energy’s 18-month Contract Period (18MCP). Though hours of use were mostly not used in calculations because most lighting measures were deemed, engineers often collected self-reported hours of use data anyway. There were six engineering reviews done of lighting projects during 18MCP in which hours of use was collected, representing 362 light fixtures of various types. This is a small sample but, unfortunately, the only data available to us.

Proposed Agriculture sector lighting hours are based on a weighted average of this sample with weights based on the number of fixtures installed. Coincidence factor is determined using a weighting system based on both hours of use and whether the respondents indicated that the lights were on during the day or during the night.[20] The resulting hours of use and CF values are shown in Table 4-16.

[20] See the lighting calculations spreadsheet for details.

Table 4-16. Agricultural Hours of Use and Coincidence Factor

Sector	Hours	CF
Agriculture	4,698	67%

The table shows that even this small sample of agriculture projects provides values that are in the expected range for hours of use and CF. The CF value shown here is lower than the current value because of the number of respondents that indicated that the lights were on at night. The CF value proposed is in the range of other building types.

v. Dormitories

The above analysis does not provided a category for dormitories. Under the above analysis, hours of use and coincidence factor values for dorms would be given the value used for "College." However, dorm lighting has usage patterns that are significantly different from other building types building types in a university setting. Dorms lights are used more like those in a residence.

For that reason, another building type category is proposed for dorms, with hours of use and coincidence factors equal to those used by Wisconsin Focus on Energy Residential Programs.[21] These values are shown in Table 4-17.

Table 4-17. Dormitory Hours of Use and Coincidence Factors

Building Type	Hours	CF
Dormitory	986	7%

B. PROPOSED PARAMETERS AND VALUES

i. Proposed Parameters

In conclusion, we recommend that lighting hours of use and coincidence factor be deemed by building type, rather than by sector. The recommended building divisions are presented in Table 4-18.

Hours of Use, Hours. Hours of use refers to the average annual operating hours of the light fixture and is measured in hours/year. Values are shown in Table 4-18.

Coincidence Factor, CF. Coincidence factor refers to the average percentage of total system wattage operating during the peak demand period, is deemed by building type, and is measured in percent. Values are shown in Table 4-18.

ii. Proposed Deemed Values

The proposed deemed savings values for these parameters can be found in Table 4-18.

[21] These values were provided to Business Programs by Residential Programs via electronic correspondence on October 19, 2009. The source of the hours of use value is cited as *Focus on Energy Public Benefits Evaluation Memo - "Adjustments to CFL Operating Hours - Residential, May 23, 2005.* The source of the CF value is cited as *MA-RI-VT Study 2005 Report.*

Table 4-18. Proposed Deemed Savings Parameters

Building Use	Hours	CF
Food Sales	5,544	92%
Food Service	4,482	84%
Health Care	3,677	78%
Hotel/Motel	3,356	35%
Office	3,526	77%
Public Assembly	2,729	67%
Public Services	3,425	64%
Retail	4,226	84%
Warehouse	3,464	79%
School	2,302	52%
College	3,900	68%
Dormitory	986	7%
Industrial	4,745	77%
Agricultural	4,698	67%
Other	3,672	67%

For comparison, the current deemed parameter values are presented again in Table 4-19.

Table 4-19. Current Deemed Parameter Values by Sector

Sector	Hours	CF
Agriculture	4,368	90%
Commercial	3,680	90%
Industrial	4,576	90%
Schools & Government	3,230	71%

iii. Discussion of Proposed Deeming Method

Changing the hours of use and coincidence factor basis from sector-level definitions to building type definitions will have an impact on administrative costs and on the accuracy of the program savings estimate. The cost of the change must be outweighed by the benefit of more accurate savings estimates. We believe that the change in method will increase overall program savings accuracy significantly, especially within the Commercial and Schools & Government sectors.

There are many benefits to changing the basis of definition. First, the inaccuracy of lumping together all building types within a sector is avoided. As can be seen from Table 4-18, hours in the Commercial sector range from 2,729 (Public Assembly) to 5,544 (Food Sales), and coincidence factors range from 35 (Hotel/Motel) to 92 percent (Food Sales). In the Schools & Government sector, values range from 2,302 hours and 52 percent CF for Schools to 3,526 hours and 77 percent for Offices. Thus, the same lighting project in two different building types within a sector will now have different savings values that more accurately reflect the lighting use in each building type. By improving the estimate for each project the overall program estimate is improved. Furthermore, most research to date has been done on a building type basis and future research is likely to follow this pattern. Values from the current research can be directly applied by building type, as can any new research that becomes available.

In addition to increasing savings estimate accuracy, the change in definition allows the program to target building types with larger hours of use or CF and realize the increased savings associated with that approach.

Finally, there is the matter of the ultimate effect of the new values on program savings. A cursory review shows that the proposed hours of use values are mostly in the range of those currently being used. Coincidence factors, however, are lower than the current values. Therefore, the program can expect an overall reduction in kW savings due to these changes.

The PSC may decide that the proposed building use definition cannot be implemented at this time. Appendix A contains an alternative, sector-level review of lighting hours and coincidence factor. If the building use definition is rejected at this time, KEMA recommends using the values in Appendix A.

iv. Confidence in Proposed Values

The basis for the current deemed values is not known. The proposed deemed values are based on primary sources, and most are based on multiple metering studies.[22] Therefore, we are much more confident in the proposed deemed parameters than we were in the current deemed parameters. Also, as discussed above, the proposed deeming method by building type increases the accuracy of deemed savings estimates for each project, thereby increasing overall savings estimate accuracy. We feel that the new estimates for lighting operating hours and coincidence factor are not conservative, but are likely to represent the actual parameters at each site. Therefore, we are confident that the energy savings estimated using these parameters will be realized.

c. RECOMMENDED FURTHER RESEARCH

i. Strengthening Current Parameter Estimates

The Agriculture sector hours of use and coincidence factor values are based on a review of only six projects installed during the 18MCP. Since there are no secondary sources that provide values for agriculture, it may be up to Focus on Energy to strengthen the parameter estimates through program data collection and tracking or primary research. By requiring and tracking lighting use profiles for projects in the Agriculture sector, the program could increase the sample size used to determine lighting hours and CF and thereby increase the accuracy of the savings estimate. A metering study of Agriculture sector lighting use would provide a more accurate estimate but also increase the cost.

The hours of use value for Colleges is based on one source and is the least supported value outside of the Agriculture sector. The hours of use and CF values for Dormitories are also based on single sources, as provided by Focus Residential Programs. The program may decide to track lighting use profiles for projects in colleges and dormitories to further strengthen these estimates.

[22] Strategies for strengthening less supported values are discussed in Section 4.1.3c.i.

ii. Interactive Savings

The Focus on Energy savings estimate does not currently account for the Interactive Factor. This factor accounts for the heat that is produced by lighting that has to be removed from buildings in the summer by air conditioning systems.[23] When lighting energy is reduced, lighting heat production is also reduced, thus saving additional energy in air conditioning systems.

An interactive factor can be defined for and applied to kW and kWh calculations. The factor for kW calculations is always larger because kW savings are measured during summer afternoons when the air conditioning system is more likely to be running.

Equations for kW and kWh savings including an Interactive Factor can be written as follows, where Interactive Factor (IF) is a percentage:

$$kW\ \ savings_{(with\ IF)} = kW\ \ savings_{(without\ IF)} * (1 + IF_{kW})$$

$$kWh\ savings_{(with\ IF)} = kWh\ savings_{(without\ IF)} * (1 + IF_{kWh})$$

Of the studies formally cited herein, only the RLW CF study reports interactive factors. However, Vermont and Connecticut also use interactive factors in their savings estimates.[24]

Table 4-20 below presents the interactive factors suggested by the studies reviewed for buildings that are air-conditioned. These values are not differentiated by building type; instead the sources report one value for all air-conditioned buildings.

Table 4-20. Interactive Factors (Air-Conditioned Buildings Only)

Source	Interactive Factor (kW)	Interactive Factor (kWh)
Vermont	30%	12%
Connecticut	30%	24%
RLW C.F.	13%	0%

The interactive factor is only applied to buildings that are cooled in the summer. Therefore, one must know whether a building is air conditioned before applying the interactive factor. Alternatively, one could determine the percentage of buildings in a particular building type category with air conditioning and determine an interactive factor that would be applied to whole building categories and not individual projects.

If Interactive Factor values are added to deemed calculations in the future, they will most likely affect the savings for buildings in the School & Government and Commercial sectors. Some Industrial sector buildings are air-conditioned and will have interactive factors while others are not. A reduced interactive factor may be appropriate for Industrial sector buildings.

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[23] There is also a component of lighting heat that adds to the heating of buildings in winter, but for internally loaded commercial buildings and industrial buildings this is a negligible factor.

[24] The Vermont and Connecticut programs are not cited herein because they are secondary sources. The basis of their parameter values is not known, and they may be based on other studies cited herein.

Since most Agriculture sector buildings are not air conditioned, the Interactive Factor generally would not apply.

We cannot formally recommend including an Interactive Factor at this time for a number of reasons. First, we must know the percentage of buildings that are air-conditioned before applying the interactive factor. That data is not currently available. Second, the Interactive Factor is weather dependent, so primary metered sources for Interactive Factor would have to be adjusted for Wisconsin's climate. Finally, only one primary source is available for Interactive Factor, so the current research does not provide strong support for the values that should be used. Since including an interactive factor may yield a more accurate savings estimate, we recommend further research into this matter.

4.2 T-8 REPLACING 8' T-12 FLUORESCENT LIGHTING

Group: Lighting

Category: Fluorescent, Linear

Technology Description: 4' 4-Lamp T-8 fluorescent light fixtures replacing 8' 2-Lamp T-12 fluorescent light fixtures in retrofit applications.

Qualifying Equipment:

- New construction projects are not included.
- Must be replacing existing 8' T-12 fixtures.
- T-8 lamps must be high-performance T-8 (≥ 3100 initial lumens with 24,000 hour lamp life at 3-hour rated start) and be on the *CEE High Performance T-8* list.
- T-8 ballasts must be ≤ 0.78 ballast factor or be an approved ballast on the *CEE High Performance T-8* list.
- Fixtures must be installed indoors.

Date Deeming Last Modified: May 2008

Reviewed by: Jeremiah Robinson

Table 4-21. T-8 Replacing 8' T-12 Fluorescent Lighting Measures, Existing Deemed Savings

Tech Code	Measure Description	Savings							
		Ag		Com		Ind		S-G	
		kW	kWh	kW	kWh	kW	kWh	kW	kWh
2.0810.170	T8 4L-4ft High Performance Replacing T12 2L-8 ft	0.0234	114	0.0234	96	0.0234	119	0.0185	83
2.0811.170	T8 4L-4ft High Performance Replacing T12HO/VHO 2L-8 ft	0.1008	489	0.1008	412	0.1008	513	0.0795	358

Savings Basis: T-8 fluorescent light fixtures save energy when replacing T-12 fluorescent fixtures because they are able to produce the same light output with a lower wattage.

4.2.1 Existing deemed savings basis and estimates

This section provides a discussion of the measures as they are currently deemed.

A. SAVINGS EQUATIONS AND PARAMETERS

Savings due to replacing light fixtures are described by the following equations:

$$kW_{savings} = \left(\frac{Ltg.\ Watts_{old} - Ltg.\ Watts_{new}}{1000} \right) * CF$$

$$kWh_{savings} = \left(\frac{Ltg.\ Watts_{old} - Ltg.\ Watts_{new}}{1000} \right) * Hours$$

where:

- Ltg. $Watts_{old}$ = lighting wattage of existing fixture, values in Table 4-22, watts
- Ltg. $Watts_{new}$ = lighting wattage of new fixture, values in Table 4-22, watts
- Hours = hours of use per year, values in values in Table 4-22, hr/year
- CF = coincidence factor, values in values in Table 4-22, percent
- 1,000 = conversion factor, watts per kilowatt

Existing Lighting Fixture Wattage, Ltg. $Watts_{old}$. The Existing Lighting Fixture Wattage is the total fixture wattage of the old fixture being replaced, including lamps and ballast.

New Lighting Fixture Wattage, Ltg. $Watts_{new}$. The New Lighting Fixture Wattage is the total fixture wattage of the new fixture being installed, including lamps and ballast.

Hours of Use, Hours. Hours of Use refers to the average annual operating hours of the light fixture and is measured in hours/year.

Coincidence Factor, CF. Coincidence Factor refers to the average percentage of total system wattage that is operating during the peak period and is measured in percent. The peak period is defined as 1–4 pm, Monday through Friday, June through August.

Table 4-22. Existing Deemed Savings Parameters

Tech Code	Measure Description	Technology		Parameters							
				Agriculture		Commercial		Industrial		Schools-Government	
		New Watts	Old Watts	Hours	CF	Hours	CF	Hours	CF	Hours	CF
2.0810.170	T8 4L-4ft High Performance Replacing T12 2L-8 ft	98	124	4,368	90%	3,680	90%	4,576	90%	3,230	71%
2.0811.170	T8 4L-4ft High Performance Replacing T12HO/VHO 2L-8 ft	130	242								

B. VALUES, ASSUMPTIONS, AND CALCULATIONS

Note: We will herein refer to measure 2.0810.170 (Table 4-22) as the “standard T-12 replacement” and measure 2.0811.170 (Table 4-22) as the “high output T-12 replacement.”

i. Existing Lighting Fixture Wattage

According to the energy savings spreadsheets provided by Focus on Energy, lighting fixture wattage was determined using American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) sources. However, we have found that the wattages reported by ASHRAE do not correspond to the wattages used in calculations. A review of other sources revealed that the wattages were actually taken from the California Standard

Performance Contract.[25] The program used fixture wattages assigned to the types of fixtures that would most likely be replaced with these measures.

For both measures, the baseline was chosen to be an 8' 2-lamp fixture with "energy saving" lamps. For the standard T-12 replacement, the fixture was a standard T-12 fixture with an energy saving magnetic ballast. For the high-output T-12 replacement, the baseline was determined by assuming that 80 percent of fixtures would be high output (HO) fixtures with energy saving magnetic ballasts (207-watt), and 20 percent would be very high output (VHO) fixtures with standard magnetic ballasts (380-watt). The deemed values for existing fixture lighting wattages are shown in Table 4-22.

ii. New Lighting Fixture Wattage

The New Lighting Fixture Wattage was defined as the average of the Consortium for Energy Efficiency (CEE) reported ballast wattages for the types of fixtures that would be installed with these measures. For both measures, the new fixture was a 4' 4-lamp T-8 fixture with 32-watt lamps. For the standard T-12 replacement, the new lighting fixture wattage was assigned the average of the ballast wattage for CEE-reported ballasts with ballast factors less than 0.98. For the high output T-12 replacement, the new lighting fixture wattage was assigned the average of the ballast wattage for CEE-reported ballasts with "high" and "normal" ballast factors. The calculation assumed that 50 percent of fixtures would be "high" (average of 144 watts) and 50 percent "normal" (average of 116 watts). The deemed values for new fixture lighting wattages are shown in Table 4-22.

iii. Hours of Use & Coincidence Factor

The values for hours of use and coincidence factor are those used for most lighting measures, deemed by sector. These sector-specific values are shown in Table 4-23.

Table 4-23. Existing Hours of Use Values

Sector	Hours	CF
Agriculture	4,368	90%
Commercial	3,680	90%
Industrial	4,576	90%
Schools-Government	3,230	71%

The development of these values, as well as a proposed update, is discussed in Section 4.1. For a thorough discussion of current and proposed lighting hours of use, refer to that section.

4.2.2 Literature review

Here we present the findings of various sources related to the replacement of 8' T-12 fluorescent light fixtures with T-8 light fixtures.

[25] Southern California Edison Business Incentives & Services Standard Performance Contract Program. *Standard Performance Contract.* "Appendix B: Table of Standard Fixture Wattages and Sample Lighting Table." January 6, 2009.

A. *CALIFORNIA STANDARD PERFORMANCE CONTRACT (SPC)*[26]

The California Standard Performance Contract (SPC) uses standard fixture wattage tables, published by Southern California Edison, to calculate energy savings for projects completed with assistance from that program. Among other things, the SPC serves as the catalog of the prescriptive and deemed savings values used in California, much like the Deemed Savings Manual currently being assembled for Wisconsin.

Table 4-24 shows the standard wattages as reported by the SPC for the various types of 8' T12 2-lamp light fixtures.

Table 4-24. T12 Wattages from the SPC

Fixture Type	Standard Mag.	ES Mag.	Electronic	Average
T12	128	123	110	120
T12HO	227	207	173	202
T12VHO	380	-	-	380

Here we see that T12 and T12HO fixtures have three categories of ballasts reported, while T12VHO has only the standard magnetic ballast.

B. *ADVANCE BALLAST CATALOG*[27]

The Advance Atlas is thought of as the best source for wattages of specific ballast types by the lighting design industry. Advance Transformer Company is the best respected and most popular ballast manufacturer among lighting designers, and its wattages are taken as the standard across the industry.

Table 4-25 shows the wattages for various 2-lamp T12 ballast types used with 8-foot light fixtures. The columns are labeled by ballast type, input voltage, and (when two ballast factor options are offered) whether the ballast has the higher or lower ballast factor. The table also shows the average of the various ballast wattages.

Table 4-25. T12 Wattages from Advance

<table>
<tr><th rowspan="3">Fixture Type</th><th colspan="4">Standard</th><th colspan="4">Energy Saving</th><th colspan="4">Electronic</th><th colspan="4" rowspan="2">Averages</th></tr>
<tr><th colspan="2">120</th><th colspan="2">277</th><th colspan="2">120</th><th colspan="2">277</th><th colspan="2">120</th><th colspan="2">277</th></tr>
<tr><th>Lo</th><th>Hi</th><th>Lo</th><th>Hi</th><th>Lo</th><th>Hi</th><th>Lo</th><th>Hi</th><th>Lo</th><th>Hi</th><th>Lo</th><th>Hi</th><th>Std</th><th>ES</th><th>Elec</th><th>Total</th></tr>
<tr><td>T12</td><td>144</td><td>158</td><td>144</td><td>158</td><td>112</td><td>126</td><td>112</td><td>126</td><td colspan="2">135</td><td colspan="2">132</td><td>151</td><td>119</td><td>134</td><td>135</td></tr>
<tr><td>T12HO</td><td colspan="2">237</td><td colspan="2">245</td><td colspan="2">203</td><td colspan="2">210</td><td>170</td><td>205</td><td>170</td><td>205</td><td>241</td><td>207</td><td>188</td><td>212</td></tr>
<tr><td>T12VHO</td><td>320</td><td>440</td><td>310</td><td>442</td><td>304</td><td>412</td><td>315</td><td>398</td><td colspan="2">198</td><td colspan="2">198</td><td>378</td><td>357</td><td>198</td><td>311</td></tr>
</table>

In this table, “Standard” refers to the standard magnetic ballast, “energy saving” refers to the energy saving magnetic ballast, and “electronic” refers to the electronic T12 ballast. Here we

[26] Southern California Edison Business Incentives & Services Standard Performance Contract Program. *Standard Performance Contract.* “Appendix B: Table of Standard Fixture Wattages and Sample Lighting Table.” January 6, 2009.

[27] Advance Transformer Company. *Advance Atlas – 2008–2009.*

see that there is a large variation between input wattages for the various ballast types. For example, the wattages for T12VHO fixtures vary between 198 and 442 watts, with an average of 311 watts.

C. CEE LIST OF HIGH PERFORMANCE T8 QUALIFIED BALLASTS [28]

The *CEE List of High Performance T8 Qualified Ballasts* provides a list of ballast input wattages for a large range of T8 ballasts, grouped by the number of lamps and ballast factor category. Ballasts fall under three ballast factor categories as shown in Table 4-26. The table shows that the "Normal" ballast factor category ballasts account for the greatest number of models in every lamp category and the "High" ballast factor category ballasts account for the lowest number of models in almost every lamp category.

Table 4-26. CEE Ballast Factor Groups

Ballast Factor Category	Range	Number of Ballasts			
		1 Lamp	2 Lamp	3 Lamp	4 Lamp
Low	0.70–0.85	10	29	39	40
Normal	0.86–1.00	26	59	69	54
High	1.01–1.33	2	30	30	15

The average ballast factor in each ballast category and the input wattages for four-lamp T8 ballasts are shown in Table 4-27. The table shows that the difference between the "Low" and "Normal" ballast category input wattages is much less than the difference between the "Normal" and "High" ballast category input wattages.

Table 4-27. CEE Average Ballast Factor and Input Wattage for 4-Lamp Ballasts

Ballast Factor Category	Average B.F.	Average Input Wattage
Low	0.76	95
Normal	0.88	108
High	1.16	145

The CEE list also includes a value known as the Ballast Efficacy Factor (BEF), which measures the ballast's efficiency by converting it to a ballast factor of 1.00. Using this data, it is possible to determine the input wattage of each fixture as if the ballast factor was 1.00, as shown in Table 4-28.

Table 4-28. CEE Input Wattage at BF=1.00

Ballast Factor Category	Average Input Wattage at BF=1.00
Low	125
Normal	123
High	124

[28] *Qualifying Products - High-Performance 120 and 277V T8 Ballasts*. CEE High-Performance Commercial Lighting Systems Initiative. Updated 03/31/09.

The table shows that the ballast factor of a ballast does not meaningfully affect its efficiency. The input wattage of the ballasts in each category at BF=1.00 are within two percent of each other.

4.2.3 Proposed deemed savings basis and estimates

Based on the above research, we recommend that deemed savings estimates be updated as provided in this section.

A. DEVELOPMENT OF PROPOSED VALUES

i. Existing Lighting Fixture Wattage

The Existing Lighting Fixture Wattage is the total fixture wattage of the old fixture being replaced, including lamps and ballast. In the previous round of deeming, the values for existing fixture wattage were taken from the California Standard Performance Contract.[29] The chosen values represent the types of fixtures that are most likely to be replaced with these measures. For the standard T12 replacement, this was a 2-lamp T12 fixture with an energy saving magnetic ballast. For the high output T12 replacement, there were two fixture types selected: one for the T12HO fixture and one for the T12VHO fixture. For the T12HO fixture, the 2-lamp T12HO with an energy saving magnetic ballast was chosen. For the T12VHO fixture, the 2-lamp T12VHO with a standard magnetic ballast was chosen (it was also the only option listed). All of the values listed in the SPC table are shown in Table 4-24 and the wattages chosen for the savings calculation are shown in Table 4-29.

Table 4-29. SPC Wattages Selected

Fixture Type	Input Watts
T12	123
T12HO	207
T12VHO	380

To verify that these wattages are appropriate, we compared them with wattages reported in the Advance Atlas[30], shown in Table 4-25. A comparison between these sources is shown in Table 4-30.

Table 4-30. Comparison between Wattages from SPC and Advance

	Input Wattage							
	California SPC				Advance			
Fixture Type	Std	ES	Elec	Total	Std	ES	Elec	Average
T12	128	123	110	120	151	119	134	135
T12HO	227	207	173	202	241	207	188	212
T12VHO	380	-	-	380	378	357	198	311

[29] Southern California Edison Business Incentives & Services Standard Performance Contract Program. *Standard Performance Contract.* "Appendix B: Table of Standard Fixture Wattages and Sample Lighting Table." January 6, 2009.

[30] Advance Transformer Company. *Advance Atlas – 2008–2009.*

The table shows that the average input wattages for the T12 and T12HO fixtures reported by the SPC are slightly less than the average wattages for the same fixture types in the Advance Atlas. For VHO fixtures, the SPC value corresponds closely to the standard magnetic ballast average from the Advance Atlas but not to the overall average wattage. The Advance and SPC standard ballast wattages are nearly identical, but Advance also lists wattages for energy saving and electronic ballasts that are not included in the California SPC table.

Based on a general knowledge of the lighting industry, we believe that electronic ballasts are very rare in T12 fixtures. A phone conversation with an Advance Transformer Company representative in Wisconsin confirms the assumption that standard magnetic ballasts (he refers to them as “pigs”) make up the vast majority of T12VHO installed fixtures, and that energy saving and electronic style ballasts are very rare. Since the standard magnetic ballast is the most common, we can disregard the energy saving and electronic wattages from the Advance catalog and only compare the standard magnetic ballast wattages from SPC and Advance, which are very similar. Therefore, we believe that the existing fixture input wattages reported by the SPC and currently used by Focus are accurate. These values are shown in Table 4-29.

In the last round of deeming, Focus assumed that 20 percent of the installed T12 HO/VHO fixtures were VHO and 80 percent were HO. To verify this claim, we had conversations with three lighting representatives in Wisconsin. The data collected during these interviews is summarized in Table 4-31.

Table 4-31. Results of Conversations with Lighting Representatives

Interview:	Location	Installed Fixtures	
		% VHO	% HO
Gene Scholler with Sylvania Lighting Services	Milwaukee	8%	92%
Neher Lightbulbs (sales representative)	Milwaukee	15%	85%
Brian with Gexpro Lightbulbs	Wauwatosa	10%	90%
	Average	11%	89%

The table shows that the surveyed representatives consistently estimate that the percentage of VHO fixtures is less than the 20 percent predicted by Focus. One representative suggested that there were many more VHO fixtures installed 20 years ago, but since then demand side management (DSM) programs like Focus on Energy have steadily chipped away at this base. The rates suggested by these surveys are 11 percent for VHO fixtures and 89 percent for HO fixtures.

Including the standard T12 fixtures along with the T12 HO/VHO fixtures weighted by the percentages above results in the existing lighting fixture wattages shown below in Table 4-32.

Table 4-32. Proposed Values for Existing Fixture Wattage

Fixture Type	Input Wattage	Weighting	Measure	Proposed Wattage
T12	123	N/A	2.0180.170	123
T12HO	207	89%	2.0181.170	226
T12VHO	380	11%		

ii. New Lighting Fixture Wattage

The New Lighting Fixture Wattage is the total fixture wattage of the new fixture being installed, including lamps and ballast. In the previous round of deeming, the values for new fixture wattage were determined from the CEE ballast list using different methods. For the standard T12 replacement, the new fixture wattage estimate was assigned the average of the input wattages for CEE-approved ballasts with ballast factors under 0.98. For the high output T12 replacement, the average of the input wattages for CEE-approved ballasts with "High" and "Normal" ballast factors were used. The calculation assumed that 50 percent of the installed fixtures would be "High" (average of 144 watts) and 50 percent would be "Normal" (average of 116 watts).

We suggest a more sophisticated method for this round of deeming. We performed a review of the measures entered in the WISeerts database to determine the average ballast factor for each measure, found on the fixture cut sheets stored in the database. Table 4-33 shows the average ballast factors based on the review.

Table 4-33. Average Ballast Factors from WISeerts

Measure	Projects Reviewed	% of Total Projects	Avg. Ballast Factor
2.0810.170	8	22%	0.80
2.0811.170	26	46%	0.87

The number of projects reviewed was higher for measure 2.0811.170 because there was greater variation in the ballast factor for this measure. Ballast factors for 2.0810.170 were very consistent.

KEMA took the average ballast factor data from Table 4-33, and multiplied it by the BEF input wattages in Table 4-28. The result is an estimate of the average input wattage for new fixtures installed under each measure. These values are shown in Table 4-34.

Table 4-34. Proposed Values for New Fixture Wattage

BF Category	Ballast Factor	Input Watts at BF=1.00	Proposed Input Wattage
Low	0.80	125	100
Normal	0.87	123	107

iii. Hours of Use and Coincidence Factor

Hours of use and coincidence factors are currently based on sector. We recommend that hours of use and coincidence factor be based on building type as developed and discussed in Section 4.1. These values are presented in Table 4-35.

Table 4-35. Hours of Use and Coincidence Factors by Building Type

Building Use	Hours	CF
Food Sales	5,544	92%
Food Service	4,482	84%
Health Care	3,677	78%
Hotel/Motel	3,356	35%
Office	3,526	77%
Public Assembly	2,729	67%
Public Services	3,425	64%
Retail	4,226	84%
Warehouse	3,464	79%
School	2,302	52%
College	3,900	68%
Dormitory	986	7%
Industrial	4,745	77%
Agricultural	4,698	67%
Other	3,672	67%

B. PROPOSED EQUATIONS, PARAMETERS, AND DEEMED VALUES

i. Proposed Equations and Parameters

In conclusion, we recommend the following formulas be used to calculate deemed savings for T-8 replacing 8' T-12 Fluorescent Lighting measures.

Savings due to replacing light fixtures are described by the following equations:

$$kW_{savings} = \left(\frac{Ltg.\ Watts_{old} - Ltg.\ Watts_{new}}{1000} \right) * CF$$

$$kWh_{savings} = \left(\frac{Ltg.\ Watts_{old} - Ltg.\ Watts_{new}}{1000} \right) * Hours$$

where:

- Ltg. $Watts_{old}$ = lighting wattage of existing fixture, values in Table 4-36, watts
- Ltg. $Watts_{new}$ = lighting wattage of new fixture, values in Table 4-36, watts
- Hours = hours of use per year, values in Table 4-37, hr/yr

- CF = coincidence factor, values in Table 4-37, percent
- 1,000 = conversion factor, watts per kilowatt.

Existing Lighting Fixture Wattage, Ltg. $Watts_{old}$. The Existing Lighting Fixture Wattage is the total fixture wattage of the old fixture being replaced, including lamps and ballast.

New Lighting Fixture Wattage, Ltg. $Watts_{new}$. The New Lighting Fixture Wattage is the total fixture wattage of the new fixture being installed, including lamps and ballast.

Hours of Use, Hours. Hours of Use refers to the average annual operating hours of the light fixture and is measured in hours/year.

Coincidence Factor, CF. Coincidence Factor refers to the average percentage of total system wattage that is operating during the peak period and is measured in percent. The peak period is defined as 1–4 pm, Monday through Friday, June through August.

ii. Proposed Deemed Values

Proposed deemed lighting wattages are provided in Table 4-36. Proposed deemed hours of use, coincidence factors, and deemed savings are provided in Table 4-37. If the PSC decides not to accept the building use lighting hours and CF definition, KEMA recommends using the alternative sector-level savings for this measure in Appendix B.

Table 4-36. Proposed Deemed Lighting Wattages

Tech Code	Measure Description	Existing Watts	New Watts
2.0810.170	T8 4L-4ft High Performance Replacing T12 2L-8 ft	123	100
2.0811.170	T8 4L-4ft High Performance Replacing T12HO/VHO 2L-8 ft	226	107

Table 4-37. Proposed Deemed Savings Values by Measure

			Proposed Deemed Savings			
			2.0810.170		2.0811.170	
Building Use	**Hours**	**CF**	**kW**	**kWh**	**kW**	**kWh**
Food Sales	5,544	92%	0.0214	129	0.1095	661
Food Service	4,482	84%	0.0196	104	0.1001	534
Health Care	3,677	78%	0.0182	86	0.0931	438
Hotel/Motel	3,356	35%	0.0081	78	0.0416	400
Office	3,526	77%	0.0178	82	0.0912	420
Public Assembly	2,729	67%	0.0155	64	0.0794	325
Public Services	3,425	64%	0.0148	80	0.0757	408
Retail	4,226	84%	0.0197	99	0.1006	503
Warehouse	3,464	79%	0.0184	81	0.0941	413
School	2,302	52%	0.0122	54	0.0625	274
College	3,900	68%	0.0159	91	0.0810	465
Dorms	986	7%	0.0016	23	0.0083	117
Industrial	4,745	77%	0.0180	111	0.0918	565
Agricultural	4,698	67%	0.0156	110	0.0797	560
Other	3,672	67%	0.0155	86	0.0794	438

For comparison, current deemed savings values are provided in Table 4-38.

Table 4-38. Current Deemed Savings Values

Tech Code	Measure Description	Current Deemed Savings							
		Ag		Com		Ind		S-G	
		kW	kWh	kW	kWh	kW	kWh	kW	kWh
2.0810.170	T8 4L-4ft High Performance Replacing T12 2L-8 ft	0.0234	114	0.0234	96	0.0234	119	0.0185	83
2.0811.170	T8 4L-4ft High Performance Replacing T12HO/VHO 2L-8 ft	0.1008	489	0.1008	412	0.1008	513	0.0795	358

iii. Confidence in Proposed Savings

The values for the old and new wattages were obtained through simple calculations based directly on strong sources, some of which are Focus on Energy-specific. Due to the simplicity of the calculations and the quality of the sources, we believe that these values are accurate, though not necessarily conservative. Therefore, we feel confident that the savings from this measure will be realized.

iv. Recommended Further Research

The parameter estimates for these measures are straightforward and accurately obtained but improvements can always be made. One way to increase confidence in the old and new wattage estimates is to better track both the ballast factors of the installed fixtures and a basic description of what was removed in WISeerts. Ballast factors are normally available on invoices and/or cut sheets, but removed fixtures are not often described. This would allow a larger sample of installed projects to be reviewed, and would provide direct data on which to base energy savings estimates.

4.3 HIGH BAY FLUORESCENT REPLACING HID

Group: Lighting

Category: Fluorescent, Linear

Technology Description: T-8 or T-5 linear fluorescent light fixtures replacing high bay HID light fixtures.

Qualifying Equipment:

- New fixtures must be replacing existing fixtures one-for-one, two-for-one, or in a consistent ratio which (adding fixture wattages together as appropriate) corresponds to the wattage requirements listed below.
- Fixtures must be installed indoors.
- Installed and removed fixture wattages must conform to the requirements shown in Table 4-39.

Table 4-39. Wattage Requirements for HID to Fluorescent Replacement

Tech. Code	Installed Wattage	Removed Wattage
2.5170.170	≤155	250–399
2.5180.170	≤365	400–999
2.5182.170	≤250	400–999
2.5185.170	≤800	1,000+
2.5186.170	≤500	1,000+

Date Deeming Last Modified: November 2008.[31]

Reviewed by: Jeremiah Robinson

Table 4-40. High Bay Fluorescent Replacing HID Measures, Existing Deemed Savings

Tech Code	Measure Description	Agriculture		Commercial		Industrial		Schools-Government	
		kW	kWh	kW	kWh	kW	kWh	kW	kWh
2.5170.170	T8 4 lamp or T5HO 2 lamp Replacing 250-399 W HID	0.1345	653	0.1345	550	0.1345	684	0.1061	478
2.5180.170	T8 6 lamp or T5HO 4 lamp Replacing 400-999 W HID	0.2120	1,029	0.2120	867	0.2120	1,078	0.1672	754
2.5182.170	T8 8 lamp or T5HO 6 lamp Replacing 400-999 W HID	0.1437	697	0.1437	587	0.1437	731	0.1133	511
2.5185.170	T8/T5HO <= 500 Watts Replacing >=1000 W HID	0.5589	2,713	0.5589	2,285	0.5589	2,842	0.4409	1,987
2.5186.170	T8 or T5HO <= 800W, Replacing >=1000 W HID	0.4244	2,060	0.4244	1,735	0.4244	2,158	0.3348	1,509

[31] 2.5182.170 added April 2007. 2.5185.170 added November 2008.

Savings Basis: Linear fluorescent light fixtures save energy when replacing high bay HID light fixtures because they are able to produce the same light output with a lower input wattage.

4.3.1 Existing deemed savings basis and estimates

This section provides a discussion of the measures as they are currently deemed.

A. SAVINGS EQUATIONS AND PARAMETERS

Savings due to replacing light fixtures are described by the following equations:

$$kW_{savings} = \left(\frac{Ltg.\ Watts_{old} - Ltg.\ Watts_{new}}{1000} \right) * CF$$

$$kW_{savings} = \left(\frac{Ltg.\ Watts_{old} - Ltg.\ Watts_{new}}{1000} \right) * Hours$$

where:

- Ltg. $Watts_{old}$ = lighting wattage of existing fixture, values in Table 4-41, watts
- Ltg. $Watts_{new}$ = lighting wattage of new fixture, values in Table 4-41, watts
- Hours = hours of use per year, values in Table 4-41, hr/yr
- CF = coincidence factor, values in Table 4-41, percent
- 1,000 = conversion factor, watts per kilowatt.

Existing Lighting Fixture Wattage, Ltg. $Watts_{old}$. The Existing Lighting Fixture Wattage is the total fixture wattage of the old fixture being replaced, including lamps and ballast.

New Lighting Fixture Wattage, Ltg. $Watts_{new}$. The New Lighting Fixture Wattage is the total fixture wattage of the new fixture being installed, including lamps and ballast.

Hours of Use, Hours. Hours of Use refers to the average annual operating hours of the light fixture and is measured in hours/year.

Coincidence Factor, CF. Coincidence Factor refers to the average percentage of total system wattage that is operating during the peak period and is measured in percent. The peak period is defined as 1–4 pm, Monday through Friday, June through August.

Table 4-41. Existing Deemed Savings Parameters

Tech Code	Measure Description	Technology		Agriculture		Commercial		Industrial		Schools-Government	
		New Watts	Old Watts	Hours	CF	Hours	CF	Hours	CF	Hours	CF
2.5170.170	T8 4 lamp or T5HO 2 lamp Replacing 250-399 W HID	146	295	4,368	90%	3,680	90%	4,576	90%	3,200	71%
2.5180.170	T8 6 lamp or T5HO 4 lamp Replacing 400-999 W HID	230	465								
2.5182.170	T8 8 lamp or T5HO 6 lamp Replacing 400-999 W HID	305	465								
2.5185.170	T8/T5HO <= 500 Watts Replacing >=1000 W HID	459	1,080								
2.5186.170	T8 or T5HO <= 800W, Replacing >=1000 W HID	608	1,080								

B. VALUES, ASSUMPTIONS, AND CALCULATIONS

i. Existing Lighting Fixture Wattage

Except for the 1000W replacement measures, it is unclear how the existing lighting fixture wattages were determined for each of these measures. There is no documentation available, except for data in a recent Focus spreadsheet that references standard wattages from the Advance and Universal ballast manufacturers. It appears that the deemed wattages may have been determined by selecting the wattage for the most popular existing fixture from the source listed and increasing it somewhat to account for other possible existing fixtures with higher wattages, as shown in Table 4-42.

The existing fixture wattage for the 1000W replacement measures is based on ASHRAE data for 1000W probe start MH fixture.

Table 4-42. Deemed Existing Fixture Wattages

Measure	Fixture	Fixture Wattage	Source	Deemed Wattage
2.5170.170	250W Probe Start MH	278	Universal	295
2.5180.170	400W Probe Start MH	459	Advance	465
2.5182.170	400W Probe Start MH	459	Advance	465
2.5185.170	1000W Probe Start MH	1,080	ASHRAE	1,080
2.5186.170	1000W Probe Start MH	1,080	ASHRAE	1,080

Here we see that the deemed wattages for all but 1000W replacements are slightly higher than the most popular fixture wattage as listed in the Focus spreadsheet. This may account for existing fixtures under these measures with higher wattages. For example, 320W Pulse Start MH fixtures could be replaced under measure 2.5170.170.

ii. New Lighting Fixture Wattage

Except for measure 2.5185.170, it is unclear how the new lighting wattages were developed. There is no documentation available, except for data in a recent Focus spreadsheet, which references standard wattages for fixtures without listing sources. Using these listed wattages, it is possible to reverse-engineer the calculations which were used to determine deemed wattages. Table 4-43 shows this process. For measure 2.5185.170, this calculation is shown in the deemed savings spreadsheet. For the other measures listed, the calculations were reverse-engineered.

Table 4-43. Deemed New Fixture Wattages and Possible Calculations

Measure	2.5170.170	2.5180.170	2.5182.170	2.5185.170
T5 Fixture	2L T5HO	4L T5HO	6L T5HO	8 lamp T5 HO
T5 Wattage	-	237	350	470
T5 Factor	-	60%	25%	50%
T8 Fixture	4L T8	6L T8	8L T8	(2) 6 lamp T8
T8 Wattage	146	219	290	448
T8 Factor	100%	40%	75%	50%
Deemed Wattage	146	230	305	459

Here we see calculations to determine deemed new lighting fixture wattages. As an example, deemed wattage for measure 2.5180.170 may have been based on an assumption of 60 percent 4-lamp T5HO fixtures and 40 percent 6-lamp T8 fixtures. For measure 2.5170.170, the T5 fixture was ignored and the wattage used was for the 4-lamp T8 fixture.

For measure 2.5186.170, there are not two obvious fixture choices to compare. Deemed new fixture wattage for this measure is 608W, which is slightly higher than that of the 10-lamp T5HO fixture (597) wattage but not close to any other fixture wattage or fixture combination.

iii. Hours of Use & Coincidence Factor

The values for hours of use and coincidence factor are those used for most lighting measures, deemed by sector. These sector-specific values are shown in Table 4-44.

Table 4-44. Existing Hours of Use and CF Values

Sector	Hours	CF
Agriculture	4,368	90%
Commercial	3,680	90%
Industrial	4,576	90%
Schools & Government	3,230	71%

Here we see that the Industrial sector has the highest hours of use at 4,576 hours/year and the Schools & Government sector the lowest at 3,230 hours/year. CF values are the same for Agriculture, Commercial, and Industrial. CF is lower for Schools & Government.

The development of these values, as well as a proposed update, is discussed in Section 4.1. For a thorough discussion of current and proposed lighting hours of use, refer to that section.

4.3.2 Literature review

Here we present the findings of various sources related to replacements of HID high bay light fixtures with fluorescent high bay light fixtures.

A. CALIFORNIA STANDARD PERFORMANCE CONTRACT (SPC)[32]

The California Standard Performance Contract (SPC) uses standard fixture wattage tables, published by Southern California Edison, for calculating energy savings for projects completed with assistance from that program. Among other things, the SPC serves as the catalog of prescriptive and deemed savings values used in California, much like the Deemed Savings Manual currently being put together for Wisconsin. The values listed in the SPC are used by many programs across the country as standard wattages for use when determining prescriptive and deemed savings.

Table 4-45 shows the standard wattages as reported by the SPC for various popular types of HID light fixtures.

Table 4-45. HID Fixture Wattages from the SPC

Fixture Type	Watts
1000W High Pressure Sodium	1,100
400W High Pressure Sodium	465
250W High Pressure Sodium	295
400W Mercury Vapor	455
250W Mercury Vapor	290
1000W Probe Start Metal Halide	1,080
750W Probe Start Metal Halide	850
400W Probe Start Metal Halide	458
250W Probe Start Metal Halide	295
750W Pulse Start Metal Halide	818
320W Pulse Start Metal Halide	365
250W Pulse Start Metal Halide	288

The table shows wattages for four different types of HID fixtures. Different fixture types use different input wattages for the same nominal output wattage. For instance, 400W high-pressure sodium, mercury vapor, and probe start metal halide use 465W, 455W, and 458W, respectively.

Table 4-46 shows the list of fluorescent fixture wattages listed in the SPC for T8 fixtures with high ballast factors (labeled VHLO) and T5HO fixtures.

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[32] Southern California Edison Business Incentives & Services Standard Performance Contract Program. *Standard Performance Contract.* “Appendix B: Table of Standard Fixture Wattages and Sample Lighting Table.” January 6, 2009.

Table 4-46. Fluorescent Ballast Wattages from the SPC

Fixture Type	Watts
2L F32T8 HBF	79
3L F32T8 HBF	112
4L F32T8 HBF	152
2L F54T5 HO	117
3L F54T5 HO	179
4L F54T5 HO	234

B. ADVANCE BALLAST CATALOG[33]

The Advance Atlas is generally agreed upon in the lighting design industry as the best source for wattages of specific ballast types. Advance Transformer Company is the best respected and most popular ballast manufacturer amongst lighting designers, and its wattages are taken as standard across the industry.

Table 4-47 shows the average wattages for various categories of ballasts sold by Advance for HID light fixtures. Wattages were determined by averaging the wattages of all products listed under the given category.

Table 4-47. HID Ballast Wattages from Advance

Fixture Type	Watts
1000W High Pressure Sodium	1,100
400W High Pressure Sodium	464
250W High Pressure Sodium	300
1000W Probe Start Metal Halide	1,080
400W Probe Start Metal Halide	460
250W Probe Start Metal Halide	295
750W Pulse Start Metal Halide	818
320W Pulse Start Metal Halide	365
250W Pulse Start Metal Halide	291

Table 4-48 shows the average wattages for various categories of ballasts sold by Advance for fluorescent light fixtures. Wattages were determined by averaging the wattages of all products listed under the given category. The ballasts chosen for T-8 fixtures are those with ballast factors in the range of 1.15-1.25.

Table 4-48. Fluorescent Ballast Wattages from Advance

Fixture Type	Watts
2L F32T8 HBF	77
3L F32T8 HBF	111
4L F32T8 HBF	144
2L F54T5 HO	119
3L F54T5 HO	182
4L F54T5 HO	237

[33] Advance Transformer Company. *Advance Atlas – 2008–2009.*

C. CEE LIST OF HIGH PERFORMANCE T8 QUALIFIED BALLASTS[34]

To develop standard wattages for fixtures at various ballast factors, we performed a review of the *CEE List of High Performance T8 Qualified Ballasts*. This source provides a list of ballast input wattages for a large number of T8 ballasts, grouped by number of lamps and ballast factor. Ballasts fall under three ballast factor categories as shown below in Table 4-49.

Table 4-49. CEE Ballast Factor Groups

Ballast Factor Category	Range
Low	0.70–0.85
Normal	0.86–1.00
High	1.01–1.33

Table 4-50 shows a list of the average wattages for ballasts in the CEE list in the high ballast factor group.

Table 4-50. Fluorescent Ballast Wattages from CEE

Fixture Type	Watts
2L F32T8 HBF	73
3L F32T8 HBF	110
4L F32T8 HBF	145

4.3.3 Proposed deemed savings basis and estimates

Based on the above research, we recommend that deemed savings estimates be updated as provided in this section.

A. DEVELOPMENT OF PROPOSED VALUES

i. Existing Lighting Fixture Wattage

Existing Lighting Fixture Wattage for these measures refers to the total fixture wattage of the old fixture being replaced, including lamps and ballast. In the previous round of deeming, values for existing fixture wattage appear to be based on data taken from ballast manufacturer catalogs or ASHRAE, as shown in Table 4-42. Documentation is not available as to how these values were developed, but it appears that they were determined by choosing the most popular fixture in each category and adjusting this wattage slightly upward to account for higher wattage fixtures that could be replaced by each measure.

Although the most popular replacement fixture will make up the vast majority of replacements, there are other fixtures that may be replaced by each measure in smaller quantities. These other fixtures generally have higher wattages than the most popular fixtures because of the way that the ranges were set up for these measures.

We propose to use this same method, adjusting it to use actual data for replaced fixtures from the WISeerts database. Based on a sample of 54 projects representing 15,015 total fixtures

[34] *Qualifying Products - High-Performance 120 and 277V T8 Ballasts*. CEE High-Performance Commercial Lighting Systems Initiative. Updated 03/31/09.

and nine percent of the total number of fixtures replaced, we determined the results shown in Table 4-51. This table shows the percentage of fixtures of each type which were replaced by each measure.

Table 4-51. Percentage of Fixtures Replaced by Each Measure [35]

Fixture Type	250–399W to 2/4 lamp	400–999W to 4/6 lamp	400–999W to 6/8 lamp	1000W to <=500W	1000W to 501–800W
1000W HPS	0%	0%	0%	2%	2%
400W HPS	0%	3%	3%	0%	0%
250W HPS	3%	0%	0%	0%	0%
400W MV	0%	1%	1%	0%	0%
250W MV	1%	0%	0%	0%	0%
1000W MH	0%	0%	0%	98%	98%
750W MH	0%	0%	1%	0%	0%
400W MH	0%	96%	95%	0%	0%
250W MH	96%	0%	0%	0%	0%
750W PS MH	0%	0%	0%	0%	0%
320W PS MH	0%	0%	0%	0%	0%
250W PS MH	0%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%

The table shows that, for 400-999W to 6/8 lamp replacements (measure 2.5182.170), 1 percent of replaced fixtures were 400W mercury vapor, 3 percent were 400W high-pressure sodium, 1 percent were 750W metal halide, and 95 percent were 400W metal halide.

To determine the wattages that are appropriate to apply to these existing fixture types, we turn to the sources cited in the literature review: the California SPC and the Advance Atlas, compared in Table 4-52.

Table 4-52. Comparison between HID Fixture Wattages from SPC and Advance

Fixture Type	Watts	
	SPC	Advance
1000W HPS	1,100	1,100
400W HPS	465	464
250W HPS	295	300
400W MV	455	-
250W MV	290	-
1000W MH	1,080	1,080
750W MH	850	-

[35] Averages based on 18MCP reviewed projects except for the following exceptions which occurred because of large, unusual projects:

- In 18MCP, 16% of 250–399W replaced fixtures were HPS (reduced to 3%, and reflected in other measures)
- In 18MCP, 3% of 400–999W replaced fixtures were mercury vapor (reduced to 1%, and reflected in other measures)
- In 18MCP, 5% of 400–999W to 6/8 lamp replaced fixtures were 600W MH (removed, as these are very rare fixtures).

Fixture Type	Watts	
	SPC	Advance
400W MH	458	460
250W MH	295	295
750W PS MH	818	818
320W PS MH	365	365
250W PS MH	288	291

The table shows that the values for each fixture type are very close between the two sources, without variation of more than five watts for any fixture type. We recommend using the values from the SPC in this case, as it has values for all fixture types and is commonly used for this purpose by many energy programs across the country. Combining the wattages provided by the California SPC and the percentages determined from the WISeerts database, we recommend the wattages shown in Table 4-53.

Table 4-53. Recommended Existing Lighting Fixture Wattages

Fixture Type	Watts	250-399W to 2/4 lamp	400-999W to 4/6 lamp	400-999W to 6/8 lamp	1000W to <=500W	1000W to 501-800W
1000W HPS	1,100	0%	0%	0%	2%	2%
400W HPS	465	0%	3%	3%	0%	0%
250W HPS	295	3%	0%	0%	0%	0%
400W MV	455	0%	1%	1%	0%	0%
250W MV	290	1%	0%	0%	0%	0%
1000W MH	1,080	0%	0%	0%	98%	98%
750W MH	850	0%	0%	1%	0%	0%
400W MH	458	0%	96%	95%	0%	0%
250W MH	295	96%	0%	0%	0%	0%
750W PS MH	818	0%	0%	0%	0%	0%
320W PS MH	365	0%	0%	0%	0%	0%
250W PS MH	288	0%	0%	0%	0%	0%
	Total	100%	100%	100%	100%	100%
Average Watts		295 W	458 W	462 W	1,080 W	1,080 W

ii. New Lighting Fixture Wattage

New Lighting Fixture Wattage is the total fixture wattage of the new fixture being installed, including lamps and ballast. The source of the new fixture wattages is not clear in the current deemed savings definition. A recent Focus spreadsheet lists fixture wattages without a source. Using reverse engineering, it was possible to determine likely calculations for most measures based on a weighting system as shown in Table 4-43.

Since data and sources supporting these values are not available, we recommend using values from sources reviewed under this round of deeming to develop new deemed values. Using the sample from the WISeerts database discussed above, we determined the results shown in Table 4-54. This table shows the percentage of fixtures of each type which were installed as a result of each measure.

Table 4-54. Percentage of Fixtures Installed by Each Measure

Fixture Type	250-399W to 2/4 lamp	400-999W to 4/6 lamp	400-999W to 6/8 lamp	1000W+ to <=500W	1000W+ to 501-800W
4L F32T8 HBF	100%	2%	0%	0%	0%
6L F32T8 HBF	0%	48%	0%	7%	0%
8L F32T8 HBF	0%	0%	2%	13%	0%
16L F32T8 HBF	0%	0%	0%	0%	28%
2L F54T5 HO	0%	13%	0%	0%	0%
4L F54T5 HO	0%	37%	0%	3%	0%
6L F54T5 HO	0%	0%	98%	54%	0%
(2) 4L F54T5 HO	0%	0%	0%	2%	0%
8L F54T5 HO	0%	0%	0%	21%	0%
10L F54T5 HO	0%	0%	0%	0%	63%
(2) 6L F54T5 HO	0%	0%	0%	0%	9%
Total	100%	100%	100%	100%	100%

The table shows that, for 400–999W to 6/8 lamp replacements (measure 2.5182.170), 2 percent of installed fixtures were 8-lamp T-8 fixtures and 98 percent were 6-lamp T5HO fixtures.

To determine the wattages that are appropriate to apply to these existing fixture types, we turn to the sources cited in the literature review: the California SPC, the Advance Atlas, and the CEE High Performance T8 Ballast List shown in Table 4-55.

Table 4-55. Comparison between Fluorescent Fixture Wattages from SPC, Advance, and CEE

Fixture Type	Watts		
	SPC	Advance	CEE
2L F32T8 HBF	79	77	73
3L F32T8 HBF	112	111	110
4L F32T8 HBF	152	144	145
6L F32T8 HBF	228	221.5	218
8L F32T8 HBF	304	288	289
10L F32T8 HBF	383	365	362
16L F32T8 HBF	608	576	578
2L F54T5 HO	117	119	-
3L F54T5 HO	179	182	-
4L F54T5 HO	234	237	-
6L F54T5 HO	355	360	-
(2) 4L F54T5 HO	468	474	-
8L F54T5 HO	468	474	-
10L F54T5 HO	585	593	-
(2) 6L F54T5 HO	709	720	-

The table shows that the SPC has the highest wattages for T-8 fixtures and the lowest for T-5 fixtures. Advance has the highest T-5 wattages. The CEE has the lowest wattages for T-8 ballasts, but does not list data for T-5 ballasts. Where wattages do not correspond to those listed by the sources, ballast wattages are added to reflect multiple ballasts being used in one fixture just as they are in actual installations. For example, 10-lamp fixture wattage is made up of (2) 4-lamp ballasts and (1) 2-lamp ballast.

We recommend using the values reported by Advance, as it is used as the industry standard amongst designers, has values for all fixture types, and lists the ballast factors that were used to determine input wattage. The SPC does not specify the ballast factor used to determine input wattage. The CEE list only catalogs the most efficient T-8 ballasts and so does not include the less efficient ballasts that can qualify for these measures.

Combining the wattages provided by the Advance Atlas and the percentages determined from the WISeerts database, we recommend the wattages shown below in Table 4-56.

Table 4-56. Recommended New Lighting Fixture Wattage

Fixture Type	Watts	250–399W to 2/4 lamp	400–999W to 4/6 lamp	400–999W to 6/8 lamp	1000W+ to <=500W	1000W+ to 501–800W
4L F32T8 HBF	144	100%	2%	0%	0%	0%
6L F32T8 HBF	222	0%	48%	0%	7%	0%
8L F32T8 HBF	288	0%	0%	2%	13%	0%
16L F32T8 HBF	576	0%	0%	0%	0%	28%
2L F54T5 HO	119	0%	13%	0%	0%	0%
4L F54T5 HO	237	0%	37%	0%	3%	0%
6L F54T5 HO	360	0%	0%	98%	54%	0%
(2) 4L F54T5 HO	474	0%	0%	0%	2%	0%
8L F54T5 HO	474	0%	0%	0%	21%	0%
10L F54T5 HO	593	0%	0%	0%	0%	63%
(2) 6L F54T5 HO	720	0%	0%	0%	0%	9%
	Total	100%	100%	100%	100%	100%
	Average Watts	144 W	212 W	359 W	363 W	535 W

iii. Hours of Use and Coincidence Factor

Hours of use and coincidence factors are currently based on sector. We recommend that hours of use and coincidence factor be based on building type as developed and discussed in Section 4.1. These values are presented in Table 4-57.

Table 4-57. Hours of Use and Coincidence Factors by Building Type

Building Use	Hours	CF
Food Sales	5,544	92%
Food Service	4,482	84%
Health Care	3,677	78%
Hotel/Motel	3,356	35%
Office	3,526	77%
Public Assembly	2,729	67%
Public Services	3,425	64%
Retail	4,226	84%
Warehouse	3,464	79%
School	2,302	52%
College	3,900	68%
Dormitory	986	7%
Industrial	4,745	77%
Agricultural	4,698	67%
Other	3,672	67%

B. PROPOSED EQUATIONS, PARAMETERS, AND DEEMED VALUES

i. Proposed Equations and Parameters

In conclusion, we recommend the following formulas be used to calculate deemed savings for high bay fluorescent fixtures replacing HID fixtures.

Savings due to replacing light fixtures are described by the following equations:

$$kW_{savings} = \left(\frac{Ltg.\ Watts_{old} - Ltg.\ Watts_{new}}{1000} \right) * CF$$

$$kW_{savings} = \left(\frac{Ltg.\ Watts_{old} - Ltg.\ Watts_{new}}{1000} \right) * Hours$$

where:

- Ltg. $Watts_{old}$ = lighting wattage of existing fixture, values in Table 4-58, watts
- Ltg. $Watts_{old}$ = lighting wattage of new fixture, values in Table 4-58, watts
- Hours = hours of use per year, values in Table 4-59, hr/yr
- CF = coincidence factor, values in Table 4-59, percent
- 1,000 = conversion factor, watts per kW.

Existing Lighting Fixture Wattage, Ltg. $Watts_{old}$. The Existing Lighting Fixture Wattage is the total fixture wattage of the old fixture being replaced, including lamps and ballast.

New Lighting fixture Wattage, Ltg. $Watts_{new}$. The New Lighting Fixture Wattage is the total fixture wattage of the new fixture being installed, including lamps and ballast.

Hours of Use, Hours. Hours of Use refers to the average annual operating hours of the light fixture and is measured in hours/year.

Coincidence Factor, CF. Coincidence Factor refers to the average percentage of total system wattage that is operating during the peak period and is measured in percent. The peak period is defined as 1–4 pm, Monday through Friday, June through August.

ii. Proposed Deemed Values

Table 4-58 shows the proposed lighting wattages for these measures.

Table 4-58. Proposed Deemed Lighting Wattages

Measure Description	New Watts	Old Watts
T8 4 lamp or T5HO 2 lamp Replacing 250-399 W HID	144	295
T8 6 lamp or T5HO 4 lamp Replacing 400-999 W HID	212	458
T8 8 lamp or T5HO 6 lamp Replacing 400-999 W HID	359	462
T8/T5HO <= 500 Watts Replacing >=1000 W HID	363	1,080
T8 or T5HO <= 800W, Replacing >=1000 W HID	535	1,080

Substituting the above values into the savings equations yields the proposed deemed savings values for this measure, found in Table 4-59. If the PSC decides not to accept the building use lighting hours and CF definition, KEMA recommends using the alternative sector-level savings for this measure in Appendix C.

Table 4-59. Proposed Deemed Parameters and Savings Values by Measure Tech Code

			2.5170.170		2.5180.170		2.5182.170		2.5185.170		2.5186.170	
Building Use	Hours	CF	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Food Sales	5,544	92%	0.1388	837	0.2265	1,366	0.0952	574	0.6592	3,975	0.5016	3,025
Food Service	4,482	84%	0.1269	677	0.2070	1,104	0.0870	464	0.6025	3,214	0.4584	2,445
Health Care	3,677	78%	0.1180	555	0.1925	906	0.0809	381	0.5604	2,636	0.4264	2,006
Hotel/Motel	3,356	35%	0.0528	507	0.0861	827	0.0362	347	0.2505	2,406	0.1906	1,831
Office	3,526	77%	0.1156	532	0.1886	869	0.0793	365	0.5489	2,528	0.4177	1,923
Public Assembly	2,729	67%	0.1006	412	0.1641	672	0.0690	283	0.4776	1,956	0.3634	1,489
Public Services	3,425	64%	0.0959	517	0.1564	844	0.0657	355	0.4552	2,456	0.3464	1,869
Retail	4,226	84%	0.1275	638	0.2081	1,041	0.0875	438	0.6055	3,030	0.4608	2,305
Warehouse	3,464	79%	0.1192	523	0.1945	853	0.0818	359	0.5661	2,484	0.4308	1,890
School	2,302	52%	0.0792	347	0.1292	567	0.0543	238	0.3760	1,650	0.2861	1,256
College	3,900	68%	0.1026	589	0.1675	961	0.0704	404	0.4875	2,796	0.3710	2,128
Dormitory	986	7%	0.0106	149	0.0172	243	0.0072	102	0.0502	707	0.0382	538
Industrial	4,745	77%	0.1163	716	0.1898	1,169	0.0798	491	0.5523	3,402	0.4203	2,589
Agricultural	4,698	67%	0.1010	709	0.1648	1,157	0.0693	486	0.4797	3,368	0.3650	2,563
Other	3,672	67%	0.1006	554	0.1641	905	0.0690	380	0.4776	2,633	0.3634	2,003

For comparison, the current deemed savings values are presented below in Table 4-60.

Table 4-60. Current Deemed Savings Values

Tech Code	Measure Description	Agriculture		Commercial		Industrial		Schools-Government	
		kW	kWh	kW	kWh	kW	kWh	kW	kWh
2.5170.170	T8 4 lamp or T5HO 2 lamp Replacing 250-399 W HID	0.1345	653	0.1345	550	0.1345	684	0.1061	478
2.5180.170	T8 6 lamp or T5HO 4 lamp Replacing 400-999 W HID	0.2120	1,029	0.2120	867	0.2120	1,078	0.1672	754
2.5182.170	T8 8 lamp or T5HO 6 lamp Replacing 400-999 W HID	0.1437	697	0.1437	587	0.1437	731	0.1133	511
2.5185.170	T8/T5HO <= 500 Watts Replacing >=1000 W HID	0.5589	2,713	0.5589	2,285	0.5589	2,842	0.4409	1,987
2.5186.170	T8 or T5HO <= 800W, Replacing >=1000 W HID	0.4244	2,060	0.4244	1,735	0.4244	2,158	0.3348	1,509

iii. Confidence in Proposed Savings

The values for the old and new wattages were obtained through simple calculations based directly on strong sources, some of which are Focus on Energy-specific. Only minor assumptions were made which resulted in miniscule adjustments to the savings estimates. Due to the simplicity of the calculations and the quality of the sources, we believe that these values are accurate, though not necessarily conservative. Therefore, we feel that the savings from this measure will be realized.

iv. Recommended Further Research

The parameter estimates for these measures are straightforward and accurately obtained but improvements can always be made. One way to increase confidence in the old and new wattage estimates is to better track in WISeerts data for installed fixtures (fixture type, number of lamps, and ballast factor) and a basic description of what was removed. Ballast factors are normally available on invoices and/or cut sheets, but removed fixtures are not often described. This would allow a larger sample of installed projects to be reviewed, and would provide direct data on which to base energy savings estimates.

The current and proposed calculation for this measure assumes that the operating hours of the fixtures remain constant before and after the fluorescent fixture installation. This is likely not the case, as HID lights require an extensive warm-up time which often causes operators to turn on the lights early in the operating period and only turn them off when they are guaranteed to no longer be needed. Fluorescent lights can be turned on and off at will and are more likely to be operated only when needed. We were unable to find any sources that specifically addressed this issue. Therefore, we recommend that a pre- and post- installation metering study be conducted to improve the estimates for hours of use and coincidence factor for high bay applications. For further recommendations on the hours of use and coincidence factor parameters for non-high bay applications, see Section 4.1.

4.4 OCCUPANCY SENSORS FOR HIGH BAY FLUORESCENT FIXTURES

Group: Lighting

Category: Controls

Technology Code: 2.5192.085

Technology Description: Occupancy sensor for high bay fluorescent fixtures, per fixture controlled.

Qualifying Equipment: Indoor wall, ceiling, or fixture mounted occupancy sensor used to control a high bay fluorescent fixture.

Date Deeming Last Modified: November 2008

Reviewed by: Jeremiah Robinson

Table 4-61. Occupancy Sensors for High Bay Fluorescent Fixtures, Existing Deemed Savings

Tech Code	Measure Description	Savings							
		Agriculture		Commercial		Industrial		Schools-Government	
		kW	kWh	kW	kWh	kW	kWh	kW	kWh
2.5192.085	Occupancy sensor for high bay fluorescent fixtures, per fixture controlled	0.0000	676	0.0000	569	0.0000	708	0.0000	344

Savings Basis: Occupancy sensors control lighting operation by turning off fixtures if they do not sense motion in an area. Sensors can detect people through infrared or ultrasonic methods or both. One sensor can control a single fixture or multiple fixtures. The sensor turns off the fixture(s) if motion is not detected over an adjustable period of time, typically between 5 and 120 minutes.

4.4.1 Existing deemed savings basis and estimates

This section provides a discussion of the measure as it is currently deemed.

A. SAVINGS EQUATIONS AND PARAMETERS

Savings due to occupancy sensor installation are described by the following equations:

$$kW_{savings} = \left(\frac{\text{Ltg. Watts}}{1000}\right) * CF$$

$$kWh_{savings} = \left(\frac{\text{Ltg. Watts}}{1000}\right) * \%\,Off * Hours$$

where:

- Ltg. Watts = lighting wattage controlled, deemed 247 watts

- Hours = baseline hours per year, values in Table 4-62, hr/yr
- % Off = percent of time lights are controlled, values in Table 4-62, percent
- CF = coincidence factor, deemed 0 percent.

Lighting Wattage, Ltg. Watts. Since the savings for this measure are determined per controlled fixture, the Lighting Wattage is equal to the average wattage of the fixtures controlled including lamps and ballasts.

Hours of Use, Hours. Hours of Use refers to the annual hours that the fixtures would have operated without the occupancy sensor.

Coincidence Factor, CF. Coincidence Factor refers to the average percentage of time during peak demand hours that the lights will be off due to occupancy sensor operation when they otherwise would have been on. The peak period is defined as 1–4 pm, Monday through Friday, June through August.

Percent Off, % Off. Percent Off refers to the percentage of time that the lights will be off due to occupancy sensor operation when they otherwise would have been on.

Table 4-62. Existing Deemed Savings Parameters

Tech Code	Measure Description	Parameters															
		Agriculture				Commercial				Industrial				Schools-Government			
		% Off	Hours	CF	Avg. Watts	% Off	Hours	CF	Avg. Watts	% Off	Hours	CF	Avg. Watts	% Off	Hours	CF	Avg. Watts
2.5192.085	Occupancy sensor for high bay fluorescent fixtures, per fixture controlled	62.5%	4,368	0%	247	62.5%	3,680	0%	247	62.5%	4,576	0%	247	43.0%	3,230	0%	247

B. VALUES, ASSUMPTIONS, AND CALCULATIONS

i. Lighting Wattage

When first deemed, the average lighting wattage was determined by using a weighted average (by number of projects) of the fluorescent fixture wattages installed as part of HID-to-fluorescent replacement measures reported in the WISeerts database. This value is the same for all sectors, at 247 watts.

The development of the HID-to-fluorescent replacement wattages, as well as a proposed update, is discussed in Section 4.3. For a thorough discussion of current and proposed HID-to-fluorescent replacement lighting wattage, refer to that section.

ii. Hours of Use

The values for Hours of Use are those used for most lighting measures, deemed by sector. These sector-specific values are shown in Table 4-63.

Table 4-63. Existing Hours of Use Values

Sector	Hours
Agriculture	4,368
Commercial	3,680
Industrial	4,576
Schools & Government	3,230

The table shows that the Industrial sector has the highest hours of use at 4,576 hours/year and the Schools & Government sector the lowest at 3,230 hours/year.

The development of these values, as well as a proposed update, is discussed in Section 4.1. For a thorough discussion of current and proposed lighting hours of use, refer to that section.

iii. Percent Off

The Percent Off values were based on data from the EPA as presented on the E-Source website.[36] These values are sector-specific, and are shown in Table 4-64.

Table 4-64. Existing Percent Off Values

Sector	% Off
Agriculture	62.5%
Commercial	62.5%
Industrial	62.5%
Schools-Government	43.0%

The calculation for the last round of deeming used data for “Storage Area/Closet” for the Commercial, Industrial, and Agriculture sectors to represent energy savings in warehouses, with a value of 62.5 percent. Data for “Classrooms” was used for the Schools & Government sector to represent energy savings in gymnasiums, with a value of 43 percent.

iv. Coincidence Factor

The Coincidence Factor is currently deemed as 0 percent for all sectors. The peak period of 1 pm to 4 pm, Monday through Friday, June through August, is a time of high occupancy for most building types, so it was judged that occupancy sensors are unlikely to control lights during this time.

Substituting the above values into the savings equations yields the deemed savings values presented in Table 4-61.

4.4.2 Literature review

Here we present the findings of various sources related to high bay fluorescent occupancy sensor applications.

[36] Section of the E-Source website describing EPA energy savings estimates for occupancy sensors: http://www.esource.com/BEA/demo/BEA_esource/PA_10.html.

A. E-SOURCE [37]

This section of the E-Source website serves as a buyer's guide to occupancy sensors. It includes a table that presents data, reportedly from the EPA, on a range of percent off values for occupancy sensors by space type. These values are shown in Table 4-65. This is the source primarily used to develop the previous round of deemed savings values.

Table 4-65. E-Source Percent Off Values

Space Type	% Off
Private Office	13–50%
Open-plan office	20–28%
Classroom	40–46%
Conference Room	22–65%
Restroom	30–90%
Corridors	30–80%
Storage area/Closet	45–80%

B. CALIFORNIA STANDARD PERFORMANCE CONTRACT PROGRAM (SPC) [38]

The California Standard Performance Contract Program (SPC) uses standard Percent Off tables, published by Southern California Edison, for calculating energy savings for projects completed with assistance from that program. Among other things, the SPC serves as the catalog of prescriptive and deemed savings values used in California, much like the Deemed Savings Manual currently being put together for Wisconsin.

For occupancy sensors, California's SPC provides percent off values for a number of different space types as shown in Table 4-66. According to the SPC, occupancy sensors are most effective in Industrial areas and warehouses with a 45 percent off value.

Table 4-66. California SPC Percent Off Values

Space Type	% Off
Gymnasium	35%
Industrial	45%
Public Assembly	35%
Retail	15%
Warehouses	45%

In addition, the SPC specifies that during peak hours this percent off value should be multiplied by 0.40 to determine coincidence factor. In other words, according to the SPC, during peak hours the occupancy sensors are 40 percent as effective as they are during the rest of the operation period. This is due to the generally higher level of commercial activity

[37] Section of the E-Source website describing EPA energy savings estimates for occupancy sensors: http://www.esource.com/BEA/demo/BEA_esource/PA_10.html.

[38] Southern California Edison Business Incentives & Services Standard Performance Contract Program. *Standard Performance Contract.* "Section 2: Estimating Energy Savings and Incentives." January 6, 2009.

during peak hours. Multiplying by 0.40 results in the values for coincidence factor shown in Table 4-67.

Table 4-67. California SPC Coincidence Factors

Space Type	CF
Gymnasium	14%
Industrial	18%
Public Assembly	14%
Retail	6%
Warehouses	18%

The peak demand period for the SPC study is defined as follows:

> *"the average grid level impact for a measure between 2:00 p.m. and 5:00 p.m. during the three consecutive weekday periods containing the weekday temperature with the hottest temperature of the year."*

C. LIGHTING RESEARCH CENTER (LRC) [39]

A study was performed by the Lighting Research Center (LRC) in coordination with the DOE's ENERGY STAR program resulting in the report *An Analysis of the Energy and Cost Savings Potential of Occupancy Sensors for Commercial Lighting Systems*. The study included a literature review of the best sources existing at the time of its writing. Table 4-68 shows the percent off values resulting from this literature review for warehouses.

Table 4-68. LRC Percent Off Values

Study	% Off (Warehouses)
CEC	50–75%
EPRI	55%
Novitas	70–90%
Watt Stopper	50–75%
Average	65%

The table shows a range of estimates, from a low of 55 percent to a high of 70–90 percent. This source included data for other spaces besides warehouses, but warehouses was the only space type included in the study where high bay lighting is commonly used.

One of the sources cited in this table, EPRI, was also used in the last round of occupancy sensor deeming. We were not able to find a copy of the EPRI source to review directly.

[39] Bill VonNeida, Lighting Research Center; Dorene Maniccia and Allan Tweed, U.S. EPA. *An Analysis of The Energy and Cost Savings Potential of Occupancy Sensors for Commercial Lighting Systems.* August 16, 2000.

D. RLW SCHOOLS STUDY [40]

The *CT & MA Utilities 2004-2005 Lighting Hours of Use for School Buildings Baseline Study* is a metering study of school buildings in New England conducted by RLW Analytics. The study involved installing 600 combination lighting/occupancy loggers at 80 schools during 2006. The loggers were installed in spaces that did not have occupancy sensor controls. The logger was able to capture both the on/off operating hours of the lights and the occupied/unoccupied nature of the space. Data from the loggers was collected and analyzed to produce estimates of the potential savings and coincidence factors for occupancy sensor installation. The results of this study for gymnasiums are shown in Table 4-69.

Table 4-69. RLW Study Percent Off and Coincidence Factor Values

Space Type	% Off	C.F.
Gymnasium	48%	15%

The table shows that the percent off value of 48 percent is just over three times the coincidence factor of 15 percent. The peak demand period for this study is 3–5 pm, Monday through Friday, June through September.

E. EFFICIENCY MAINE [41]

The *Technical Reference User Manual* is put together by Efficiency Maine serves as the catalog of prescriptive and deemed savings values used in Maine, much like the Deemed Savings Manual currently being put together for Wisconsin.

Table 4-70 shows Maine's estimates for percent off values for gymnasiums and warehouses. The table shows that warehouses have a significantly higher percent off value than gymnasiums according to this source.

Table 4-70. Efficiency Maine Percent Off Values

Space Type	% Off
Gymnasiums	35%
Warehouses	50%

4.4.3 Proposed deemed savings basis and estimates

Based on the above research, we recommend that the deemed savings estimates be updated as provided in this section.

[40] RLW Analytics. *CT & MA Utilities 2004-2005 Lightng Hours of Use for School Buildings Baseline Study – Final Report.* September 7, 2006.

[41] Efficiency Maine. *Technical Reference User Manual.* March 5, 2007.

A. DEVELOPMENT OF PROPOSED VALUES

i. Lighting Wattage

Lighting Wattage refers to the wattage controlled by the occupancy sensor being installed. This occupancy sensor measure is specified as an add-on to HID-to-fluorescent replacement measures, which have deemed replacement wattage values associated with them.

In the previous round of deeming, a review was done of the WISeerts database to determine the average installed fluorescent wattage for the HID-to-fluorescent replacement measures. Here we present a similar analysis with updated data.

To determine the average wattage controlled, we reviewed data from the WISeerts database for HID-to-fluorescent replacement measures. We found the average of the deemed wattages weighted by the total number of installed measures for each measure type. We also created separate values for each sector because different wattages are more or less prevalent in some sectors. The results of the analysis are found in Table 4-71.

Table 4-71. Weighted Average HID-to-Fluorescent Lighting Replacement Wattage

Tech Code	Measure	Watts	Distribution of Savings Across Sectors				
			Ag	Com	Ind	S&G	Total
2.517	T8 4 lamp or T5HO 2 lamp Replacing 250-399 W HID	144	13.9%	5.1%	9.7%	18.5%	9.0%
2.518	T8 6 lamp or T5HO 4 lamp Replacing 400-999 W HID	212	73.5%	61.4%	74.9%	70.4%	70.7%
2.5182	T8 8 lamp or T5HO 6 lamp Replacing 400-999 W HID	359	12.6%	30.4%	10.3%	9.2%	16.0%
2.5185	T8 or T5HO <= 500W, Replacing >=1000 W HID	363	0.0%	2.5%	4.4%	1.1%	3.6%
2.5186	T8 or T5HO <= 800W, Replacing >=1000 W HID	535	0.0%	0.6%	0.7%	0.7%	0.7%
		Total	100%	100%	100%	100%	100%
		Average Watts	221	259	230	217	237

The overall average wattage across sectors is 237 watts. The values for lighting wattage could be defined by sector, as the analysis results show variation between sectors. However, by moving to a building-type definition for other savings values such as hours of use, coincidence factor, and percent off, deeming lighting wattage by sector does not make sense.

ii. Hours of Use

Hours of Use refers to the number of hours that the lights would have been on in baseline conditions without occupancy sensor control. In the previous method of deeming, the hours of use values that were deemed for other lighting measures were used for this measure as well.

We recommend using this method again. We believe that it is the most accurate method because this measure is an add-on to other lighting measures that use these same hours of use values. Table 4-72 shows the proposed new values based on the analysis in Section 4.1.

Table 4-72. Lighting Hours of Use

Building Use	Hours
Food Sales	5,544
Food Service	4,482
Health Care	3,677
Hotel/Motel	3,356
Office	3,526
Public Assembly	2,729
Public Services (non-food)	3,425
Retail	4,226
Warehouse	3,464
School	2,302
College	3,900
Dormitory	986
Industrial	4,745
Agriculture	4,698
Other	3,672

It should be noted that we considered adjusting the baseline hours of use to represent a non-occupancy sensor controlled fixture. This would have accounted for the fact that the above hours of use include some percentage of lighting systems that are currently controlled by occupancy sensors. We abandoned this effort for two reasons. First, some of the fixtures in the baseline conditions for this measure may actually be controlled by occupancy sensors (HID hi/lo switching). Second, we reviewed several studies regarding the installation rates of occupancy sensors and found that less than two percent of installed lighting is currently occupancy sensor controlled. Therefore, occupancy sensors are not prevalent enough to significantly alter the above hours.

iii. Percent Off

Percent Off represents the percentage of time that the fixtures, on average, will be turned off by the occupancy sensors when they would otherwise have been on. In the previous method of deeming, the percent off value was based primarily on one study done by E-Source, discussed above in Section 4.4.2a. We do not suggest using the same values in this review because this source does not specifically provide data for areas where high bay fixtures are typically installed. When this measure was first deemed, it was assumed that classrooms are similar enough to gymnasiums and storage rooms similar enough to warehouses to make the data applicable. However, given that other data is available, we suggest that these approximations are unnecessary.

For this round of deeming, we reviewed approximately two dozen papers on occupancy sensor usage and found four that included data specific to high-bay lighting applications. Data for non-high-bay lighting is much more readily available but is not directly applicable to this measure. These four papers are discussed above in the literature review and summarized in Table 4-73, which also shows the average of the percent off values from the various sources. The “Other” category is the average of the five specified categories.

Table 4-73. Percent Off Values from Various Sources

Space Type	Cal. SPC	RLW Schools	LRC	Maine	Avg.
Gymnasiums	35%	48%	-	35%	39%
Industrial	45%	-	-	-	45%
Retail	15%	-	-	-	15%
Warehouses	45%	-	65%	50%	53%
Public Assembly	35%	59%	-	-	47%
Other	-	-	-	-	40%

The table shows that Retail lighting has the lowest percent off value at 15 percent and Warehouses have the highest value at 53 percent. This is not unexpected, as an aisle of a warehouse may often go for hours without anyone passing through it. However, if an aisle of a big box store often went without customers, managers would probably stop selling the products in that aisle.

The values in the “Avg.” column are the recommended percent off values, determined by space type. We considered weighting the results of the studies given the relative accuracy of the methods used. However, with the exception of the RLW Schools study, none of the sources included information on how the results were determined such as data collection methodology or secondary source review. This left us without clear criteria for weighting; therefore, we calculated a straight average. The results used from the LRC study were actually pulled from several sources and reported comparison values to the LRC metered results. The original sources were published ten to twenty years ago. They could have been referenced separately but due to their age were weighted as a single study.

iv. Coincidence Factor

The Coincidence Factor represents the average percentage of time during peak demand hours that the fixtures will be turned off by the occupancy sensors when they otherwise would have been on. The previous method of deeming assumed that the coincidence factor was zero. Spaces are more likely to be fully occupied during peak periods and therefore savings are less likely to occur. However, while the coincidence factor may be low, it should not be zero, as some lights will likely be turned off by the occupancy sensor during the peak period.

For this round of deeming, we were able to find two papers with data for occupancy sensor coincidence factors specific to high-bay applications. These two papers are discussed above in the literature review and summarized in Table 4-74, which also shows the average of the coincidence factor values from both sources. The table shows the same trend that we saw for the percent off value, with Warehouses and Industrial having the highest value at 18 percent and Retail the lowest at 6 percent. The “Other” category is the average of the five specified categories. The values in the “Avg.” column are the recommended percent off values, determined by space type. As discussed above, these sources are un-weighted due to the lack of clear criteria from which to develop a weighting method.

Table 4-74. Coincidence Factors from Various Sources

Type of Space	Cal. SPC	RLW Schools	Avg.
Gymnasiums	14%	15%	15%
Industrial	18%	-	18%
Retail	6%	-	6%
Warehouses	18%	-	18%
Public Assembly	14%	10%	12%
Other	-	-	14%

Since different utilities and different states have different peak demand periods and different methods for measuring peak kW, we also include a discussion of the methods used in the two papers. The peak demand calculation method that is used in the RLW schools study[42] is different from Focus on Energy's peak demand period primarily in that September is included. One would expect that including September in the peak period would increase lighting use during the peak period due to the students being back in school. However, looking at coincidence factor values for general, non-occupancy sensor controlled lighting elsewhere in the report (generally in the 0.30 range), that does not appear to have happened. Because the expected difference in the coincidence factors based on the difference in peak demand periods is not apparent in the study's conclusions, we believe that the values determined in this study are also applicable to Wisconsin.

The peak demand calculation method that is used in the California Standard Performance Contract[43] Program is very different from that used in Wisconsin. The peak demand period for SPC is defined as follows:

> *"the average grid level impact for a measure between 2:00 p.m. and 5:00 p.m. during the three consecutive weekday periods containing the weekday temperature with the hottest temperature of the year."*

These three days would most likely occur during Focus on Energy's peak demand period (June–August). Since lighting is not HVAC dependent, the peak kW for lighting in Wisconsin should not vary significantly over the peak demand months. Also, the periods of the day used for both states are similar (2–5 pm for SPC vs. 1–4 pm for Focus). For these reasons, we feel that the coincidence factors presented in the California SPC are applicable to Wisconsin.

B. PROPOSED EQUATIONS, PARAMETERS, AND DEEMED VALUES

i. Proposed Equations and Parameters

In conclusion, we recommend the following formulas be used to calculate deemed savings for high bay occupancy sensors.

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[42] RLW Analytics. *CT & MA Utilities 2004–2005 Lighting Hours of Use for School Buildings Baseline Study – Final Report.* September 7, 2006.

[43] Southern California Edison Business Incentives & Services Standard Performance Contract Program. *Standard Performance Contract.* "Section 2: Estimating Energy Savings and Incentives." January 6, 2009.

Energy savings for this measure are calculated using the following formulas:

$$kW_{savings} = \left(\frac{Ltg.\ Watts}{1000}\right) * CF$$

$$kWh_{savings} = \left(\frac{Ltg.\ Watts}{1000}\right) * \%\ Off * Hours$$

where:

- Ltg. Watts = lighting wattage controlled, values in Table 4-75, watts
- Hours = baseline hours per year, values in Table 4-75, hr/yr
- CF = coincidence factor, values in Table 4-75, percent
- % Off =percent of time lights are controlled, values in Table 4-75, percent
- 1,000 = conversion factor, watts per kilowatt

Lighting Wattage, Ltg. Watts. Since the savings for this measure are determined per controlled fixture, the Lighting Wattage is equal to the average wattage of the fixtures controlled including lamps and ballasts.

Hours of Use, Hours. Hours of Use refers to the annual hours that the fixtures would have operated without the occupancy sensor.

Coincidence Factor, CF. Coincidence Factor refers to the average percentage of time during peak demand hours that the lights will be off due to occupancy sensor operation when they otherwise would have been on.

Percent Off, % Off. Percent Off refers to the percentage of time that the lights will be off due to occupancy sensor operation when they otherwise would have been on.

ii. Proposed Deemed Values

Substituting the values into the savings equations yields the proposed deemed savings values for this measure, found in Table 4-75. If the PSC decides not to accept the building use lighting hours and CF definition, KEMA recommends using the alternative sector-level savings for this measure in Appendix D.

Table 4-75. Proposed Deemed Savings and Parameters

Building Type	Hours	kWh Savings by Space Type					
		Gymnasium	Industrial	Retail	Warehouse	Public Assembly	Other
Food Sales	5,544	517	591	197	701	618	525
Food Service	4,482	418	478	159	567	499	424
Health Care	3,677	343	392	131	465	410	348
Hotel/Motel	3,356	313	358	119	424	374	318
Office	3,526	329	376	125	446	393	334
Public Assembly	2,729	254	291	97	345	304	258
Public Services	3,425	319	365	122	433	382	324
Retail	4,226	394	451	150	534	471	400
Warehouse	3,464	323	370	123	438	386	328
School	2,302	215	246	82	291	256	218
College	3,900	364	416	139	493	434	369
Dormitory	986	92	105	35	125	110	93
Industrial	4,745	442	506	169	600	529	449
Agriculture	4,698	438	501	167	594	523	445
Other	3,672	342	392	131	464	409	348
Percent Off		39%	45%	15%	53%	47%	40%
Coincidence Factor		15%	18%	6%	18%	12%	14%
kW Savings		**0.034**	**0.043**	**0.014**	**0.043**	**0.028**	**0.032**

iii. Comparison with Current Values

Table 4-76 below shows the current deemed savings parameters, for comparison.

Table 4-76. Current Deemed Savings Values

Tech. Code	Measure Description	Watt-age	CF	Agriculture		Commercial		Industrial		Schools-Government	
				kW	kWh	kW	kWh	kW	kWh	kW	kWh
2.5192.085	Occupancy sensor for high bay fluorescent fixtures, per fixture controlled	247	0%	0.00	676	0.00	569	0.00	708	0.00	344
Percent Off				62.5%		62.5%		62.5%		43.0%	
Hours of Use				4,368		3,680		4,576		3,230	

iv. Confidence in Proposed Savings

The values for lighting wattage are based directly on data from WISeerts and are as accurate as reasonably possible. The values for percent off (four sources) and coincidence factor (two sources) are based on a limited number of studies; therefore, our confidence in the values is somewhat limited. A strategy for increasing confidence in these values is discussed below. The proposed calculation method uses a building type definition to determine the fixture operating hours and a space type definition to determine the percent off and coincidence factor values. Using these new definitions, determined from a number of sources, will greatly improve the accuracy of the savings estimate. We believe that the proposed values are as accurate as possible, though not necessarily conservative. Therefore, we feel that the savings from this measure will be realized.

v. Recommended Further Research

One way to increase confidence in the estimate of the fixture wattage controlled is to record data for the fixture (number of lamps, fixture type, and ballast factor) in WISeerts as part of the occupancy sensor measure. This data is not currently available as invoices do not often indicate which fixtures are controlled by which occupancy sensors.

Due to the lack of significant study data available in the industry, values for percent off, hours of use, and coincidence factor could be improved through a metering study of customer installations. This would be a simple study to execute and should include metering data from high bay fluorescent fixtures controlled by occupancy sensors as well as those that are not. The study could be done in conjunction with a study on high bay hours of use discussed in Section 4.3.

4.5 SCREW-IN CFL ≤ 32W AND CFL REFLECTOR FLOOD LAMP ≤ 30W

Group: Lighting

Category: Fluorescent, Compact (CFL)

Technology Description:

- Screw-in compact fluorescent lamp rated 32 watts or less replacing an incandescent lamp rated ≤ 100W.
- Screw-in compact fluorescent reflector flood lamp rated 30 watts or less replacing an incandescent reflector flood lamp rated ≤100W.

Qualifying Equipment:

- Lamps must be screw-in type.
- New lamps must replace existing lamps one-for-one.
- Rebated lamps may not be used for resale or giveaway type promotions.
- Lamps must be installed indoors.

Date Deeming Last Modified:

- CFL ≤ 32W deemed March 2005.
- CFL Reflector Flood Lamp deemed May 2008.

Reviewed by: Jeremiah Robinson

Table 4-77. CFL Lighting Measures, Existing Deemed Savings

Tech Code	Measure Description	Ag		Com		Ind		S-G	
		kW	kWh	kW	kWh	kW	kWh	kW	kWh
2.0300.1650	CFL <= 32 Watts, replacing incandescent	0.051	199	0.050	175	0.048	323	0.038	161
2.0307.1650	CFL reflector flood lamps replacing incandescent reflector flood lamps	0.0495	192	0.0495	172	0.0495	336	0.0391	178

Savings Basis: CFL lamps save energy when replacing incandescent lamps because they are able to produce the same light output with a lower input wattage.

Note: These measures were submitted for re-deeming on May 13, 2009. Proposals made in the new submission will be addressed in this section in addition to the assumptions and calculations from the previous deemed savings method.

The May 13 proposal suggested that the description for measure 2.030.1650 be changed from *CFL ≤ 30 watts replacing incandescent* to *CFL ≤ 32 watts replacing incandescent*, presumably to match what is listed on the rebate application. This measure from herein will be referred to using the 32 watt nomenclature.

4.5.1 Existing deemed savings basis and estimates

This section provides a discussion of the measures as they are currently deemed.

A. SAVINGS EQUATIONS AND PARAMETERS

The two measures reviewed here, CFL ≤ 32 Watts and CFL Reflector Flood Lamps, currently have different sets of formulas for calculating kW and kWh savings.

i. CFL ≤ 32 Watts

Savings due to replacing low wattage CFL lamps are described by the following equations:

$$kW_{savings} = \left(\frac{\Delta Watts}{1000}\right) * CF$$

$$kW_{savings} = \left(\frac{\Delta Watts}{1000}\right) * Hours$$

where:

- Δ Watts = nominal wattage savings, values in Table 4-78, watts
- Hours = hours of use per year, values in Table 4-78, hours/year
- CF = coincidence factor, values in Table 4-78, percent
- 1,000 = conversion factor, watts per kilowatt.

Nominal Wattage Savings, Δ Watts. The difference in wattage between the new CFL lamp and the replaced incandescent lamp in watts.

Hours of Use, Hours. Hours of use refers to the average annual operating hours of the light fixture and is measured in hours/year.

Coincidence Factor, CF. Coincidence factor refers to the average percentage of total system wattage that is operating during the peak period and is measured in percent. The peak period is defined as 1 pm to 4 pm, Monday through Friday, June through August.

Note: The formulas described above are a summary of the formulas that were used when this measure was initially deemed. The names of some values have been changed to be consistent with other measures and the calculations have been simplified. The results are the same.

ii. CFL Reflector Flood Lamp

Savings due to replacing CFL reflector flood lamps are described by the following equations:

$$kW_{savings} = \left(\frac{Ltg.\ Watts_{old} - Ltg.\ Watts_{new}}{1000}\right) * CF$$

$$kW_{savings} = \left(\frac{Ltg.\ Watts_{old} - Ltg.\ Watts_{new}}{1000} \right) * Hours$$

where:

- Ltg. $Watts_{old}$ = lighting wattage of existing lamp, values in Table 4-78, watts
- Ltg. $Watts_{new}$ = lighting wattage of new lamp, values in Table 4-78, watts
- Hours = hours of use per year, values in Table 4-78, hr/yr
- CF = coincidence factor, values in Table 4-78, percent
- 1,000 = conversion factor, watts per kilowatt.

Existing Lamp Wattage, Ltg. $Watts_{old}$. The Existing Lamp Wattage is the total wattage of the incandescent lamp being replaced, in watts.

New Lamp Wattage, Ltg. $Watts_{new}$. The New Lamp Wattage for this measure is the total fixture wattage of the CFL lamp being installed, in watts.

Hours of Use, Hours. Hours of Use refers to the average annual operating hours of the light fixture and is measured in hours/year.

Coincidence Factor, CF. Coincidence Factor refers to the average percentage of total system wattage that is operating during the peak period and is measured in percent. The peak period is defined as 1 pm to 4 pm, Monday through Friday, June through August.

Table 4-78. Existing Deemed Savings Parameters

<table>
<tr><th rowspan="3">Tech Code</th><th rowspan="3">Measure Description</th><th colspan="2" rowspan="2">Technology</th><th colspan="12">Parameters</th></tr>
<tr><th colspan="3">Ag</th><th colspan="3">Com</th><th colspan="3">Ind</th><th colspan="3">S-G</th></tr>
<tr><th>New Watts</th><th>Old Watts</th><th>Delta Watts</th><th>Hours</th><th>CF</th><th>Delta Watts</th><th>Hours</th><th>CF</th><th>Delta Watts</th><th>Hours</th><th>CF</th><th>Delta Watts</th><th>Hours</th><th>CF</th></tr>
<tr><td>2.0300.1650</td><td>CFL <= 32W, replacing incandescent <=100W</td><td>N/A</td><td>N/A</td><td>57</td><td rowspan="2">3,490</td><td rowspan="2">90%</td><td>56</td><td rowspan="2">3,130</td><td rowspan="2">90%</td><td>53</td><td rowspan="2">6,100</td><td rowspan="2">90%</td><td>53</td><td>3,040</td><td rowspan="2">71%</td></tr>
<tr><td>2.0307.1650</td><td>CFL reflector flood lamps <=30W replacing incandescent reflector flood lamps <=100W</td><td>20</td><td>75</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>3,230</td></tr>
</table>

Note: The CFL Reflector Flood Lamps measure had been using an hours of use value of 3,040 hr/yr as shown in the table above. This was due to a copying error when transferring values from the CFL $\leq$ 32W measure to here. The error is corrected everywhere it occurs in this review, starting here.

B. VALUES, ASSUMPTIONS, AND CALCULATIONS

i. Nominal Wattage Savings (CFL $\leq$ 32W)

The Nominal Wattage Savings for the Commercial and Agricultural sectors were based on a review of the data collected from impact evaluation surveys conducted with Focus customers who installed low wattage CFLs. Customers were asked to identify the wattage of the bulbs that they installed and the wattage of the bulbs that they removed. KEMA calculated the weighted average of the incandescent lamp wattage and the CFL wattage. Subtracting these two values yielded the nominal wattage savings used for this measure.

The data from the impact evaluation surveys was not available for the Industrial or Schools & Government sectors. However, overall sales data was available and represented the Commercial, Industrial, and Schools & Government sectors combined. The average wattage savings from the overall sales data was calculated and assigned to the Industrial and Schools & Government sectors.

ii. Existing Lamp Wattage (CFL Reflector Flood Lamps)

This value was deemed to be 75 watts with no source or justification provided.

iii. New Lamp Wattage (CFL Reflector Flood Lamps)

This value was deemed to be 20 watts with no source or justification provided.

iv. Hours of Use

The CFL hours of use are currently deemed differently than the hours of use for the rest of the lighting measures. Measures which use the CFL deemed hours of use are as shown in Table 4-79.

Table 4-79. Measures Which Use CFL Hours of Use

Tech Code	Description
2.0300.165	CFL <= 30 Watts, replacing incandescent
2.0307.165	CFL reflector flood lamps replacing incandescent reflector flood lamps
2.0310.165	CFL Direct Install, replacing incandescent, WPS Hometown Checkup
2.0400.165	CFL Fixture, replacing incandescent fixture

The Hours of Use for the Agriculture and Commercial sectors were based on a review of the data collected from impact evaluation surveys conducted with Focus customers who installed low wattage CFLs. Customers were asked a series of questions that were used to determine the annual hours of use for each bulb installed. KEMA calculated the weighted average of the annual hours of use.

The Hours of Use for the Industrial and Schools & Government sectors were based on data from the *U.S. Lighting Market Characterization*[44], which was a large national inventory of installed lighting wattages and operating hours. For the Industrial sector, “Industrial” data was taken directly from tables in the study. For the Schools & Government sector, data was taken from the “Office/Professional” category to represent government installations and the “Schools” category to represent school installations. The average of the two values was taken for the sector. The results of the Hours of Use analysis are shown in Table 4-80.

[44] Navigant Consulting. *U.S. Lighting Market Characterization – Volume 1: National Lighting Inventory and Energy Consumption Estimate*. September 2002.

Table 4-80. Existing Hours of Use Values

Sector	Hours	Source
Agricultural	3,490	Engineering Reviews
Commercial	3,130	Engineering Reviews
Industrial	6,100	DOE Study
Schools & Government	3,230	Average of Office and Schools
Office	3,720	DOE Study
Schools	2,740	DOE Study

It should be noted that the CFL Reflector Flood Lamps measure had been using an hours of use value of 3,040 hours/yr, but this was due to a copying error when transferring values from the other CFL measures to this measures. The error is corrected everywhere it occurs in this review.

v. Coincidence Factor

The Coincidence Factors (CF) used for the CFL deemed savings calculation are currently the same as the CF used for non-CFL lighting measures and assigned by sector. It is not clear when the current CF values first came to be used. However, the justification for the 90 percent factor used for the Agriculture, Commercial, and Industrial sectors was presented in March 2005 in the CFL deemed savings calculation documentation. The documentation claims that the data was based on a suggestion by the Edison Electric Institute (EEI). We have not been able to identify this source.

We also could not find the source of the 71 percent value used for the Schools & Government sector. The 2005 CFL deemed savings documentation suggests a value of 63 percent, which was apparently abandoned at some indeterminate point in time.

4.5.2 Literature review

Here we present the findings of various sources related to the replacement of incandescent lamps with compact fluorescent lamps.

A. DEPARTMENT OF ENERGY STUDY [45]

The *U.S. Lighting Market Characterization – Volume 1: National Lighting Inventory and Energy Consumption Estimate* was performed by Navigant Consulting in 2002. The study was an attempt at a comprehensive classification of installed lighting throughout the U.S. and consisted of telephone surveys of 5,432 commercial and 17,877 industrial buildings. It included data on the square-footage and installed lighting wattage in the various building types, and hours of use weighted both by building type and lamp type.

Table 4-81 shows the hours of use reported by the DOE study for both CFL and incandescent lamps. Incandescent lamps represent the baseline equipment for this measure.

[45] Navigant Consulting. *U.S. Lighting Market Characterization – Volume 1: National Lighting Inventory and Energy Consumption Estimate*. September 2002.

Table 4-81. CFL and Incandescent Hours of Use from DOE

Lamp	Commercial		Industrial	
	Reported	Average	Reported	Average
CFL Screw-In	3,869	3,650	5,256	5,220
Incandescent	3,431		5,183	
CFL Reflector Screw-In	3,760	3,650	3,504	4,198
Incandescent Reflector	3,541		4,891	

The table shows that hours of use across the Commercial sector are consistent, with standard lamps and reflector lamps operating approximately the same number of hours per year. The CFLs had higher hours of use values when compared to incandescents in both the standard and reflector categories. For the Industrial sector, the hours of use for CFL reflector lamps are relatively low at 3,504 hours/year. The Industrial hours of use are greater than the Commercial hours of use for all other categories.

Table 4-82 shows the wattages reported by the DOE study for both CFL and incandescent lamps. The table shows that wattages are slightly higher for the Commercial sector CFLs (16 watts) when compared to the Industrial sector CFLs (14 watts). For incandescent lamps, the Industrial lamps use much more power (126 watts) than the Commercial sector lamps (83 watts).

Table 4-82. CFL and Incandescent Wattages from DOE

Lamp	Commercial	Industrial	Average
CFL Screw-In	16	14	15
Incandescent	83	126	105
CFL Reflector Screw-In	16	14	15
Incandescent Reflector	104	102	103

B. SCE IMPACT EVALUATION [46]

The *SCE Impact Evaluation* was performed by Decision Sciences Research Associates in 1996. It was an impact evaluation of the commercial CFL program and consisted of 203 on-site inspections, 101 logger installations at 26 sites, and an engineering analysis of 616 participating customers.

Table 4-83 shows the energy savings data, including hours of use and CF, obtained from the SCE study.

Table 4-83. CFL Savings Data from SCE

Watts	Sample	% of Sample	Delta Watts	Hours	CF
4–13	168,223	52.4%	39.0	4,581	17.4
14–20	54,930	17.1%	55.5	2,512	53.0
21–45	97,056	30.2%	80.3	1,675	76.9
Weighted Average			54.3	3,345	41.5
45+	849	0.3%	122	785	0

[46] Decision Sciences Research Associates, Inc. *1994 Commercial CFL Evaluation First Year Impact Evaluation Report*. February 1996.

The table shows that the hours of use drop with the size of the lamp. Higher wattage lamps operate fewer hours than lower wattage lamps. The opposite is true for CF which increases as lamp wattage increases.

It should be noted that the 33-45 watt lamps included in this study do not qualify for an incentive under the measure currently being discussed. Data for 45+ watt lamps is included for comparison only.

The SCE Impact Evaluation study also assigned building uses to the sites that were reviewed. The distribution of building uses across the reviewed sites is shown in Table 4-84.

Table 4-84. Building Uses in SCE Study

Building Use	Percent
Hotels	59%
Multi-Family	20%
Egg Producer	10%
Restaurant	7%
Others	4%

4.5.3 Proposed deemed savings basis and estimates

Based on the above research, we recommend that deemed savings estimates be updated as provided in this section.

A. DEVELOPMENT OF PROPOSED VALUES

i. Existing and New Lamp Wattages – CFL $\leq$ 32 Watts

The Existing Lamp Wattage is the total wattage of the incandescent lamp being replaced. The New Lamp Wattage is the total wattage of the CFL being installed. In the previous round of deeming, wattage values for the CFL ≤ 32 watts measure were determined based on a review of impact evaluation surveys. Different values were determined for each sector. KEMA repeated the analysis using data from the most recent rounds of impact evaluation.

The Existing Lamp Wattage and New Lamp Wattage for the Commercial and Agricultural sectors were calculated from the data collected during impact evaluation surveys conducted with Focus customers who installed low wattage CFLs over the last three rounds of impact evaluation.[47] Customers were asked to identify the wattage of the bulbs that were installed and the wattage of the bulbs that were removed. KEMA calculated the weighted average of the incandescent lamp wattage and the CFL wattage. The results are shown in Table 4-85.

[47] Data is from the last three rounds of impact evaluation that included CATI surveys.

Table 4-85. CFL and Incandescent Wattage Based on Survey Analysis[48]

Sector	Period	Sample	CFL Watts	Incand. Watts	Delta Watts
Agriculture	18 MCP	36	20.5	79.4	59.0
Agriculture	FY04	25	19.2	70.0	50.8
Agriculture	FY06	8	19.3	71.3	52.0
Commercial	18 MCP	60	19.5	74.4	54.9
Commercial	FY04	23	20.0	71.1	51.1
Channel	FY06	101	20.2	77.5	57.3
Overall	18 MCP	96	19.9	76.5	56.6
Overall	FY04	48	19.6	70.6	50.9
Overall	FY06	109	20.2	77.1	57.0

The table shows that the incandescent lamp wattage varies significantly across years when compared to the CFL lamp wattage, with the Agriculture sector showing values as low as 70.0 watts and as high as 79.4 watts. The CFL lamp wattage varies less dramatically, with all values between 19.2 and 20.5 watts.

The data is summarized across years in Table 4-86.

Table 4-86. Summary of CFL Values from Survey Analysis

Sector	Sample	CFL Watts	Incandescent Watts	Delta Watts
Agriculture	69	19.9	75.1	55.2
Commercial	83	19.7	73.5	53.8
Channel	101	20.2	77.5	57.3
Overall	253	20.0	75.7	55.7

The table shows that Channel lighting has the highest delta watts value with 57.3 watts. The Commercial sector has the lowest delta watts values with 53.8 watts. These values represent one possible source for updating the CFL deemed savings measure.

In the previous rounds of deeming, the wattages for the *CFL ≤ 32 watts* measure were determined for each sector rather than using a single value for all sectors. This is inconsistent with all other lighting measures except for the *CFL Direct Install* and *CFL Fixture* measures. It was likely done because survey data was specifically available for two of the sectors (Agricultural and Commercial), and the delta watts values determined through the analysis varied between the sectors by as much as four watts. In this round of analysis, however, we see that the Overall delta watts values predicted by the survey analysis are less than two watts different from either the Commercial or Agriculture delta watts values.

The recent Focus deemed savings submittal includes a proposal to change the delta watts value to a single wattage across all 4 sectors. We agree that the program should allow

[48] Channel refers to the Commercial, Industrial, and Schools & Government sectors which were reported together in FY06.

wattage values to be calculated the same way that they are for all other measures, with an existing lamp wattage and a new lamp wattage that is the same for all sectors.

As part of the most recent deemed savings submission, Focus on Energy provided the results of interviews with employees from the three largest CFL manufacturers in Wisconsin. The employees were asked to provide the distribution of incandescent and CFL sales across various lamp wattages. It is not clear from the data whether these values are based on national sales or Wisconsin sales. The results of the interviews are shown in Table 4-87.

Table 4-87. Results of CFL Manufacturer Interviews[49]

Wattages			Distribution of Sales			
CFL	Incan-descent	Delta Watts	GE	Westing-house	Sylvania	Average
10	40	30	13%	1%	8%	7.2%
15	60	45	54%	76%	62%	64.1%
19	75	56	12%	10%	6%	9.5%
25	100	75	21%	13%	24%	19.2%
16.9	67.7	50.7	Weighted Average Based on Dist. of Sales			

Here we see that the most popular CFL wattage for all three manufacturers is 15 watts with 64.1 percent of sales when averaged across manufacturers. Overall, the least popular wattage is 10 watts with only 7.2 percent of sales. Again, these values represent one possible source for updating the CFL deemed savings measure.

The results of the literature review, survey data analysis, and manufacturer interviews are collected in Table 4-88.

Table 4-88. Summary of CFL Wattage Values from Various Sources

Source	Incandescent	CFL	Delta Watts
Focus Survey Analysis	75.7	20.0	55.7
Mfr. Interviews	67.7	16.9	50.7
SCE Impact Evaluation	-	-	54.3
DOE (Standard)	104.5	15.0	89.5
DOE (Reflector)	103.0	15.0	88.0

The table shows that the delta watts values are fairly consistent across all of the sources except the DOE study. Data from the DOE study suggests higher incandescent wattages and lower CFL wattages than the other studies. However, the DOE data is not as applicable to this analysis as the other sources because it includes data from wattages that do not qualify for this incentive.

The Focus survey analysis provides data that is the most applicable because it directly reflects Focus installations. The results of the analysis are also similar to the delta watts values identified through the manufacturer interviews. KEMA recommends using the values shown in Table 4-89.

[49] KEMA corrected an apparent calculation error resulting from percentages which did not add up to 100%.

Table 4-89. Recommended Values for CFL ≤ 32W Existing and New Wattage

Value	Watts
Existing Watts	75.7
New Watts	20.0
Delta Watts	55.7

ii. Existing and New Lamp Wattages – CFL Reflector Flood Lamps

In the previous round of deeming, CFL flood lamp wattage values were not supported by any calculations or source documentation. For this review, we were unable to find any secondary source information that specifically addressed CFL reflector flood lamps in wattage ranges consistent with the measure definition. Therefore, we performed a review of the WISeerts database to determine the installed lamp wattage. The results of the analysis are shown in Table 4-90. The number of lamps represented by the projects that we reviewed are shown in the column labeled Sample and the total number of lamps rebated are in the column labeled Total.

Table 4-90. Percentage of Fixtures Installed by Each Measure

Sector	Sample	Total	Percent	Avg. Watts
Agriculture	6	6	100%	15.0
Commercial	7,190	26,471	27%	18.4
Industrial	162	281	58%	14.4
Schools & Government	6,420	7,350	87%	14.4
Average	13,778	34,108	40%	17.5

The table shows that only six lamps were installed by the Agricultural program and reported in the WISeerts database with an average wattage of 15.0 watts. KEMA determined the average wattages for all sectors and weighted the results by the total number of lamps rebated to produce an overall average wattage value of 17.5 watts for CFL reflector flood lamps.

Existing Lamp Wattages were not available in the WISeerts database but we were able to estimate them by applying a ratio based on the existing vs. new lamp wattages from the CFL ≤ 32 watts data to the New Lamp Wattage determined for the CFL reflector measure. This is a reasonable ratio to use because the wattage of a CFL selected to replace an incandescent lamp is based on lumen output. The lumen output ratio between incandescent and CFL lamps is the same regardless of whether a reflector is included as part of the lamp. The values used to determine the Existing Lamp Wattage for CFL reflector flood lamps are shown in Table 4-91. The Existing Lamp Wattage is 66.3 watts.

Table 4-91. Calculation for Existing Wattage from Reflector Flood Lamps

Measure	Category	Value
CFL ≤ 32W	New	20.0
	Existing	75.7
	Ratio	3.8
Reflector Flood	New	17.5
	Existing	66.3

We recommend using these values for the new and existing lamp wattages for the CFL Reflector Flood Lamps measure. The recommended values are shown in Table 4-92.

Table 4-92. Recommended Values for Reflector Flood Lamp Existing and New Wattage

Value	Watts
Existing Watts	66.3
New Watts	17.5
Delta Watts	48.8

iii. Hours of Use

Hours of Use refers to the annual operating hours of the lamp. In the previous round of deeming, both the CFL ≤ 32 watts measure and the CFL reflector flood lamp measure used the same hours of use values, which were different from the values used for most other lighting measures. The Agricultural and Commercial sector hours of use values were determined by analyzing data from impact evaluation surveys. The Industrial and Schools & Government sectors hours of use values were determined from the DOE study cited above. The Industrial and Schools & Government sectors were assigned values for general lighting operating hours, not CFL-specific hours.

For the Agriculture and Commercial sectors, KEMA repeated the previous survey data analysis using data from the most recent rounds of impact evaluation. The Hours of Use for the Commercial and Agricultural sectors were calculated from the data collected during impact evaluation surveys conducted with Focus customers who installed low wattage CFLs over the last three rounds of impact evaluation.[50] Customers were asked to answer a series of questions relating to the operating hours of the new equipment. Using that data, KEMA calculated the weighted average of the Hours of Use. The results are shown in Table 4-93.

Table 4-93. CFL and Incandescent Hours of Use Based on Survey Analysis[51]

Sector	Period	Sample	Hours/Year
Agriculture	18 MCP	36	2,902
Agriculture	FY06	8	2,327
Agriculture	FY04	25	1,856
Commercial	18 MCP	60	3,337
Commercial	FY04	23	2,604
Channel	FY06	101	3,216
Overall	18 MCP	96	3,158
Overall	FY06	109	3,170
Overall	FY04	48	2,271

The table shows that the hours of use vary significantly across years even within the same sector. The table also shows that, in several cases, the hours of use values have increased over time.

The data is summarized across years in Table 4-94. The table shows that Channel lighting has the highest hours of use value with 3,207 hours per year. The Agriculture sector has the

[50] Data is from the last three rounds of impact evaluation that included CATI surveys.

[51] Channel refers to the Commercial, Industrial, and Schools & Government sectors, which were reported together in FY06.

lowest hours of use value with 2,450 hours per year. These values represent one possible source for updating the CFL deemed savings measures.

Table 4-94. Summary of CFL Hours of Use from Survey Analysis

Sector	Sample	Hours/Year
Agriculture	69	2,450
Commercial	83	3,126
Channel	101	3,207
Overall	253	2,987

The Hours of Use from the DOE study, the SCE Impact Evaluation, the impact evaluation survey analysis, and the Focus non-CFL measures were collected in Table 4-95. For the Schools & Government sector, the hours of use values are broken out by building type. The "Other" row is the average of the three specified rows for Schools & Government and is used for buildings that are not primarily office, college, or school buildings. The basis for the Commercial sector value for the Focus non-CFL column is an early analysis that was done of six studies for Section 4.1 and subsequently supplanted. The analysis is available in Appendix A.

Table 4-95. CFL Hours of Use from Various Sources

<table>
<tr><th colspan="2" rowspan="2">Sector</th><th colspan="2">DOE Study</th><th rowspan="2">SCE</th><th rowspan="2">Focus Survey Analysis</th><th rowspan="2">Focus Non-CFL</th></tr>
<tr><th>Standard</th><th>Reflector</th></tr>
<tr><td colspan="2">Agriculture</td><td>-</td><td>-</td><td>-</td><td>2,450</td><td>4,698</td></tr>
<tr><td colspan="2">Commercial</td><td>3,650</td><td>3,650</td><td>-</td><td>3,138</td><td>3,730</td></tr>
<tr><td colspan="2">Industrial</td><td>5,220</td><td>4,198</td><td>-</td><td>-</td><td>4,745</td></tr>
<tr><td rowspan="4">Schools & Government</td><td>School</td><td>-</td><td>-</td><td>-</td><td>-</td><td>2,302</td></tr>
<tr><td>College</td><td>-</td><td>-</td><td>-</td><td>-</td><td>3,900</td></tr>
<tr><td>Office</td><td>-</td><td>-</td><td>-</td><td>-</td><td>3,526</td></tr>
<tr><td>Other</td><td>-</td><td>-</td><td>-</td><td>-</td><td>3,672</td></tr>
<tr><td colspan="2">Average</td><td>4,435</td><td>3,924</td><td>3,345</td><td>2,962</td><td>3,796</td></tr>
</table>

The table shows that the values for the Commercial sector are fairly consistent across sources and lamp types with values that are in a range surrounding 3,500 hours/year. The Focus survey analysis suggests slightly lower values than the other sources for the Commercial sector (3,138 hours/year). The Industrial sector values show relative consistency between the reflector hours of use (4,198 hours/year) and those of the Non-CFL data (4,745 hours/year), but the data for standard CFLs provided by DOE is higher (5,220 hours/year). For the Schools & Government sector, the only value available is from the non-CFL lighting measures. For the Agriculture sector, the data from the Focus survey analysis is much lower (2,450 hours/year) than the non-CFL Focus lighting measures value (4,698 hours/year).

In Section 4.1 of this report, KEMA has recommended that all of the other (non-CFL) lighting measures rebated by Focus use values for hours of use which are defined by building type. Using a different (sector-level) definition of hours of use for only the CFL measures will introduce significant implementation problems for both the program and the PSCW that may not result in a comparable increase in the accuracy of the savings estimates. The estimates shown in Table 4-95 are consistent with the hours of use recommended in Section 4.1 except for the Agriculture estimate. As the Agriculture sector is represented in only one building use in Section 4.1, it is not difficult to insert the results of the analysis outlined above for the

Agriculture sector in the newly recommended building use definitions without increasing implementation complexity. Since the other sector estimates are comparable with the associated building uses in Section 4.1, KEMA recommends that the same hours of use recommended in that section be used for CFL measures as well. The recommended values are shown in Table 4-96.

Table 4-96. Recommended Values for Hours of Use

Building Use	Hours
Food Sales	5,544
Food Service	4,482
Health Care	3,677
Hotel/Motel	3,356
Office	3,526
Public Assembly	2,729
Public Services	3,425
Retail	4,226
Warehouse	3,464
School	2,302
College	3,900
Dormitory	986
Industrial	4,745
Agricultural	2,450
Other	3,672

iv. Coincidence Factor

Coincidence factor refers to the average percentage of total system wattage that is operating during the peak period. The peak period is defined as 1–4 pm on weekdays, June through August.

In the previous method of deeming, a value of 90 percent was used for the Commercial, Industrial, and Agriculture sectors. A value of 71 percent was used for the Schools & Government sector. Sources for these values are not available or have been lost. The values that were used for CFL measures last round are the same values that were used for the rest of the lighting measures.

Based on the literature review, there are no good sources for data on non-residential CFL coincidence factor. The only source found, the SCE Impact Evaluation, is 13 years old and made up primarily of data from hotels where lamps operate at different hours than they do in typical commercial or industrial buildings.

Based on the lack of quality data, we recommend that the values used for other lighting measures be used for CFLs also. These values are proposed in Section 4.1 of this report and shown in Table 4-97, defined by building type.

Table 4-97. CF Values Proposed for CFL Measures

Building Use	CF
Food Sales	92%
Food Service	84%
Health Care	78%
Hotel/Motel	35%
Office	77%
Public Assembly	67%
Public Services (non-food)	64%
Retail	84%
Warehouse	79%
School	52%
College	68%
Dormitory	7%
Industrial	77%
Agriculture	67%
Other	67%

B. PROPOSED EQUATIONS, PARAMETERS, AND DEEMED VALUES

i. Proposed Equations and Parameters

We recommend that the following formulas be used to calculate deemed savings for the CFL ≤ 32W and CFL reflector flood lamps replacing incandescent lamps.

Savings due to replacing light fixtures are described by the following equations:

$$kW_{savings} = \left(\frac{Ltg.\,Watts_{old} - Ltg.\,Watts_{new}}{1000} \right) * CF$$

$$kW_{savings} = \left(\frac{Ltg.\,Watts_{old} - Ltg.\,Watts_{new}}{1000} \right) * Hours$$

where:

- Ltg. $Watts_{old}$ = lighting wattage of existing fixture, values in Table 4-98, watts
- Ltg. $Watts_{new}$ = lighting wattage of new fixture, values in Table 4-98, watts
- Hours = hours of use per year, values in Table 4-99, hr/yr
- CF = coincidence factor, values in Table 4-99, percent
- 1,000 = conversion factor, watts per kilowatt.

Existing Lamp Wattage, Ltg. $Watts_{old}$. The Existing Lamp Wattage is the total wattage of the incandescent lamp being replaced, in watts.

New Lamp Wattage, Ltg. $Watts_{new}$. The New Lamp Wattage is the total fixture wattage of the CFL lamp being installed, in watts.

Hours of Use, Hours. Hours of Use refers to the average annual operating hours of the light fixture and is measured in hours/year.

Coincidence Factor, CF. Coincidence Factor refers to the average percentage of total system wattage that is operating during the peak period and is measured in percent. The peak period is defined as 1–4 pm, Monday through Friday, June through August.

ii. Proposed Deemed Values

Substituting the parameters into the savings equations yields the proposed deemed savings values for this measure, found in Table 4-99. If the PSC decides not to accept the building use lighting hours and CF definition, KEMA recommends using the alternative sector-level savings for this measure in Appendix E.

Table 4-98. Proposed Deemed Wattages

Tech Code	Measure Description	New Watts	Old Watts
2.0300.1650	CFL <= 32W, replacing incandescent <=100W	20.0	75.7
2.0307.1650	CFL reflector flood lamps <=30W replacing incandescent reflector flood lamps <=100W	17.5	66.3

Table 4-99. Proposed Deemed Parameters and Savings

			Savings by Measure			
			CFL <32 W		CFL Reflector Flood	
Building Use	Hours	CF	kW	kWh	kW	kWh
Food Sales	5,544	92%	0.0512	309	0.0449	271
Food Service	4,482	84%	0.0468	250	0.0410	219
Health Care	3,677	78%	0.0435	205	0.0382	180
Hotel/Motel	3,356	35%	0.0195	187	0.0171	164
Office	3,526	77%	0.0426	196	0.0374	172
Public Assembly	2,729	67%	0.0371	152	0.0325	133
Public Services	3,425	64%	0.0354	191	0.0310	167
Retail	4,226	84%	0.0470	235	0.0412	206
Warehouse	3,464	79%	0.0440	193	0.0386	169
School	2,302	52%	0.0292	128	0.0256	112
College	3,900	68%	0.0379	217	0.0332	190
Dormitory	986	7%	0.0039	55	0.0034	48
Industrial	4,745	77%	0.0429	264	0.0376	232
Agricultural	2,450	67%	0.0373	136	0.0327	120
Other	3,672	67%	0.0371	205	0.0325	179

iii. Comparison with Old Method

Table 4-100 shows the existing deemed savings values for comparison.[52]

[52] The error which was made in the hours of use for the Schools & Government sector is corrected here.

Table 4-100. Existing Deemed Savings Values

Tech Code	Measure Description	Delta Watts				Agriculture		Commercial		Industrial		Schools-Government	
		Ag.	Com.	Ind.	S&G	kW	kWh	kW	kWh	kW	kWh	kW	kWh
2.0300.1650	CFL <= 32W, replacing incandescent <=100W	57.0	56.0	53.0	53.0	0.0513	199	0.050	178	0.0477	323	0.038	171
		New Watts		Old Watts									
2.0307.1650	CFL reflector flood lamps <=30W replacing incandescent reflector flood lamps <=100W	20.0		75.0		0.0495	131	0.0495	173	0.0495	336	0.039	178
	Coincidence Factor					90%		90%		90%		71%	
	Hours of Use					3,490		3,130		6,100		3,230	

iv. *Other Affected Measures*

We recommend that the hours of use and CF values proposed in this section be applied to all measures in which compact fluorescent lamps replace incandescent lamps. We also recommend that measures which currently use the wattages which were deemed for CFL ≤ 32 Watts be updated to reflect new wattages. The resulting savings are shown in Table 4-101 and Table 4-102. If the PSC decides not to accept the building use lighting hours and CF definition, KEMA recommends using the alternative sector-level savings for this measure in Appendix E.

Table 4-101. Proposed kW Savings for Other Measures Impacted by Adjusted Values

<table>
<tr><th>WISeerts Tech Code</th><th>Measure Description</th><th>New Watts</th><th>Old Watts</th><th>Food Sales</th><th>Food Service</th><th>Health Care</th><th>Hotel/ Motel</th><th>Office</th><th>Public Assembly</th><th>Public Services (non-food)</th><th>Retail</th><th>Warehouse</th><th>School</th><th>College</th><th>Industrial</th><th>Agriculture</th><th>Other</th><th>Dorms</th></tr>
<tr><td>2.0301.165</td><td>CFL High Wattage 31-115 Watts, replacing incandescent</td><td>65.0</td><td>200.0</td><td>0.124</td><td>0.113</td><td>0.106</td><td>0.047</td><td>0.103</td><td>0.090</td><td>0.086</td><td>0.114</td><td>0.107</td><td>0.071</td><td>0.092</td><td>0.104</td><td>0.090</td><td>0.090</td><td>0.009</td></tr>
<tr><td>2.0305.060</td><td>CFL Cold Cathode Screw-In, replacing incandescent</td><td>4.0</td><td>25.0</td><td>0.019</td><td>0.018</td><td>0.016</td><td>0.007</td><td>0.016</td><td>0.014</td><td>0.013</td><td>0.018</td><td>0.017</td><td>0.011</td><td>0.014</td><td>0.016</td><td>0.014</td><td>0.014</td><td>0.001</td></tr>
<tr><td>2.0310.165</td><td>CFL Direct Install, replacing incandescent, WPS Hometown Checkup</td><td rowspan="6">20.0</td><td rowspan="6">75.7</td><td rowspan="6">0.051</td><td rowspan="6">0.047</td><td rowspan="6">0.044</td><td rowspan="6">0.019</td><td rowspan="6">0.043</td><td rowspan="6">0.037</td><td rowspan="6">0.035</td><td rowspan="6">0.047</td><td rowspan="6">0.044</td><td rowspan="6">0.029</td><td rowspan="6">0.038</td><td rowspan="6">0.043</td><td rowspan="6">0.037</td><td rowspan="6">0.037</td><td rowspan="6">0.004</td></tr>
<tr><td>2.0400.165</td><td>CFL Fixture, replacing incandescent fixture</td></tr>
<tr><td>n/a</td><td>Replace incandescent lamps with 14 Watt compact fluorescent lamps, WPS Hometown Checkup</td></tr>
<tr><td>n/a</td><td>Replace incandescent lamps with 20 Watt compact fluorescent lamps, WPS Hometown Checkup</td></tr>
<tr><td>n/a</td><td>Replace incandescent lamps with 23 Watt compact fluorescent lamps, WPS Hometown Checkup</td></tr>
<tr><td>n/a</td><td>Replace incandescent spotlight lamps with 16 Watt spotlight compact fluorescent lamps, WPS Hometown Checkup</td></tr>
<tr><td colspan="4">Coincidence Factor</td><td>92%</td><td>84%</td><td>78%</td><td>35%</td><td>77%</td><td>67%</td><td>64%</td><td>84%</td><td>79%</td><td>52%</td><td>68%</td><td>77%</td><td>67%</td><td>67%</td><td>7%</td></tr>
</table>

Table 4-102. Proposed kWh Savings for Other Measures Impacted by Adjusted Values

<table>
<tr><th>WISeerts Tech Code</th><th>Measure Description</th><th>New Watts</th><th>Old Watts</th><th>Food Sales</th><th>Food Service</th><th>Health Care</th><th>Hotel/ Motel</th><th>Office</th><th>Public Assembly</th><th>Public Services (non-food)</th><th>Retail</th><th>Warehouse</th><th>School</th><th>College</th><th>Industrial</th><th>Agriculture</th><th>Other</th><th>Dorms</th></tr>
<tr><td>2.0301.165</td><td>CFL High Wattage 31-115 Watts, replacing incandescent</td><td>65.0</td><td>200.0</td><td>749</td><td>605</td><td>496</td><td>453</td><td>476</td><td>368</td><td>462</td><td>570</td><td>468</td><td>311</td><td>527</td><td>641</td><td>331</td><td>496</td><td>133</td></tr>
<tr><td>2.0305.060</td><td>CFL Cold Cathode Screw-In, replacing incandescent</td><td>4.0</td><td>25.0</td><td>116</td><td>94</td><td>77</td><td>70</td><td>74</td><td>57</td><td>72</td><td>89</td><td>73</td><td>48</td><td>82</td><td>100</td><td>51</td><td>77</td><td>21</td></tr>
<tr><td>2.0310.165</td><td>CFL Direct Install, replacing incandescent, WPS Hometown Checkup</td><td rowspan="6">20.0</td><td rowspan="6">75.7</td><td rowspan="6">309</td><td rowspan="6">250</td><td rowspan="6">205</td><td rowspan="6">187</td><td rowspan="6">196</td><td rowspan="6">152</td><td rowspan="6">191</td><td rowspan="6">235</td><td rowspan="6">193</td><td rowspan="6">128</td><td rowspan="6">217</td><td rowspan="6">264</td><td rowspan="6">136</td><td rowspan="6">205</td><td rowspan="6">55</td></tr>
<tr><td>2.0400.165</td><td>CFL Fixture, replacing incandescent fixture</td></tr>
<tr><td>n/a</td><td>Replace incandescent lamps with 14 Watt compact fluorescent lamps, WPS Hometown Checkup</td></tr>
<tr><td>n/a</td><td>Replace incandescent lamps with 20 Watt compact fluorescent lamps, WPS Hometown Checkup</td></tr>
<tr><td>n/a</td><td>Replace incandescent lamps with 23 Watt compact fluorescent lamps, WPS Hometown Checkup</td></tr>
<tr><td>n/a</td><td>Replace incandescent spotlight lamps with 16 Watt spotlight compact fluorescent lamps, WPS Hometown Checkup</td></tr>
<tr><td colspan="4">Hours of Use</td><td>5,544</td><td>4,482</td><td>3,677</td><td>3,356</td><td>3,526</td><td>2,729</td><td>3,425</td><td>4,226</td><td>3,464</td><td>2,302</td><td>3,900</td><td>4,745</td><td>2,450</td><td>3,672</td><td>986</td></tr>
</table>

v. Confidence in Proposed Savings

The values for old and new wattage are based directly on data from surveys of Focus on Energy customers and therefore represent the best data available. The Focus data are consistent with what is found elsewhere in the industry, and we believe it to be accurate.

The values for hours of use for the Agriculture building type is also based on data from surveys of Focus customers, and therefore is Focus-specific. However, customers have a more difficult time estimating hours of use than reporting wattage. We feel that this data represents the best estimate available but further research may be warranted.

The values for hours of use for the other building types are addressed in Section 4.1 and are based on thorough research of general lighting, not research on CFLs specifically. Though we feel that this data is accurate in general, the accuracy is limited. The same can be said for the coincidence factor values for all of the building types.

Given the data available, we believe that the savings estimates proposed are as accurate as possible. Due to the simplicity of the calculations and the sources available, we believe that these estimates are accurate though not necessarily conservative. Therefore, we feel that the savings from this measure will be realized.

Savings estimates for the CFL Reflector Flood Lamps measure are less accurate than for the CFL ≤ 32 Watts measures, as they are based on data which is specific to the other measure. It is still the best available data. The CFL Reflector Flood Lamps measure is also much less popular, and so has a lower effect on overall program savings.

vi. Recommended Further Research

The wattage estimates for all building uses and the hours of use for the Agricultural building use are based on data from surveys with Focus on Energy participants. This is a telephone survey that collects customer-reported data. While it has been suggested in a number of studies that customers do not consistently over or under-report wattages or hours of use, the estimates that they provide are not necessarily accurate.

One way to improve the wattage estimate is to collect this data on the application and to record it in the tracking database. This would allow for a very large sample and more accurate data. For the hours of use and coincidence factor estimates, the quality of the data could be improved by conducting a metering study of the various types of CFLs in the non-residential sector. The study results would increase the accuracy of the parameter estimates using the building type definition, and provide CFL-specific data for the non-Agriculture building types. The study should meter pre- and post-installation operating hours and coincidence factor.

4.6 HIGH EFFICIENCY VENTILATION FANS

Group: HVAC

Category: Fans

Technology Description: High efficiency ventilation fans in agricultural facilities.

Qualifying Equipment:

- Measure is limited for use by the agriculture sector only.
- Intended for barn ventilation propeller type fans.[53]
- Ventilation fans must have a minimum rating of 21 CFM/W at 0.00 inches H_2O static pressure, 20 CFM/W at 0.05 inches H_2O static pressure, or be approved by Focus on Energy prior to sale and must be rated through the Bioenvironmental and Structural Systems Laboratory (BESS Lab) or Air Movement and Control Association International laboratory (AMCA Lab).

Date Deeming Last Modified: May 2008

Reviewed by: Dale Tutaj

Table 4-103. High Efficiency Ventilation Fan Measures

Tech Code	Measure Description	Deemed Savings		
		kW	kWh	Therms
4.0736.150	Ventilation Fans, High Efficiency - 36"	0.322	1,094	0
4.0742.150	Ventilation Fans, High Efficiency - 42"	0.396	1,483	0
4.0748.150	Ventilation Fans, High Efficiency - 48"	0.470	1,872	0
4.0750.150	Ventilation Fans, High Efficiency - 50"	0.664	2,553	0
4.0751.150	Ventilation Fans, High Efficiency - 51"	0.664	2,553	0
4.0752.150	Ventilation Fans, High Efficiency - 52"	0.664	2,553	0
4.0754.150	Ventilation Fans, High Efficiency - 54"	0.664	2,553	0
4.0755.150	Ventilation Fans, High Efficiency - 55"	0.664	2,553	0
4.0760.150	Ventilation Fans, High Efficiency - 60"	0.664	2,553	0
4.0772.150	Ventilation Fans, High Efficiency - 72"	0.664	2,553	0

Savings Basis: High efficiency ventilation fans replace existing, less efficient ventilation fans. High efficiency fans are able to move an equivalent amount of air with less power. Fan efficiency is a function of all of the components of fan design including fan motors, fan blades, fan drive, housing, shutters, guards, and other accessories.

[53] Deemed savings documentation refers to this equipment as "ventilation fan." This language is consistent with the previous Dairy and Livestock Incentive Application (valid January 1, 2009, to June 30, 2009). However, the current application (valid from July to December 31, 2009), refers to this equipment as "exhaust fan."

4.6.1 Existing basis and assumptions

This section provides a discussion of the measure as it is currently deemed.

A. SAVINGS EQUATIONS AND PARAMETERS

Savings due to ventilation fan installations are described by the following equations:

$$kW_{savings} = kW_b - kW_q + (kW_T \times TR)$$

$$kWh_{Savings} = (kW_{savings} \times Hours) + (kW_T \times Hours \times TR)$$

or

$$kWh_{Savings} = \left(kW_b - kW_q + (kW_T \times TR)\right) \times Hours + (kW_T \times Hours \times TR)$$ [54]

where:

- *Hours = annual fan runtime, deemed 3,397 hours/year*
- kW_b = baseline fan power, values in Table 4-107, kilowatts
- kW_q = qualifying fan power, values in Table 4-107, kilowatts
- kW_T = fan power savings due to size transition, values in Table 4-109, kilowatts
- TR = transition rate, values in Table 4-109, percent.

Annual Runtime, Hours. Annual fan runtime represents the hours per year that the average fan will operate.

Fan Power, Baseline, kW_b Baseline fan power represents the power drawn by the average replaced fan in kilowatts.

Fan Power, Qualifying, kW_q. Qualifying fan power represents the power drawn by the average high efficiency fan in kilowatts.

Size Transition Power Savings, kW_T. The overall reduction in fan power from increasing fan size and reducing the number of fans in kilowatts.

Transition Rate, TR. The percent of projects in which many smaller existing fans are replaced with fewer larger fans.

It should be noted that 42" fans do not follow this calculation method, but are given kW and kWh savings values which are an average between 36" and 48" fans.

[54] This equation reflects the calculation that is used for deemed savings. However, it is likely that this is not the intended equation for $kWh_{Savings}$, as it has redundancies. This is discussed further in Section 1.1.3.

B. VALUES, ASSUMPTIONS, AND CALCULATIONS

i. Annual Fan Runtime

Annual fan runtime estimates are based on industry recommendations and the program's experience for three different types of dairy facilities. The calculation includes a description about each of these types, as follows:

- **Free stall barn:** The most widely researched and utilized barn style today. They are open structures, or partially enclosed. Often a long wall of curtains can be dropped to allow for natural ventilation, though some fan use is required year 'round to ensure that ammonia and unhealthy concentrations of gases do not build up. Air movement also helps prevent flies from congregating and reduces the moisture buildup on the barn facilities. Thus, it is standard practice to set 10 percent of fans run to continuously, while 30 percent run during moderate temperatures and 60 percent run during the hottest weather[55].
- **Stall barn:** Typically has three fans controlled manually and by thermostats. Temperatures in the barn are higher than ambient air due to heat gain. For hours of operation, we assume one fan operates at "cold" temperatures, two at "moderate" temperatures, and all three at "hot" temperatures. Since there are usually only three fans in stall barns, it is impossible to have 10 percent of fans operating–in actual practice, one of the fans runs usually runs 18 hours/day, every day (observed practice).
- **Cross-ventilated barn:** Similar to stall barn. These barns are a growing trend and use many fans. Cross-ventilated barns are enclosed free stall barns that use banks of fans to move air across the width of the barn (not length). They operate similarly to stall barns in terms of maintaining cow comfort, air quality, and moisture management. However, one bank of fans operates continuously.

According to the deemed savings documentation, industry recommended runtimes are as shown in Table 4-104 though no source is cited. Hours listed for the given outdoor dry bulb temperature ranges are determined from typical meteorological year (TMY2) data (location not specified).

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[55] It should be noted that 10 percent, 40 percent, and 100 percent of fans run during “cold,” “moderate,” and “hot” temperatures, respectively. In the previous round of deeming, there was confusion on this issue. The text of the spreadsheet and the memo suggested that 10 percent, 30 percent, and 60 percent of fans run during these periods, respectively. This was a misunderstanding made by both Focus and KEMA, and a misinterpretation of the calculations (which were correct). In other words, the 10 percent of fans running during “cold” temperatures will also run during “moderate” and “hot” temperatures, and the 30 percent of fans that come on during “moderate” temperatures will stay on during “hot” temperatures. All fans run during “hot” temperatures.

Table 4-104. Industry-Recommended Fan Runtimes

Bin Category	Definition	Hours	Percent of Fans Operating
Cold	<50°F	4,577	10%
Moderate	≥ 50°F	2,908	40%
Hot	≥ 70°F	1,275	100%

The hot period is defined as 70°F and greater; therefore, 100 percent of fans will run for 1,275 hours/yr. Based on this information, the percent of fans running in each category for each dairy facility type is described in Table 4-105. It should be noted that stall barns use different bin category definitions, as described in the assumptions.

Table 4-105. Dairy Facility Type Weighted Hours and Assumptions

Dairy Facility Type	Bin Category	Hours	Percent of Fans Operating	Weighted Hours	Assumptions
Stall Barn	Cold and warmer	6,570	33%	4,009	assumes one fan, 18 hours per day
	Moderate and warmer	4,183	33%		assumes one fan added at 50°F or higher
	Hot	1,275	33%		assumes one fan added at 70°F or higher
Free Stall / Cross-Ventilated Barns	Cold	4,577	10%	2,896	industry recommended values
	Moderate	2,908	40%		industry recommended values
	Hot	1,275	100%		industry recommended values

The hours for each temperature bin are weighted by the percent of fans operating at those temperatures to determine the average weighted hours. The annual runtime is weighted by the market share of each dairy facility type, shown in Table 4-106. No source was provided for these values.

Table 4-106. Dairy Facility Type Market Share and Average Weighted Hours

Dairy Facility Type	Market Share of Fan Sales	Weighted Hours
Stall Barns	45%	4,009
Free Stall Barns	50%	2,896
Cross Ventilated Barns	5%	2,896
Average Weighted Runtime	-	3,397

Based on the market share of each facility type, the average annual runtime is 3,397 hr/yr.

ii. Fan Power, Baseline and Qualifying

Fan power is determined from the BESS Lab performance test data.[56] The results from each test are listed with the fan's manufacturer, model number, nominal fan diameter, cone use, and shutter type. Fans are tested for airflow and ventilating efficiency ratio (VER) at 0.05 and 0.10 inches H_2O static pressure. BESS Lab tests with duplicate entries (tests that have

[56]Website: http://bess.illinois.edu., Agricultural Ventilation Fans Performance and Efficiencies, Bioenvironmental and Structural Systems Laboratory, Department of Agricultural and Biological Engineering, The University of Illinois at Urbana-Champaign.

identical model number, fan diameter, cone, and shutter) are consolidated by averaging the VER, airflow, and airflow ratio for each identical test.

Motor input kW for each test case is calculated using the airflow and VER at 0.05 inches H_2O static pressure. The input kW values are determined based on a parameter with values of 0, 0.5, 1.0, or 1.5 and is assigned to each fan. It is unclear why this process is used. The following equations are used to calculate the motor input kW.

If unnamed parameter = 0,

$$\text{Motor Input kW} = \left(\frac{0.625 \times \text{Airflow}}{1{,}000 \times \text{VER}}\right) \times 0.85$$

If unnamed parameter = 1,

$$\text{Motor Input kW} = \left(\frac{0.5 \times \text{Airflow}}{1{,}000 \times \text{VER}}\right) \times 0.85$$

where:

- Airflow = air flow rate, CFM
- VER = ventilation efficiency ratio, CFM/W

For test cases with an unnamed parameter of 0.5 or 1.5, motor input kW is a fixed value which was entered into the spreadsheet without a calculation. It is unclear how the fixed values were determined.

For each fan size, results are separated by VER ≥ 20 CFM/W (qualifying) and VER < 20 CFM/W (baseline).[57] The average input kW for baseline (kW_b) and qualifying (kW_q) fans is determined by taking the average input kW for fans in for the appropriate VER group, as shown in Table 4-107.

Table 4-107. Fan Power, Baseline and Qualifying

Fan Size	kW_q (VER $\geq$ 20 CFM/W)	kW_b (VER < 20 CFM/W)
36 inch	0.86	1.19
48 inch	1.71	2.10
50 inch+	1.87	2.44

iii. Size Transition Power Savings & Transition Rate

Deemed savings values incorporate savings due to the movement from smaller to larger fans. On average, larger fans have a higher efficiency, moving more air with less energy. Installing larger fans allows the total number of fans to be reduced and energy to be saved due to the higher efficiency.

[57] Based on 0.05 H_2O static pressure test conditions.

To determine transition rate, the calculation splits fans into three categories: 36”, 48”, and 50+”. The transition rate was based on information provided by the program with no supporting documentation. It is assumed that 25 percent of customers purchasing 48” or 50+” fans would have bought smaller fans if Focus had not been involved. In other words, a customer purchasing 48” fans might have bought 36” fans without Focus. A customer purchasing 50+” fans might have bought either 36” fans or 48” fans without Focus. It is also assumed that customers who were influenced to purchase larger fans maintained the same design air flow, thus purchasing fewer fans than they had intended. This trend is illustrated in Table 4-108.

Table 4-108. Values Needed to Calculate kW Savings from Fan Size Transition[58]

Transition	Description	$kW/Fan_{Smaller}$	kW/Fan_{Larger}	Fan Ratio	kW Savings
T1	from 36" to 48"	1.13	1.89	1.95	0.32
T2	from 36" to 50+"	1.13	2.01	2.25	0.54
T3	from 48" to 50+"	1.89	2.01	1.15	0.16

A transition from 36” to 48” fans will result in a kW savings of 0.32 for each 48” fan installed. Given the average airflow for each fan size, (1.95) 36” fans are needed to move the same amount of air as (1) 48” fan.

Table 4-109 shows how these size transition savings are applied to deemed savings. Since customers choosing to purchasing 50+” fans could have installed either 36” or 48” fans, Focus assumed that half of these customers fell into each category. In other words, half of 50+” transition customers upgraded from 36” fans, and half from 48” fans. The TR of 25 percent is used for the larger fan sizes. No source was provided to support the TR estimate.

Table 4-109. Transition Rates and kW Savings from Transition

Fan Size (dia.)	Transition	kW_T	TR
36 inch	N/A	N/A	N/A
48 inch	T1	0.32	25%
50 inch+	Average of T2 & T3	0.35	25%

[58] $kW/Fan_{Smaller}$ and kW/Fan_{Larger} are the average motor input kW for all BESS Lab test data in each respective size category. Similarly, airflow (used to determine fan ratio) is the airflow for all BESS Lab test data in each respective size category.

The size transition kW savings is calculated using the following equation.[59]

$$kW_T = (kW/Fan_{smaller} \times Fan\,Ratio) - kW/Fan_{larger}$$

where:

- $kW/Fan_{smaller}$ = power used by smaller fan, kilowatts
- kW/Fan_{larger} = power used by larger fan, kilowatts
- Fan Ratio = ratio of the number of smaller fans needed to create the same airflow as one larger fan, dimensionless
- kW_T = power savings resulting from the transition to the larger fan, kilowatts.

4.6.2 Literature review

Here we present the findings from various sources related to high efficiency ventilation fans. These documents provide information that either bolsters existing assumptions or provides a foundation for recommendations made in Section 4.6.3.

A. REVIEW OF BESS LAB PERFORMANCE TESTS DATA

The BESS Lab provides performance test data for over 800 commercially available agricultural ventilation fans with diameters ranging from 8" to 54" and greater. The laboratory is used for research, product testing, and education. BESS performance test results are the primary source of deemed savings values.

Each test is recorded by manufacturer, nominal fan diameter, cone use, and shutter type. Fans are tested for airflow and VER at 0.05 and 0.10 inches H_2O static pressure testing conditions. The airflow ratio is also provided, and is defined as the ratio of airflow at 0.20 to airflow at 0.05 inches H_2O static pressure.

The BESS Lab website states that the 0.10 inches H_2O static pressure test condition is representative of typical operating pressures. Also, an airflow ratio approaching 1 is important for fans running during cold weather as the fan will operate over a broad range of pressures.[60]

The deemed savings calculations use performance tests that are not contained in the current performance test data. These test results have probably been moved to discontinued

[59] The deemed savings calculation uses additional parameters such as CFM per cow and cows per farm. However, these values cancel out and are not needed. The reduced equation is shown here for simplicity.

[60] Section of website that contains this information: http://www.bess.illinois.edu/selcrit.html. Website accessed July 7, 2009.

performance test archive data. There are several performance tests in the current performance test data on the BESS Lab's website.[61]

B. *REVIEW OF AMERICAN SOCIETY OF AGRICULTURAL AND BIOLOGICAL ENGINEERS (ASABE) GUIDELINES*[62]

ASABE is an international professional and technical organization dedicated to the advancement of engineering applicable to agriculture, food, and biological systems. ASABE standards are for informational and advisory purposes.

This document provides an overview of agricultural ventilation fan technologies including types of fans, fan performance, maintenance, and controls.

According to this document, typical agricultural exhaust fans operate at 0.10" static pressure. Three main factors influencing the amount of static pressure are identified as follows:

- Facility, methods and operation of ventilation equipment
- Maintenance, dirt build-up, damaged blades, etc.
- Wind, direct, or indirect.

Recommended minimum efficiencies for energy efficient fans over a range of static pressures are provided in Table 4-110. The guidelines state that larger fans are more efficient than smaller fans. A large diameter blade will move more air per unit of input power. Also, for any given area, fewer large fans will generally be more efficient than more small fans.

Table 4-110. Recommended Minimum Efficiencies for Energy Efficient Agricultural Ventilation Fans[63]

Static Pressure (inches H_2O)	VER (CFM/W)		
	24" Fans	36" Fans	48" Fans
0.00	14.0	14.0	21.9
0.05	12.9	18.3	19.7
0.10	11.9	16.2	17.6
0.15	10.9	14.1	15.4
0.20	9.7	11.4	12.6
0.25	8.2	8.6	9.6

[61] Section of website containing new test results: http://bess.illinois.edu/current.asp. (60 Hz, 1 phase 230V was selected). Website accessed July 7, 2009.

[62] American Society of Agricultural and Biological Engineers (ASABE), *ASAE EP566.1 AUG 2008,* "Guidelines for Selection of Energy Efficient Agricultural Ventilation Fans"

[63] It is not clear how VERs were derived in the guidelines.

C. UNIVERISITY OF WISCONSIN EXTENSION ENERGY CONSERVATION IN AGRICULTURE ARTICLE[64]

This article provides general information regarding several types of agricultural fans. Available efficiency ranges as well as recommended efficiencies for high efficient fans are provided as shown in Table 4-111.

Table 4-111. Available Ranges and High Efficiency VERs[65]

Fan Size	Available VER Range (CFM/W)	High Efficiency VER (CFM/W)
24"	8.7 - 19.4	16
36"	12.7 - 23.7	20
48"	13.5 - 27.0	20
50 to 54"	16.1 - 33.0	23

D. MILKPRODUCTS.COM ARTICLE[66]

This document outlines recommended minimum ventilation rates for dairy barns. Fans are categorized by three usage types:

- Winter ventilation, supplied by a single continuously running fan
- Mild ventilation, controlled by the barn's internal temperature thermostats (40°F to 45°F)
- Summer ventilation, additional fans run (typically manual, although thermostats are becoming more common).

The recommended minimum ventilation rates for each of these periods are provided in Table 4-112. The percent of fans running during each period can be approximated with the percent of the maximum ventilation rate.

Table 4-112. Recommended Minimum Ventilation Rates for Dairy Barns[67]

Weather Conditions	Ventilation Rate (CFM/Cow)	Percent of Maximum Ventilation Rate (Percent of Fans Operating)
Winter	50	10%
Mild Weather	170	34%
Summer	500	100%

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[64] Sanford, University of Wisconsin-Extension. *Energy Conservation in Agriculture*, "Ventilation and Cooling Systems for Animal Housing," 2003.

[65] VER based on 0.05 inches H_2O static pressure.

[66] Chastain, MILKPRODUCTION.COM. "Improving Mechanical Ventilation in Dairy Barns," December 19, 2006, section of website containing article: http://www.milkproduction.com/Library/Articles/Improving_mechanical_ventilation.htm.

[67] Weather conditions not defined.

This article recommends using 0.125” H_2O static pressure conditions when determining the ventilation provided by a fan. Also, the article says that fan performance should be based on certified tests such as AMCA, not manufacturer-provided ratings.

E. COLLEGE OF AGRICULTURAL AND BIOLOGICAL SCIENCES ARTICLE, PENNSYLVANIA STATE UNIVERSITY [68]

This article, titled “Selecting Rated Ventilation Fans,” is provided by the College of Agricultural Sciences Cooperative Extension at Pennsylvania State University. It contains general information about agriculture ventilation fans and import factors relevant to their operations. The College of Agricultural Sciences Cooperative Extension is a U.S Department of Agriculture-funded program dedicated to provide education and technical support to business and community.

This article advises the use of AMCA- or BESS-standardized performance test data when determining air delivery capabilities of a fan. Total ventilation system static pressure typically ranges from 0.08” to 0.20” H_2O static pressure, with 0.10” or 0.125” suggested as a standard design condition. Table 4-113 lists the static pressure contributions of various typical obstructions in barns. The total static pressure is the sum of all applicable resistances.

Table 4-113. Typical Resistance to Air Movement

Source		Static Pressure (inches H_20)
Properly sized and managed inlet		0.04
Shutter	clean	0.02 - 0.10
	dirty	0.05 - 0.20
Exhausting against wind (no shielding)	5 mph	0.02
	10 mph	0.05
	15 mph	0.10
	20 mph	0.20
Fan guards, clean	wire mesh	0.05 - 0.15
	round ring	0.01 - 0.02
Ducts	geothermal tubes	0.50 - 1.50
	solar collector	0.20 - 1.00

From this table, the resistance of an inlet will be 0.04” H_2O static pressure. As other resistances are factored in, the total fan resistance under typical operating conditions will increase.

Current deemed savings require fans to be tested by either the BESS Lab or the AMCA Lab. A case study described in this article supports the use of these tests as manufacture provided information may be unclear or incorrect for fans that are not tested. Based on test conditions that reflect operating conditions, a 36” fan supplied 26 percent less flow than manufacturer ratings indicated, as manufacturer-rated test data was based on 0.00” H_2O static pressure, with no guards or shutters used.

[68] Wheeler, Agricultural and Biological Engineering, University of Pennsylvania State University. “Selecting Rated Ventilation Fans.”

F. PACIFIC NORTHWEST EXTENSION, ARTICLE [69]

The Pacific Northwest Extension is a combination of Oregon State University Extension Services, Washington State University Cooperative Extension, University of Idaho Cooperative Extension System, and the U.S. Department of Agriculture. This article is an overview of ventilation needs, characteristics of air, and types of ventilation systems available.

This document provides minimum ventilation flow rates per cow, as shown in Table 4-114. Similar to the discussion in Section D, the percent of fans running during each weather period can be determined by assuming that the percent of the maximum ventilation rate is equivalent to the percent of fans operating during that period.

Table 4-114. Recommended Minimum Ventilation Rates for Dairy Cows[70]

Weather Period	Ventilation Rate (CFM/Cow)	Percent of Maximum Ventilation Rate (Percent of Fans Operating)
Winter Weather	50	11%
Mild Weather	170	36%
Summer Weather	470	100%

4.6.3 Proposed deemed savings basis and estimates

Based on the above research, we recommend that deemed savings estimates be updated as provided in this section.

A. DEVELOPMENT OF PROPOSED VALUES

i. Error in kWh Savings Calculation

The current deemed kWh savings are calculated using the following equations:

$$kWh_{Savings} = (kW_{savings} \times Hours) + (kW_T \times Hours \times TR)$$

$$kW_{savings} = kW_b - kW_q + (kW_T \times TR)$$

When the $kW_{savings}$ equation is substituted into the $kWh_{savings}$ equation, it results in the following:

$$kWh_{Savings} = \left(kW_b - kW_q + (kW_T \times TR) + (kW_T \times TR)\right) \times Hours$$

This equation accounts for the transition rate savings twice. We recommend that kWh savings be calculated as follows, accounting for the transition rate only once:

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[69] Moore, Oregon State University. *Pacific Northwest Extension Publication,* "Basic Ventilation Considerations for Livestock or Poultry Housing," Reprinted June 1993.

[70] Weather periods not defined. Values are based on 1,400 lbs cows.

$$kWh_{Savings} = \left(kW_b - kW_q + (kW_T \times TR)\right) \times Hours$$

where:

- *Hours = annual fan runtime, hours/year*
- kW_b = baseline fan power, kilowatts
- kW_q = qualifying fan power, kilowatts
- kW_T = fan power savings due to size transition, kilowatts
- TR = transition rate, percent.

ii. Annual Fan Runtime

KEMA was unable to locate the source for industry recommended fan runtimes in the current deemed savings documentation. While many documents relevant to agricultural ventilation fans were reviewed, limited data is available regarding recommended runtimes and typical runtimes in practice. Two of the documents discussed above include recommended minimum ventilation needs for dairy cows. By using airflow needs by weather seasons, the percent of fans operating to meet that need can be estimated, as shown in Table 4-115.

Table 4-115. Minimum Ventilation Needs and Percent of Airflow

Weather Period	Improving Mechanical Ventilation in Dairy Barns		Basic Ventilation Considerations for Livestock and Poultry		Currently Deemed Percent of Fans Running
	Ventilation Rate (CFM/Cow)	Percent of Air Flow	Ventilation Rate (CFM/Cow)	Percent of Air Flow	
Winter Weather	50	10%	50	11%	10%
Mild Weather	170	34%	170	36%	40%
Summer Weather	500	100%	470	100%	100%

While it is unclear how the weather conditions are defined, the currently deemed assumptions for the percent of fans operating in each weather period align closely with the two sources. Therefore, estimates appear reasonable.

It should be noted that 10 percent, 40 percent, and 100 percent of fans run during “cold,” “moderate,” and “hot” temperatures, respectively. There was confusion on this issue during the previous round of deeming. The text of the spreadsheet and the memo suggested that 10 percent, 30 percent, and 60 percent of fans run during these periods, respectively. This was a misunderstanding made by both Focus and KEMA, and a misinterpretation of the calculations (which were correct). In other words, the 10 percent of fans running during “cold” temperatures will also run during “moderate” and “hot” temperatures, and the 30 percent of fans which come on during “moderate” temperatures will stay on during “hot” temperatures. All fans run during “hot” temperatures. It is recommended that text in the deemed savings documentation be corrected to avoid confusion.

The location of the TMY2 data is not provided in the deemed savings analysis. For the purposes of this review, we will assume that the data provided by the program is from a location that is representative of the typical program participant. The source and location should be added in the future for clarity.

iii. Fan Power, Baseline and Qualifying

It is unclear how input motor kW was calculated in the previous round of deeming. The equation currently used is:

$$\text{Motor Input kW} = \left(\frac{(\text{undefined variable} \times \text{Airflow})}{1{,}000 \times \text{VER}}\right) \times 0.85$$

Without more information, we are unable to verify the appropriateness of this equation. We recommend that the following equation be used:

$$\text{Motor Input kW} = \left(\frac{\text{Airflow}}{1{,}000 \times \text{VER}}\right)$$

where:

- *Motor Input kW = Motor input power, kilowatts*
- *Airflow = rated fan airflow, CFM*
- VER = *ventilating efficiency ratio*, *CFM/watt*
- 1,000 = conversion factor, watts per kilowatt.

The existing savings methodology uses a VER of 20 CFM/W or higher to define the efficiency of qualifying equipment. This is close to several of the recommended minimum efficiencies described in the literature review section. We agree with using BESS lab data and the current minimum VER of 20 CFM/W. However, based on several documents that were reviewed, it is apparent that the operating conditions of ventilation fans vary widely. Currently, the calculation is based on VERs at 0.05” H_2O static pressure. All of the documents that were reviewed suggest that typical operating static pressures are much higher than this. We recommend using 0.10” H_2O static pressure test conditions as the basis for assessing baseline and qualifying fan power. This will more accurately reflect typical operating conditions.

A review of the current BESS Lab performance test data shows that approximately 40 test results have been added and several have been removed since this measure was last deemed. It is recommended that the updated test results be used.

Current and proposed values are provided in Table 4-116.

Table 4-116. Modified Baseline and Qualifying Fan kW

	Currently Deemed Values		Proposed Values	
Fan Size	**kW_q (VER ≥ 20 CFM/W)**	**kW_b (VER < 20 CFM/W)**	**kW_q (VER ≥ 20 CFM/W)**	**kW_b (VER < 20 CFM/W)**
36 inch	0.86	1.19	0.53	0.73
48 inch	1.71	2.10	1.06	1.30
50 inch+	1.87	2.44	1.17	1.49

iv. Size Transition Power Savings & Transition Rate

Based on the program's initial estimate, the current transition rate is assumed to be 25 percent. More information is needed to understand actual transition rates. This parameter accounts for the participant's decision to move to fewer larger fans in a percentage of installations. Therefore, the deemed transition rate can only be revised by information collected within the program. The current dairy and livestock application collects brand, model, fan size, and quantity of equipment to be incentivized. Additional data could be collected on the application to capture the quantity and size of the fans to be replaced. The findings could inform future adjustments to the transition rate.

The current calculation uses the following equation to determine the size transition power savings:

$$kW_T = (kW/Fan_{smaller} \times Fan\ Ratio) - kW/Fan_{larger}$$

where:

- $kW/Fan_{smaller}$ = power used by smaller fan, kilowatt
- kW/Fan_{larger} = power used by larger fan, kilowatt
- Fan Ratio = ratio of the number of smaller fans needed to create the same airflow as one larger fan, dimensionless
- kW_T = power savings resulting from the transition to the larger fan, kilowatt.

The fan power used for both smaller and larger fans is calculated by taking the average of the motor input power for all BESS Lab tests for each fan size category (36," 48," 50+"), both qualifying and non-qualifying equipment. By using the average of all fans in each size category, both the smaller and larger kW/Fan will be biased by the VER distribution of BESS Lab test data. If any given fan size has a disproportionate distribution of BESS Lab tests with either high or lower VERs relative to another fan size, the resulting transition rate power savings will be skewed. For example, say the 48" fan category contains data from 30 fans. Twenty-five tests show a VER < 20 cfm/W and five show a VER > 20 cfm/W. The average VER for this category will be the same whether the 48" fan is a high efficiency version replacing a 36" fan or a standard efficiency fan being replaced by a 50+" fan. In contrast, the qualifying and baseline fan powers are calculated by averaging the input motor power of all fans with VERs ≥ 20CFM/W or < 20CFM/W, respectively.

Since the transition rate is based on smaller standard efficiency fans being replaced by larger high efficiency fans, the smaller fans will have the same performance as the baseline fans in that size category. Similarly, the average performance of the larger fans will be the same as the qualifying fan in that size category. It is recommended that the baseline and qualifying fan performance be used for the smaller and larger fans in determining size transition kW savings. Note that the same size assumptions still apply. For example, a 48" qualifying fan will replace a 36" baseline fan.

The proposed size transition kW savings are:

$$kW_T = (kW_{b,\ Smaller} \times \text{Fan Ratio}) - kW_{q,\ Larger}$$

where:

- $kW_{b,Smaller}$ = fan power of the smaller baseline fan, kilowatt
- $kW_{q,\ Larger}$ = fan power of the larger qualifying fan kilowatt
- Fan Ratio = ratio of the number of baseline fans with smaller diameters needed to create the same airflow as one qualifying fan with larger fan diameter, dimensionless.

The $kW_{b,Smaller}$ variable was formerly referred to as $kW/Fan_{Smaller}$ and the $kW_{q,\ Larger}$ was formerly referred to as kW/Fan_{larger}.

However, if this approach is used then the kWh savings calculation needs to be adjusted, resulting in the following equations:

$$kWh_{Savings} = \left((kW_b - kW_q) \times (1 - TR) + (kW_T \times TR)\right)$$

$$kWh_{Savings} = \left((kW_b - kW_q)(1 - TR) + (kW_T \times TR)\right) \times Hours$$

where:

- *Hours = annual fan runtime, hours/year*
- kW_b = baseline fan power, kilowatt
- kW_q = qualifying fan power, kilowatt
- kW_T = fan power savings due to size transition, kilowatt
- TR = transition rate, percent.

The only change is that the portion of savings that result from a typical one-to-one fan replacement is multiplied by (1 - TR).

B. PROPOSED EQUATIONS, PARAMETERS, AND DEEMED VALUES

i. Proposed Equations and Parameters

Savings due ventilation fan installations are described by the following equations:

$$kW_{Savings} = \left((kW_b - kW_q) \times (1 - TR) + (kW_T \times TR)\right)$$

$$kWh_{Savings} = \left((kW_b - kW_q) \times (1 - TR) + (kW_T \times TR)\right) \times Hours$$

where:

- *Hours = annual fan runtime, deemed 3,397 hours/year*
- kW_b = baseline fan power, values in Table 4-117, kilowatt
- kW_q = qualifying fan power, values in Table 4-117, kilowatt
- kW_T = fan power savings due to size transition, values in Table 4-118, kilowatt
- TR = transition rate, values in Table 4-119, percent.

Annual Runtime, Hours. Annual fan runtime represents the hours per year that the average fan will operate.

Fan Power, Baseline, kW_b Baseline fan power represents the power drawn by the average replaced fan in kilowatts.

Fan Power, Qualifying, kW_q. Qualifying fan power represents the power drawn by the average high efficiency fan in kilowatts.

Size Transition Power Savings, kW_T. The overall reduction in fan power from increasing fan size and reducing the number of fans in kilowatts.

Transition Rate, TR. The percent of projects in which many smaller existing fans are replaced with fewer larger fans.

It should be noted that 42” fans do not follow this calculation method, but are given kW and kWh savings values which are an average between 36” and 48” fans.

Table 4-117. Proposed Fan Power Parameters

Fan Size	kW_q (VER $\geq$ 20 CFM/W)	kW_b (VER < 20 CFM/W)
36 inch	0.53	0.73
48 inch	1.06	1.30
50 inch+	1.17	1.49

Table 4-118. Proposed Transition Power Savings Parameters

Transition	Description	$kW_{b, Smaller}$	$kW_{q, Larger}$	Fan Ratio	kW Savings
T1	from 36" to 48"	0.73	1.06	1.94	0.37
T2	from 36" to 50+"	0.73	1.17	2.22	0.25
T3	from 48" to 50+"	1.30	1.17	1.11	0.28

Table 4-119. Proposed Transition Rate

Fan Size (dia.)	Transition	kW_T	TR
36 inch	N/A	N/A	N/A
48 inch	T1	0.37	25%
50 inch+	Average of T2 & T3	0.27	25%

ii. Proposed Deemed Values

Substituting the above values into the savings equation yields the proposed deemed savings values for this measure, found in Table 4-120. Since the program is introducing a measure for circulation fans, we also recommend that the measure descriptions be changed to those provided in this table to distinguish them from the new measures.[71]

Table 4-120. Proposed and Current Deemed Savings Values

Tech Code	Measure Description	Current Deemed Savings		Proposed Deemed Savings	
		kW	kWh/yr	kW	kWh/yr
4.0736.150	Agricultural Exhaust Fan, High Efficiency - 36"	0.322	1,094	0.206	700
4.0742.150	Agricultural Exhaust Fan, High Efficiency - 42"	0.396	1,483	0.240	815
4.0748.150	Agricultural Exhaust Fan, High Efficiency - 48"	0.470	1,872	0.274	930
4.0750.150	Agricultural Exhaust Fan, High Efficiency - 50"	0.664	2,553	0.305	1,037
4.0751.150	Agricultural Exhaust Fan, High Efficiency - 51"	0.664	2,553	0.305	1,037
4.0752.150	Agricultural Exhaust Fan, High Efficiency - 52"	0.664	2,553	0.305	1,037
4.0754.150	Agricultural Exhaust Fan, High Efficiency - 54"	0.664	2,553	0.305	1,037
4.0755.150	Agricultural Exhaust Fan, High Efficiency - 55"	0.664	2,553	0.305	1,037
4.0760.150	Agricultural Exhaust Fan, High Efficiency - 60"	0.664	2,553	0.305	1,037
4.0772.150	Agricultural Exhaust Fan, High Efficiency - 72"	0.664	2,553	0.305	1,037

iii. Confidence in Proposed Savings

There are several assumptions with significant uncertainty that make up the deemed savings values. Given the information available, the savings estimates are likely conservative, increasing the likelihood that savings will be realized. However, there are a number of possibilities for divergence.

The annual runtime hours are based on Focus on Energy staff experience and confirmed by minimum dairy ventilation requirements. Ventilation fan runtimes are likely accurate and modestly conservative. However, minimum ventilation requirements are defined on a per animal basis, not per building or per ventilation system. The difference in definitions is a source of uncertainty. It is also likely that, in practice, fans will operate for longer periods of time to overcome inefficiencies in system design and to add a ventilation safety factor. Finally, uncertainty is introduced by using loosely defined weather conditions.

The accuracy of the transition rate from smaller to larger fans is difficult to gauge. For all fans 48 inches and larger, 25 percent are assumed to be replacing a smaller fan. Larger fan

[71] This change is made at the request of the program.

models have been increasingly available in recent years. However, the source of this estimate is unknown and likely unsupported by research or market data.

Some of the sources reviewed suggest that poor maintenance will dramatically impact a ventilation fan's performance. Some documents cite a 30 percent to 50 percent reduction in performance for poorly maintained fans. However, it is unclear what portion of fans suffer from poor maintenance and what impacts this may have. Soiled fans will result in larger static pressures, causing in lower airflow and VERs. In regards to the deemed savings calculations, the effect of soiled fans will impact both baseline and qualifying equipment. Each fan model's airflow and VER will respond to static pressure increases differently. The inability to project the effect of the soiled fan results in calculation uncertainty.

iv. Recommended Further Research

There are many relevant agricultural ventilation fan sources to inform the deemed savings estimates. However, there were also several assumptions that were made with limited information.

While the estimates for annual runtime hours are probably conservative, future research could improve accuracy. The research could involve collecting detailed information from participating Ag ventilation projects or fielding a metering study of fan operating run times.

As mentioned above, the accuracy of the transition rate from smaller to larger fans is difficult to gauge. Future research should be conducted on the proportion of projects that include a size transition and how it compares to the market as a whole.

As mentioned above, poorly maintained fans will get soiled and their effectiveness will be reduced. With limited market data, it is difficult to assess the potential impacts that soiling and poor maintenance will have. Further research should address this issue.

4.7 HVAC STEAM TRAPS

Group: HVAC

Category: Steam Trap

Technology Description: Repair leaking steam trap, building space conditioning system

Tech Code: 4.1000.390

Qualifying Equipment:

- Boiler must be used for space heating, not process applications.
- Repaired traps must be leaking steam, not failed closed or plugged.
- Incentive is available once per year per system.
- Municipal steam systems do not qualify.

With a steam trap survey:

- Repairs should be performed within 9 months of steam trap survey completion.[72]
- A steam trap survey and repair log must be completed. Required information includes a trap ID tag Number, location description, nominal steam pressure, trap type, trap condition (functioning, failed not leaking, failed leaking), and orifice size. A survey form can be found on the Focus web site.[73]

Without a steam trap survey:

- If mass replacement of steam traps occurs without a survey, it is assumed that 30 percent of the replaced traps were leaking, and the incentive is paid for 30 percent of the replaced traps.

Date Deeming Last Modified: May 2008

Reviewed by: Brian Dunn

Current Deemed Savings: 718 therms per year

Savings Basis: Steam traps that fail in the open position allow steam to escape into the condensate lines before the available heat energy can be used for space heating, wasting the

[72] Because the language used is "should," rather than "must," it is not clear whether this is a requirement.

[73] http://www.focusonenergy.com/files/Document_Management_System/Business_Programs/steamtrapsurveyrepairlog_template.xls.

energy used to make the steam. By replacing or repairing traps that have failed in the open position, the wasted heat energy can be conserved.

4.7.1 Existing deemed savings basis and estimates

This section provides a discussion of the measure as it is currently deemed.

A. SAVINGS EQUATIONS AND PARAMETERS

Savings due to steam trap repairs are described by the following equations:

$$therm\ savings\ =\ DF \times\ Loss\ Rate \times\ \ Energy\ Content \times\ \left(\frac{1}{eff}\right) \times\ Hr \div 100{,}000$$

where:

- *DF = derating factor, deemed 50%*
- *Loss Rate = discharge rate of steam through the leaking trap, values in Table 4-121, lb/hr*
- *Energy Content = energy content of steam, deemed 1,000 Btu/lb*
- *eff = combustion efficiency of boiler, deemed 75%*
- *Hr = annual hours of trap operation, deemed 1,696 hr for thermostatic traps and 4,664 hr for float and thermostatic*
- *100,000 = conversion factor, Btu per therm.*

Derating factor, DF. The derating factor adjusts the maximum trap orifice size to account for partial trap closures or condensate in the orifice which affect the discharge rate of the steam. The effective orifice size is often not equal to the actual orifice size when fully open. Traps can fail at 100 percent open or at any fraction thereof. The derating factor is measured in percent.

Discharge Rate of Steam, Loss Rate. Discharge rate refers to the rate that steam passes through a given orifice size from a given system pressure to atmospheric pressure.

Boiler Efficiency, eff. Boiler efficiency refers to the boiler's combustion efficiency in percent.

Annual hours of operation, Hr. The annual hours of operation correspond to the number of hours per year that the steam trap is exposed to steam. This varies based on the location of the steam trap in the system. Since different types of steam traps are used at different locations within the system, operating hours may also be based on steam trap type.

B. VALUES, ASSUMPTIONS, AND CALCULATIONS

i. Derating Factor

According to the Department of Energy (DOE), "assuming a trap has failed with an orifice size equivalent to one-half its fully open condition is probably prudent.[74]" Therefore, the derating factor is assumed to be 50 percent.

ii. Energy Content of Steam

The energy content of steam was assumed to be 1,000 Btu/lb.

iii. Discharge Rate of Steam

The steam lost through leaking traps is a function of the system pressure and the size of the orifice through which the steam is leaking. Table 4-121 shows estimates of steam loss for various system pressures and orifice sizes.

Table 4-121. Steam Loss in Leaking Traps by Pressure and Orifice Size

	Steam Loss, lb/hr						
Orifice Diameter	**2 psi**	**5 psi**	**10 psi**	**15 psi**	**25 psi**	**50 psi**	**75 psi**
1/32"	0.31	0.49	0.7	0.85	1.14	1.86	2.58
1/16"	1.25	1.97	2.8	3.4	4.6	7.4	10.3
3/32"	2.81	4.44	6.3	7.7	10.3	16.7	15.4
1/8"	4.5	7.9	11.2	13.7	18.3	29.8	41.3
5/32"	7.8	12.3	17.4	21.3	28.5	46.5	64.5
3/16"	11.2	17.7	25.1	30.7	41.1	67	93
7/32"	15.3	24.2	34.2	41.9	55.9	91.2	126
1/4"	20	31.6	44.6	54.7	73.1	119	165
9/32"	25.2	39.9	56.5	69.2	92.5	151	209
5/16"	31.2	49.3	69.7	85.4	114	186	258
11/32"	37.7	59.6	84.4	103	138	225	312
3/8"	44.9	71	100	123	164	268	371
13/32"	52.7	83.3	118	144	193	314	436
7/16"	61.1	96.6	137	167	224	365	506
15/32"	70.2	111	157	192	257	419	580
1/2"	79.8	126	179	219	292	476	660

Source: http://uesystems.com/tech_support_charts_steam_loss.asp (accessed July 3, 2009)

In order to use the above values in the savings calculation, certain further assumptions and calculations are made.

- Assumptions were made regarding the market prevalence of various orifice sizes and the prevalence of steam system pressures based on interviews with Tim Thuemling, owner of Thuemling Industrial Products, Inc. in 2005. Table 4-122 shows

[74] *Steam Trap Performance Assessment.* Federal Energy Management Program. DOE/EE-0193, July 1999, p.12. Available at: http://www1.eere.energy.gov/femp/pdfs/FTA_SteamTrap.pdf.

the assumed prevalence of orifice size for thermostatic steam traps, Table 4-122 shows the assumed prevalence of orifice size for float and thermostatic (F&T) steam traps, and Table 4-124 shows the prevalence of steam system pressures.

Table 4-122. Thermostatic Steam Trap Prevalence

Orifice Size	Prevalence
7/32"	5%
1/4"	5%
5/16"	90%

Table 4-123. F&T Steam Trap Prevalence

Orifice Size	Prevalence
7/32"	48%
1/4"	47%
5/16"	5%

Table 4-124. Steam System Pressure Prevalence

Pressure (psig)	Prevalence
5	45%
10	45%
15	10%

The discharge rate of steam is determined by entering Table 4-121 at the three orifice sizes and three steam pressures identified by Mr. Thuemling. Table 4-125 shows the discharge rates for the nine combinations.

Table 4-125. Discharge Rates of Steam

	Discharge Rate (lb/hr)		
	Steam Pressure, psig		
Orifice Size	5	10	15
7/32"	24.2	34.2	41.9
1/4"	31.6	44.6	54.7
5/16"	49.3	69.7	85.4

iv. Annual Operating Hours

As stated above, the operating hours of a steam trap depend on where the trap is located in the system. Thermostatic steam traps are typically downstream from a steam control valve and are only exposed to steam when the zone is actively being heated. Float and thermostatic control valves are typically exposed to steam whenever the boiler is operating.

The values for annual operating hours are shown in Table 4-126. These hours are based on 212 boiler operating days per year which corresponds to a heating season from October to April. This timeframe is based on the actual operating schedule per school building operators. During these operating days, thermostatic steam traps are assumed to be exposed to steam for eight hours per day. In the deeming documentation, this eight-hour estimate is described as a blend of outside air heating hours and simple building envelope heat loss hours.

Table 4-126. Existing Annual Operating Hours Values

Trap Type	Hours
Thermostatic	1,696
Float and Thermostatic	4,664

Float and thermostatic steam traps are assumed to be exposed to steam for 22 hours per day. This is based on the assumption that most boilers operate 24 hours per day during the heating season, but some boilers may be turned off at night.

v. Boiler Efficiency

The savings calculation assumes a 75 percent boiler combustion efficiency. This is based on the assumption that most large old buildings (especially schools) are using old and inefficient boilers.

vi. Calculation Method

The energy loss was calculated for each discharge rate in Table 4-125 using the operating hours from Table 4-126. Separate calculations were conducted for the two trap types. Then the weighted average energy loss was determined across the orifice size distribution in Table 4-122 and Table 4-123 and again across the steam system pressure distribution in Table 4-124. Finally, thermostatic steam traps were assumed to make up approximately 90 percent of the population and mechanical F&T traps were assumed to make up approximately 10 percent. This distribution was used to determine the final average energy savings for this measure, 718 therms/year.

4.7.2 Literature review

Here we present the findings of various sources related to steam trap repair.

A. FEDERAL TECHNOLOGY ALERTS [75]

This report provides information for evaluating the performance of steam traps. While most of the report is dedicated to describing various trap types and trap testing methods, it also contains information that is useful in estimating steam loss through leaking traps.

According to the report, “approximately 20 percent of the steam leaving a central boiler plant is lost via leaking traps in a typical space heating system.” The report further states that “the best equipment and programs can reduce losses to less than 1 percent.” Finally, the report provides a graph that illustrates the annual losses by trap size and system pressure (see Figure 4-2).

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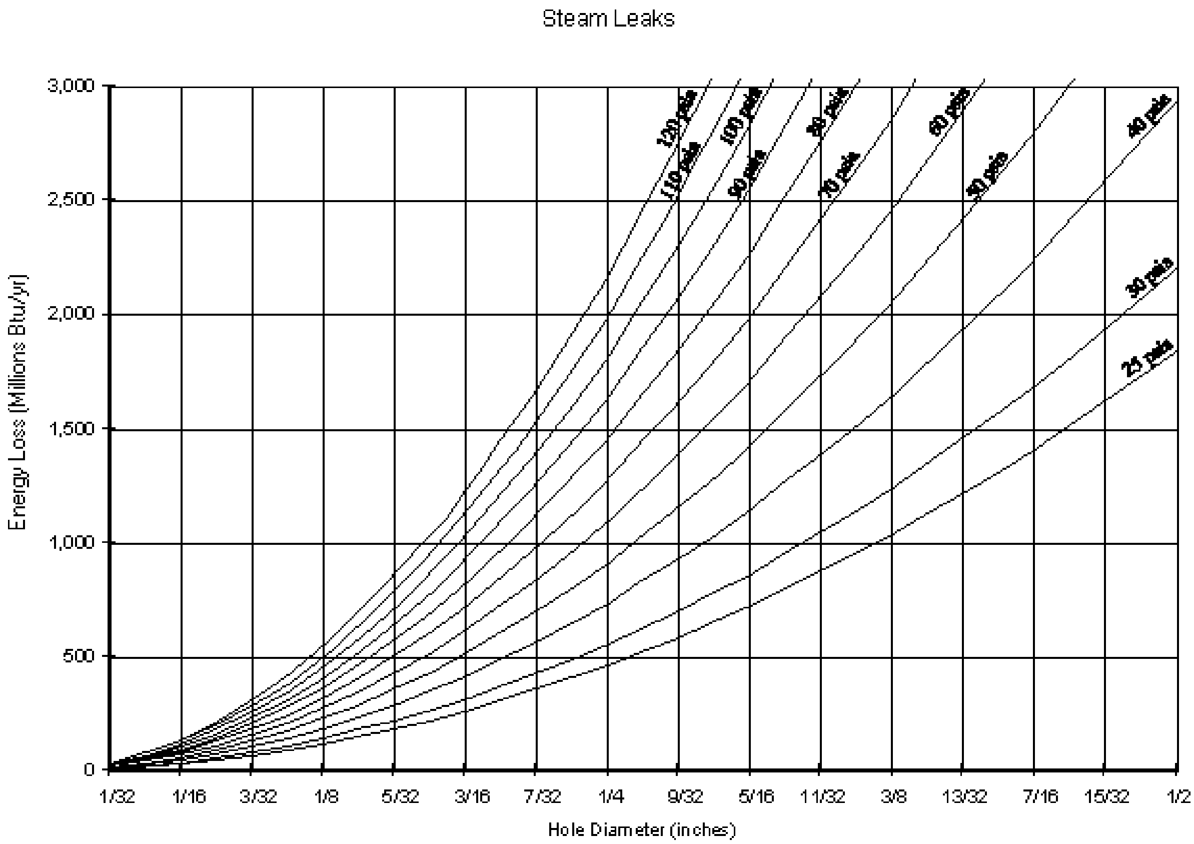
[75] Steam Trap Performance Assessment, Advanced technologies for evaluating the performance of steam traps, Federal Technology Alerts, http://www.plantsupport.com/download/Steam%20Trap%20Performance%20Assessment.pdf (accessed July 6, 2009).

Figure 4-2. Energy Loss from Leaking Steam Traps



This figure was developed in earlier research using Grashof's equation and some assumptions that may or may not apply to steam systems in Wisconsin. This figure is often quoted as the source for energy loss due to steam trap leaks. It assumes any steam lost through the trap does not contribute to the space heating of the building. It also assumes that all condensate must be replaced with make-up water at 60°F (energy and condensate are both lost). For steam traps returning condensate, this assumption will overstate the energy savings.

This report indicated that a trap can fail open anywhere from one to 100 percent. To deal with this unknown, the report suggested assuming that "a trap has failed with an orifice size equivalent to one-half of its fully-opened condition is probably prudent."

The assumptions behind this figure seem to lead to many savings estimates in other sources that are currently available; however, we are unable to determine if these assumptions were used to develop the current deemed savings estimates used by the program.

B. STEAM TRAP MONITORING: ADDING VALUE BY CUTTING WASTE [76]

This article, published in Mechanical Engineering, adds further clarity to Figure 4-2. It states that Grashof's equation "captures the relationship between the area of the orifice and the pressure of the steam line, and how these proportionally affect the flow of steam through the orifice." In addition, it provides the equation as:

$$\dot{Q} = 0.7 \times 0.0165 \times 3600 \times A \times p^{0.97}$$

where:

- $\dot{Q}$ = the flow rate of steam, lb/hr
- 0.7 = the coefficient of discharge for the hole, dimensionless
- A = the area of the hole, in^2
- p = pressure inside the line, psia.

This equation provides results that are similar to those in Table 4-121 for pressures greater than 10 psig but not for pressures less than 10 psig. Since we do not know the source of the data in Table 4-121, we do not know why the equation results differ from the table results for lower pressures. The equation can be used to develop an estimation tool that is consistent with data shown in Figure 4-2 with assumptions appropriate to steam systems in Wisconsin.

C. ENERGY TIPS - STEAM [77]

This tip sheet provides general information on steam trap leaks. The sheet states "in steam systems that have not been maintained for three to five years, between 15 to 30 percent of the installed steam traps may have failed. In systems with a regularly scheduled maintenance program, leaking traps should account for less than 5 percent of the trap population."

D. THE NATURAL GAS BOILER BURNER CONSORTIUM [78]

This website provides general information on boilers, including conversion factors and efficiencies. According to this site, typical boiler efficiencies will be in the 75 to 85 percent range. However, the site does not indicate whether these efficiencies are for steam or hot water boilers.

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[76] Ashley Prins, "Steam Trap Monitoring: Adding Value by Cutting Waste," Mechanical Engineering the Magazine of ASME, edited by Executive Editor Harry Hutchinson, February 2009.

[77] U.S. Department of Energy, *Energy Efficiency and Renewable Energy, Industrial Technologies Program, Steam Tip Sheet #1*, January 2006.

[78] http://www.energysolutionscenter.org/boilerburner/Eff_Improve/Primer/Boiler_Introduction.asp accessed July 6, 2009.

E. ARMSTRONG GUIDE[79]

This website provides general information on steam traps. According to this site, F&T type traps fail closed and thermostatic traps can fail either open or closed depending on the design.

F. INTERVIEW WITH TIM THUEMLING[80]

The original deemed savings estimate provides the market prevalence of various trap sizes and pressures obtained through an interview with Tim Thuemling in 2005. We contacted Mr. Thuemling to verify these values. He confirmed that Table 4-122, Table 4-123, and Table 4-124 are still appropriate values to use.

We also discussed the tendency of thermostatic and F&T traps to fail in the open or closed position. According to Mr. Thuemling, thermostatic traps will fail open "nine times out of ten." F&T traps are more complex. These types of traps have a thermostatic part and float part. According to Mr. Thuemling, the thermostatic part will tend to be the location of the failure since its life expectancy is only three to five years. This part will tend to fail open. The life expectancy of the float part is five to ten years. This part will tend to fail closed. In general, Mr. Thuemling stated that F&T traps are likely to fail open approximately 66 percent of the time.

4.7.3 Proposed deemed savings basis and estimates

Based on the above research, we recommend that deemed savings estimates be updated as provided in this section.

A. DEVELOPMENT OF PROPOSED VALUES

i. Hours of Operation

In order to determine operating hours, we first assume that the boiler will operate only on days when the high temperature is below 65 ºF. This is a reasonable assumption since most commercial, industrial, school, and government buildings have a high internal heat load due to electronic equipment, lighting, and people. These loads will help heat the building when the outdoor air temperature is below the internal set point temperature until cooler weather persists. Based on TMY2 data, the average number of days when the high temperature is below 65 is 226 days. This is slightly greater than the 212 days used in the current deemed savings estimate.

Additionally, the current deemed savings estimate assumes that thermostatic traps operate for eight hours a day and that F&T traps operate for 22 hours per day. We analyzed the assumptions for each of these trap types separately.

[79] http://www.armstronginternational.com/files/common/allproductscatalog/consguidelines.pdf. Accessed July 6, 2009.

[80] Phone interview with Tim Thuemling, July 6, 2009 at 11:00 AM. http://www.thuemling.com/. Accessed July 6, 2009.

The operating hours for thermostatic traps are controlled by steam system valves upstream from the thermostatic traps. These valves close when the system is not calling for heat. Leakage will only occur when these upstream valves are open. As a check of the current assumptions, we calculated the operating hours of a thermostatic trap using the equivalent full load hours of a space heating boiler and the following equations:

$$EFLH = \frac{HDD \times 24\ hours/day}{T_{Indoor} - T_{Outdoor}}$$

$$OH = \frac{EFLH}{Boiler\ Operating\ Days}$$

where:

- EFLH = Equivalent full load operating hours of the boiler, hr/yr
- HDD = Heating degree days for Wisconsin, 7,699 degrees F-day
- T_{Indoor} = Indoor design temp, assumed to be 65 degrees F.
- $T_{Outdoor}$ = Outdoor design temp, deemed to be -15 degrees F.
- OH = Thermostatic Steam Trap Operating Hours per heating day
- Boiler Operating Days = 226 days, cited above.,
- Using the above equations results in 2,310 hours per year for EFLH and 10.2 operating hours per day for a thermostatic steam trap. In the current method, thermostatic steam traps are assumed to operate for 8 hours per day. EFLH can be used to estimate the operating hours of a thermostatic steam trap because the thermostatic steam trap is only exposed to steam when a particular zone is calling for heat, and when it does, it is either on or off. Therefore, we propose using 2,310 hours as the operating hours for a thermostatic steam trap.

The operating hours for F&T traps are based on the hours when the boiler is actually producing steam because these traps generally are not down stream from control valves. During the heating season, the boiler will generally produce steam 24 hours a day. It is possible that the boiler may only operate for partial days in the early and late heating seasons. Therefore, we assume the boilers (and therefore F&T traps) will operate 22 hours per day. Based on 226 days per year, F&T traps will operate 4,972 hours per year. Table 4-127 provides a summary of recommended steam trap operating hours.

Table 4-127. Recommended Annual Steam Trap Operating Hours Estimates

Trap Type	Hours
Thermostatic	2,310
Float and Thermostatic	4,972

ii. Boiler Efficiency

The current deemed savings estimate assumed a boiler efficiency of 75 percent because most schools are thought to have old, inefficient boilers and schools are thought to make up the majority of the participants for this measure. According to the Natural Gas Boiler Burner

Consortium, typical boiler efficiency will be in the 75 to 85 percent range. The midpoint of this range, 80 percent, corresponds to the Wisconsin Commercial Code. Therefore, we recommend using 80 percent for boiler efficiency, which is consistent with the assumption used for other deemed boiler measures.

iii. Energy Content of Steam

The current deemed savings estimate assumes that the energy content of steam is 1,000 Btu per pound. However, the latent heat content of steam will vary based on the pressure of the steam system. This measure covers low pressure HVAC systems only. Therefore, we recommend using the values in Table 4-128, from steam tables.

Table 4-128. Energy Content of Steam by Pressure

Steam Pressure (psig)	Latent Heat (Btu/lb)
5	960.1
10	952.1
15	945.3

iv. Discharge Rate and Derating Factor

As discussed earlier, the steam leakage rate is dependent on the system pressure and the size of the leaking orifice. We were unable to determine the source of the table provided in the current deemed savings calculation. The referenced website provides the table but no information on how the estimates in the table were determined. We therefore used Grashof's equation to estimate the leakage. For a given trap orifice size, we applied the derating factor to the orifice size to determine the leakage rate. The derating factor is assumed to be 50 percent based on a source discussed earlier.[81] Table 4-129 shows the recommended discharge rates.

Table 4-129. Leaking Steam Trap Discharge Rate, Including Derating Factor

	Discharge Rate (lb/hr)		
	Steam Pressure, psig		
Orifice Size	5	10	15
7/32"	14.3	17.7	21.2
1/4"	18.7	23.2	27.6
5/16"	29.2	36.2	43.2

v. Trap Type Population Weights

As discussed earlier, the thermostatic traps comprise 90 percent of the population and F&T traps comprise 10 percent. Either of these traps can fail open or closed, although thermostatic traps tend to fail open more frequently. We estimated weighting factors based on the population percentages and the rate that fail open, shown in Table 4-130. The weight in the right column refers to the portion of "failed open" traps that are of each trap type. For example, the thermostatic weight is 92 percent. Therefore, 92 percent of the traps that fail open are assumed to be thermostatic traps.

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[81] Steam Trap Performance Assessment, Op Cit.

Table 4-130. Trap Type Weights

Trap Type	Population Percentage	Rate that Fail Open	Population Percentage that Fail Open	Weight
Thermostatic	90%	90%	81%	92%
F&T	10%	66%	7%	8%

B. PROPOSED EQUATIONS, CALCULATIONS, AND DEEMED VALUES

i. Proposed Equations and Parameters

To determine the deemed savings value, we first calculate the therms lost through each type of trap at each orifice size and at each pressure. We do this using the same savings equation that is used in the current deemed savings method minus the discharge rate, which is now included in the Loss Rate.

Energy savings for this measure is calculated using the following formula:

$$therm\ savings\ =\ Loss\ Rate \times\ Energy\ Content \times \left(\frac{1}{eff}\right) \times Hr \div 100{,}000$$

where:

- *Loss Rate = discharge rate of steam through the leaking orifice that is 50% of the fully opened orifice, values in Table 4-129, lb/hr*
- *Energy Content = energy content of steam by pressure, values in Table 4-128, Btu/lb*
- *eff = combustion efficiency of boiler, deemed 80 percent*
- *Hr = annual hours of trap operation, deemed by trap type, values in Table 4-127, hr/yr*
- *100,000 = conversion factor, Btu per therm.*

The results of the calculations for thermostatic traps by orifice size are shown in Table 4-131. Those results were weighted by steam system pressure as seen in Table 4-132. The average energy savings from a thermostatic steam valve are 889 therms per year.

Table 4-131. Therms Savings per Year, Thermostatic Steam Traps Across System Pressures

		Therms Saved per Year		
		Steam Pressure, psig		
Orifice Size	Prevalence	5	10	15
7/32"	5%	396	488	578
1/4"	5%	517	637	755
5/16"	90%	808	995	1,179
Weighted average	100%	773	952	1,128

Table 4-132. Therms Savings per Year, F&T Steam Traps Across System Pressures

Steam Pressure	Prevalence	Therm Savings
5	45%	773
10	45%	952
15	10%	1,128
Weighted average	100%	889

The process was repeated for F&T steam traps. The results of the calculations for F&T traps by orifice size are shown in Table 4-133. Those results were weighted by steam system pressure as seen in Table 4-134. The average energy savings from a thermostatic steam valve are 1,172 therms per year.

Table 4-133. Therms Savings per Year by Repairing Leaking F&T Steam Traps

		Therms Saved per Year		
		Steam Pressure, psig		
Orifice Size	Prevalence	5	10	15
7/32"	48%	852	1,049	1,244
1/4"	47%	1,113	1,371	1,624
5/16"	5%	1,739	2,142	2,538
Weighted average	100%	1,019	1,255	1,487

Table 4-134. Therms Savings per Year, F&T Steam Traps Across System Pressures

Steam Pressure	Prevalence	Therm Savings
5	45%	1,019
10	45%	1,255
15	10%	1,487
Weighted average	100%	1,172

Finally, we calculate a weighted average for the population of steam traps:

$$Deemed\ Therm\ Savings = Wt_{Thermostatic} \times Therms_{Thermostatic} + Wt_{F\&T} \times Therms_{F\&T}$$

where:

- $Wt_{Thermostatic}$ = Weight of population of failed open traps that are thermostatic, deemed 92 percent
- $Wt_{F\&T}$ = Weight of population of failed open traps that are F&T, deemed 8 percent
- $Therms_{Thermostatic}$ = weighted average therms saved annually for thermostatic steam traps, 889 therms per year
- $Therms_{F\&T}$ = weighted average therms saved annually for thermostatic steam traps, 1,172 therms per year.

ii. Proposed Deemed Values

Substituting the above values into the savings equation yields the proposed deemed savings value for this measure, found in Table 4-135.

Table 4-135. Proposed and Current Deemed Savings Values

Tech Code	Measure Description	Current Deemed Savings (therms per year)	Proposed Deemed Savings (therms per year)
4.1000.390	Repair leaking steam trap, building space conditioning system	718	910

iii. Confidence in Proposed Savings

When possible, the deemed savings estimates proposed above are based on conservative assumptions. However, the current estimate assumes the trap has leaked for a full year prior to being repaired. Best practices state that steam trap reviews and repairs should be performed on an annual basis. Adhering to best practice will mean that the average time that a steam trap would leak would be reduced, possibly as much as six months, which would reduce the savings estimate by half. As the program or other forces influence steam system operators to perform annual steam trap surveys and maintenance, the proposed savings may not be realized.

The deemed savings estimates are also based on the experience of one steam trap service provider in Wisconsin. Though the service provider has been very active in the program and likely implemented a strong percentage of participating projects, the data he presents is not based on empirical research. Therefore, the savings estimates provided here are not as accurate as they could be. KEMA's confidence in the deemed savings estimates is relatively low for this measure. However, custom calculation estimates will not improve on the deemed estimates; therefore we recommend that this measure continue to be deemed.

iv. Recommended Further Research

The sources described in this review are based on theoretical estimates of leakage rates, assumed operating hours, and expert opinions on market prevalence of steam system pressures and trap types and sizes. We were unable to find empirical research demonstrating savings due to steam trap repairs in an HVAC system. A study that examined the actual realized savings throughout the state of Wisconsin would provide a more accurate statement of expected savings.

4.8 BOILER TUNE-UPS

Group: Boilers & Burners

Category: Boiler

Tech Code: 1.1300.430

Technology Description: Tune-up natural gas boilers to improve combustion efficiency.

Qualifying Equipment:

- The boiler must be fueled by natural gas and have a minimum output of 120MBh.
- The burner must be adjusted to improve combustion efficiency, and the service provider must perform pre- and post-service combustion efficiency tests.

Date Deeming Last Modified: May 2008

Reviewed by: Brian Dunn

Current Deemed Savings: 0.679 Therms per year per boiler input capacity (in MBh)

Savings Basis: As a boiler operates over a period of time, the combustion efficiency can decrease due to fouling, controls maladjustment, or other issues. The efficiency can be improved by tuning up the boiler to return it to near optimal operating conditions. This efficiency gain will save natural gas.

4.8.1 Existing deemed savings basis and estimates

This section provides a discussion of the measure as it is currently deemed.

A. SAVINGS EQUATIONS AND PARAMETERS

Savings due to performing a boiler tune-up are described by the following equation. Savings are determined by applying a savings factor to an estimate of the boiler consumption prior to the tune-up. The energy savings for this measure are determined per input boiler capacity in MBh.

$$\frac{Therm\ Savings}{MBh\ Input} = SF \times \frac{HDD \times 24}{(T_{Indoor} - T_{Outdoor}) \times Eff_{Pre-TuneUp} \times 100}$$

where:

- SF = Savings Factor, deemed 2.5 percent
- $Eff_{Pre\text{-}TuneUp}$ = Efficiency of the boiler prior to the tune-up, deemed 85 percent
- T_{Indoor} = Indoor design temp, assumed to be 65°F.
- $T_{Outdoor}$ = Outdoor design temp, deemed -15°F.

- HDD = Heating Degree Days for Wisconsin, deemed 7,699
- 100 = conversion factor, MBh (thousand Btu per hour) per therm.
- *Savings Factor, SF.* The savings factor is an estimate of the portion of the annual gas consumption that is saved due to tuning up the boiler.[82]
- *Efficiency of the Boiler Prior to Tune-up, $Eff_{Pre\text{-}TuneUp}$.* The efficiency of the boiler prior to tune-up is the assumed combustion efficiency of the boiler that will be serviced.
- *Indoor design temperature, T_{Indoor}.* The indoor design temperature is the standard balance temperature used in system design calculations.
- *Outdoor design temperature, $T_{Outdoor}$.* In system design calculations, the outdoor design temperature is the coldest temperature for which a heating system is designed to meet the heating load, disregarding any oversizing. For this calculation, we use a population-weighted average of outdoor design temperatures for Wisconsin.

B. VALUES, ASSUMPTIONS, AND CALCULATIONS

The values used for each parameter in the current deemed savings calculation are discussed below.

i. Efficiency of the Boiler Prior to Tune-up

The assumed boiler baseline efficiency is 85 percent. This value is halfway between the minimum boiler efficiency in the Wisconsin Commercial Code and the efficiency of the most efficient boilers available on the market. The estimate assumes that half of the serviced boilers met code at installation and half were high efficiency.

ii. Savings Factor

The current savings calculation uses a deemed savings factor of 2.5 percent. The deemed savings documentation states that boilers that are tuned regularly will have small efficiency improvements, near one percent, and those that are not maintained regularly can improve up to ten percent. It also states that typical efficiency improvements are in the three to five percent range. A savings factor of 2.5 percent was chosen which is thought to be a conservative estimate.

iii. Indoor Design Temperature

The indoor design temperature, 65°F, is the standard balance temperature in design calculations.

[82] Note that this savings factor is not the same thing as “efficiency improvement,” a parameter that would represent the difference between the efficiency before the tune up and the efficiency after. If the value were for efficiency improvement, the equation would take a different form.

iv. Outdoor Design Temperature

The outdoor design temperature is based on a population-weighted average of Department of Commerce design temperatures. The average Wisconsin design temperature is -15°F.

4.8.2 Literature review

Here we present the findings of various sources related to boiler tune-ups.

A. BUILDING TUNE-UP AND OPERATIONS PROGRAM EVALUATION[83]

The Building Tune-up and Operations Program Evaluation was performed for the Energy Trust of Oregon and covered a broad spectrum of measures. Of interest to this review is the finding that annual savings from boiler tune-ups were approximately one percent of the boiler's pre-service energy consumption. The study also concluded that systems with the potential for the greatest savings have already implemented annual maintenance programs. This study appeared to be specific to HVAC boilers, though it was never explicitly stated.

B. ENBRIDGE STEAM SAVER PROGRAM, COMMERCIAL/INSTITUTIONAL[84]

The Enbridge Steam Saver Program focused on energy conservation measures related to steam systems. The document stated that, based on combustion tests performed on hundreds of boilers, "a regular boiler tune-up will save an average of 1.6 percent of the total fuel consumed by the average boiler plant."

C. THE NATURAL GAS BOILER BURNER CONSORTIUM[85]

The Natural Gas Boiler Burner Consortium website provides general information on boilers, including conversion factors and efficiencies. According to this site, typical boiler efficiencies will be in the 75 to 85 percent range. However, the site does not indicate whether these efficiencies are for steam or hot water boilers.

4.8.3 Proposed deemed savings basis and estimates

While this measure is not restricted to HVAC boilers, some of the smaller boilers eligible for this measure are likely to be HVAC boilers. We base our deemed savings estimate on the assumption that the boilers that are serviced are likely used primarily for space heating. Large process boilers are likely to have greater savings than we have deemed due to longer

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[83] Linda Dethman and Rick Kunkle for Energy Trust of Oregon, Phil Degens, evaluation manager. *Final Report, Building Tune-Up and Operations Program Evaluation*. *http://www.energytrust.org/library/reports/0705_BTO_ProgramEvaluation.pdf?link_programs_reports_lin1Page=2*. Accessed July 7, 2009.

[84] *Enbridge Steam Saver Program, Commercial/Institutional, https://portal-plumprod.cgc.enbridge.com/enbridge/files/comm_steam_saver.pdf*. Accessed July 7, 2009.

[85] http://www.energysolutionscenter.org/boilerburner/Eff_Improve/Primer/Boiler_Introduction.asp. Accessed July 6, 2009.

operating hours and a higher load factor.[86] Based on this assumption and the above research, we recommend that deemed savings estimates be updated as provided in this section.

A. DEVELOPMENT OF PROPOSED VALUES

i. Efficiency Improvement due to Boiler Tune-up

The two studies that researched actual savings due to boiler tune-ups found improvements from 1.0 to 1.6 percent. Many other sources made claims of more substantial savings, but claims in these sources are unsubstantiated or only applied to a boiler that had never been tuned up.

Since participants are eligible for the rebate every year, we believe that many will implement an annual maintenance program and use the annual rebate. Therefore, the majority of the service work would be performed on regularly tuned boilers. We assumed an efficiency improvement of 1.6 percent for this measure based on the sources found. We chose the higher end of the savings range to account for the higher energy savings that will be realized from process boilers, which are also eligible for this measure.

ii. Standard Boiler Efficiency

The current deemed savings estimate assumed an efficiency of 85 percent based on the Wisconsin Commercial Code and the highest efficiency available on the market. According to the Natural Gas Boiler Burner Consortium, the typical boiler efficiency will be in the 75 to 85 percent range. Since the midpoint of that range agrees with Wisconsin code, we recommend using 80 percent for this measure.

iii. Boiler Oversize Factor

The existing deeming method assumes that the boiler is designed to meet the design heating load of the building exactly. However, boilers will generally be oversized due to safety factors and limitations on the discrete sizing of boilers. For that reason, we introduce an additional factor to the calculation to account for this over sizing. This is consistent with other deeming calculations. We have used a 77 percent oversize factor for boilers in space heating measures and recommend using the same value for this measure.

B. PROPOSED EQUATIONS, PARAMETERS, AND DEEMED VALUES

i. Proposed Equations and Parameters

In conclusion, we recommend the following formulas be used to calculate deemed savings for boiler tune-ups.

Energy savings due to boiler tune-ups are calculated by the following equations:

[86] These large boilers are also more likely to be maintained regularly thereby reducing potential savings.

$$\frac{\text{Therm Savings}}{\text{MBh Input}} = BOF \times SF \times \frac{HDD \times 24}{(T_{Indoor} - T_{Outdoor}) \times Eff_{Pre-TuneUp} \times 100}$$

where:

- BOF = Boiler oversize factor, deemed 77 percent
- SF = Savings Factor, deemed 1.6 percent
- $Eff_{Pre\text{-}TuneUp}$ = Efficiency of the boiler prior to the tune-up, deemed 80 percent
- T_{Indoor} = Indoor design temp, assumed to be 65°F.
- $T_{Outdoor}$ = Outdoor design temp, deemed -15°F.
- HDD = Heating Degree Days for Wisconsin, deemed 7,699
- 100 = conversion factor, MBh (thousand Btu per hour) per therm.
- *Savings Factor, SF.* The savings factor is an estimate of the percent of annual gas consumption that is saved due to tuning up the boiler.[87]
- *Efficiency of the Boiler Prior to Tune-up, $Eff_{Pre\text{-}TuneUp}$.* The efficiency of the boiler prior to tune-up is the assumed combustion efficiency of the boiler that will be serviced.
- *Indoor design temperature, T_{Indoor}.* The indoor design temperature is the standard balance temperature used in system design calculations.
- *Outdoor design temperature, $T_{Outdoor}$.* In system design calculations, the outdoor design temperature is the coldest temperature for which a heating system is designed to meet the heating load, disregarding any oversizing. For this calculation, we use a population-weighted average of outdoor design temperatures for Wisconsin.

ii. Proposed Deemed Values

Substituting the above values into the savings equation yields the proposed deemed savings value for this measure, found in Table 4-136.

Table 4-136. Proposed and Current Deemed Savings Values

Tech Code	Measure Description	Current Deemed Savings (therms per year per input MBh)	Proposed Deemed Savings (therms per year per input MBh)
1.1300.430	Boiler Tune-up - service buy-down	0.679	0.356

[87] Note that this savings factor is not the same thing as “efficiency improvement,” a parameter that would represent the difference between the efficiency before the tune up and the efficiency after. If the value were for efficiency improvement, the equation would take a different form.

iii. Confidence in Proposed Savings

The deemed savings estimates proposed above are generally based on conservative assumptions and empirical research. We believe these deemed savings will be fully realized.

iv. Recommended Further Research

Two of the sources described in this review are based on empirical research to determine actual savings due to boiler tune-ups. These studies were not performed in a climate identical to Wisconsin's and actual savings in Wisconsin could vary somewhat. However, we do not believe that any improvements in accuracy would be substantial. The climate in one study was warmer than Wisconsin's while the climate for the other study was colder. Regardless, performing research in Wisconsin on boiler combustion efficiency may provide improved accuracy since the types and efficiencies of boilers in the population could differ from the two empirical studies.

4.9 LINKAGELESS BOILER CONTROLS

Group: Boilers & Burners

Category: Controls

Technology Description: Linkageless Boiler Controls

Tech Code: 1.0711.085

Qualifying Equipment: Controls must be installed on natural gas forced draft boilers 200 hp or greater that operate for a minimum of 4,000 hours per year.

Date Deeming Last Modified: November 2008

Reviewed by: Brian Dunn

Current Deemed Savings: 27 therms per year per boiler horsepower

Savings Basis: Traditional boiler combustion controls consist of a single servo motor and a series of linkages to control the air and fuel flows into the combustion chamber. The linkage connections are susceptible to hysteresis which limits the accuracy of the control. In addition, linkage controls are unable to match the combustion curve for airflow and fuel flow across a range of burn rates. Therefore, combustion efficiency is not optimized. Linkageless controls eliminate these issues and can improve the efficiency of the boiler.[88]

4.9.1 Existing deemed savings basis and estimates

This section provides a discussion of the measure as it is currently deemed.

A. SAVINGS EQUATIONS AND PARAMETERS

Savings due to the installation of linkageless controls are described by the following equation:

$$\frac{\text{Therm}_{\text{savings}}}{BoilerHP} = \left(\frac{33{,}469.8 \times \text{BLF} \times \text{hours}}{\text{Eff}_{\text{Boiler}} \times 100{,}000}\right) * \text{SF}$$

where:

- 33,469.8 = Conversion Factor, Btuh per Boiler HP
- BLF = Boiler Load Factor, deemed 50 percent
- Hours = Annual boiler operating hours, deemed 4,380 hours

[88] Oxygen trim controls are generally an add-on feature to linkageless boiler controls and could even be included as part of a linkageless control system. The savings deemed in this document are only for the portion of savings related to linkageless control. If oxygen trim is an option installed as part of the linkageless system, the savings need to be estimated separately.

- EFF_{Boiler} = Boiler Efficiency, deemed 80 percent
- 100,000 = Conversion factor, Btu per therm
- SF = Savings Fraction due to linkageless controls, deemed 3.0 percent.

Boiler Load Factor, BLF. The boiler load factor is the estimated average percent load on the boiler. It is the average percent of boiler capacity at which the boiler operates.

Operating Hours, Hours. Operating hours refers to the average annual operating hours of the boiler on which linkageless controls are being installed.

Boiler Efficiency, EFF_{Boiler}. Boiler efficiency in this calculation refers to the combustion efficiency of the boiler on which linkageless controls are installed.

Savings Fraction, SF. Savings fraction is the percent of annual consumption that will be saved due to linkageless controls.

B. VALUES, ASSUMPTIONS, AND CALCULATIONS

The values used for each parameter in the current deemed savings calculation are discussed below.

i. Boiler Load Factor

The existing deemed savings calculation assumes that the boiler will operate at an average of 50 percent of rated load. No source is given for this value.

ii. Operating Hours

The minimum value required to receive the incentive is 4,000 hours. The assumed value for operating hours is 4,380 hours or one-half of the year. Some boilers operate only during the heating season, but many other large boilers operate year round.

iii. Boiler Efficiency

The baseline boiler efficiency is 80 percent. This is the minimum Wisconsin code value and was deemed in the modulating boiler measures review in May 2008.

iv. Savings Fraction

The savings fraction is the percent of annual energy usage that is expected to be saved due to a linkageless control retrofit. One source states that, "many engineers report having saved as much as five to 15 percent or more installing a linkageless-control upgrade on an existing burner package."[89] Another source claimed, "[installing linkageless combustion controls]

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[89] http://hpac.com/bse/burner-controls-boilers/. Accessed July 7, 2009.

typically results in savings in the three to ten percent range."[90] Three percent of annual energy use was selected as a conservative estimate.

4.9.2 Literature review

Here we present the findings of various sources related to boiler linkageless controls.

A. YORKLAND CONTROLS WEBSITE[91]

The Yorkland Controls website provides an estimating tool where users can calculate potential savings related to linkageless control systems. The tool outlines the benefits of linkageless controls and provides guidelines for the potential energy savings resulting from each benefit. The following is a summary:

- Linkage systems have wear over time. Linkageless systems have no hysteresis across the actuator stroke and typically operate with 0.1 percent accuracy. Removing linkage wear can save from 0 to 1 percent.
- Linkage systems cannot maintain consistent excess air across the firing curve. Linkageless systems can, improving combustion and reducing stack temperature and emissions. Improved combustion can save from 0.5 to 3 percent.
- "Linkage systems lite-off and minimum modulation positions are typically the same. Linkageless system lite-off and minimum modulation positions are independent, increasing turndown." Turndown is the degree to which a boiler can modulate its firing rate. Increased turndown can save from 0.5 to 1.5 percent.

Summing the individual savings for each benefit, this site claims that total savings from linkageless controls range from 1.0 to 5.5 percent.

B. GUIDE TO INDUSTRIAL ASSESSMENTS FOR POLLUTION PREVENTION AND ENERGY EFFICIENCY[92]

The Guide to Industrial Assessments for Pollution Prevention and Energy Efficiency describes the effect that excess air can have on boiler efficiency. Table 4-137 shows the relationship between excess air, net stack temperature, and combustion efficiency. Net stack temperature is the difference between the flue gas temperature and the combustion air temperature. This source also states that ten percent excess air is the optimal balance point between efficiency and other practical concerns such as pollution.

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[90] http://thermalenergyconservation.biz/linkageless.html. Accessed July 7, 2009.

[91] http://www.yorkland.net/counter.htm. Accessed July 7, 2009.

[92] Guide to Industrial Assessments for Pollution Prevention and Energy Efficiency, http://www.p2pays.org/ref/19/18351.pdf. Accessed July 7, 2009.

Table 4-137. Boiler Combustion Efficiency Based on Excess Air and Net Stack Temperature

Excess Air	O_2 %	CO_2%	Combustion Efficiency by Net Stack Temperature						
			220 F	230 F	240 F	246 F	250 F	260 F	270 F
0.0	0.0	11.8	85.3	85.1	84.9	84.8	84.7	84.5	84.2
2.2	0.5	11.5	85.2	85.0	84.8	84.7	84.6	84.4	84.1
4.5	1.0	11.2	85.1	84.9	84.7	84.6	84.5	84.2	84.0
6.9	1.5	11.0	85.0	84.8	84.6	84.5	84.4	84.1	83.9
9.5	2.0	10.7	84.9	84.7	84.5	84.3	84.2	84.0	83.8
12.1	2.5	10.4	84.8	84.6	84.4	84.2	84.1	83.9	83.7
15.0	3.0	10.1	84.7	84.5	84.2	84.1	84.0	83.8	83.5
18.0	3.5	9.8	84.6	84.4	84.1	84.0	83.9	83.6	83.4
21.1	4.0	9.6	84.5	84.2	84.0	83.8	83.7	83.5	83.2
24.5	4.5	9.3	84.3	84.1	83.8	83.7	83.6	83.3	83.1
28.1	5.0	9.0	84.2	83.9	83.7	83.5	83.4	83.2	82.9
31.9	5.5	8.7	84.1	83.8	83.5	83.4	83.3	83.0	82.7
35.9	6.0	8.4	83.9	83.6	83.3	83.2	83.1	82.8	82.5
40.3	6.5	8.2	83.7	83.4	83.2	83.0	82.9	82.6	82.3
44.9	7.0	7.9	83.5	83.3	83.0	82.8	82.7	82.4	82.1
49.9	7.5	7.6	83.4	83.1	82.8	82.6	82.5	82.2	81.9
55.3	8.0	7.3	83.1	82.8	82.5	82.3	82.2	81.9	81.6
61.1	8.5	7.0	82.9	82.6	82.3	82.1	82.0	81.6	81.3
67.3	9.0	6.7	82.7	82.3	82.0	81.8	81.7	81.4	81.0
74.2	9.5	6.5	82.4	82.1	81.7	81.5	81.4	81.0	80.7
81.6	10.0	6.2	82.1	81.8	81.4	81.2	81.1	80.7	80.3
89.8	10.5	5.9	81.8	81.4	81.1	80.9	80.7	80.3	79.9
98.7	11.0	5.6	81.5	81.1	80.7	80.5	80.3	79.9	79.5
108.7	11.5	5.3	81.1	80.7	80.3	80.1	79.7	79.4	79.0
119.7	12.0	5.1	80.6	80.2	79.8	79.4	79.4	78.9	78.5

Finally, this source states that, "in the absence of any reference temperature, it is normally expected that the stack temperature be less than 100°F above the saturated steam temperature at a high firing rate in a saturated steam boiler (this doesn't apply to boilers with economizers and air pre-heaters)." Boilers with economizers and preheaters will have a lower stack temperature and a higher efficiency because more of the heat of combustion is captured.

C. BOILER EFFICIENCY FACTS [93]

The Boiler Efficiency Facts sheet is provided by Cleaver Brooks, a boiler manufacturer. It includes information about excess air operating points for boilers. According to this fact sheet, boilers with complex linkage control systems usually operate with more than 15 percent excess air. This exceeds the 10 percent excess air needed for optimal efficiency. Therefore, linkage control systems cannot operate the system at optimal efficiency. A linkageless system, however, can generally provide better control and improved combustion efficiency.

[93] http://www.boilerspec.com/EmmisEffic/boiler_efficiency_facts.pdf. Accessed July 7, 2009.

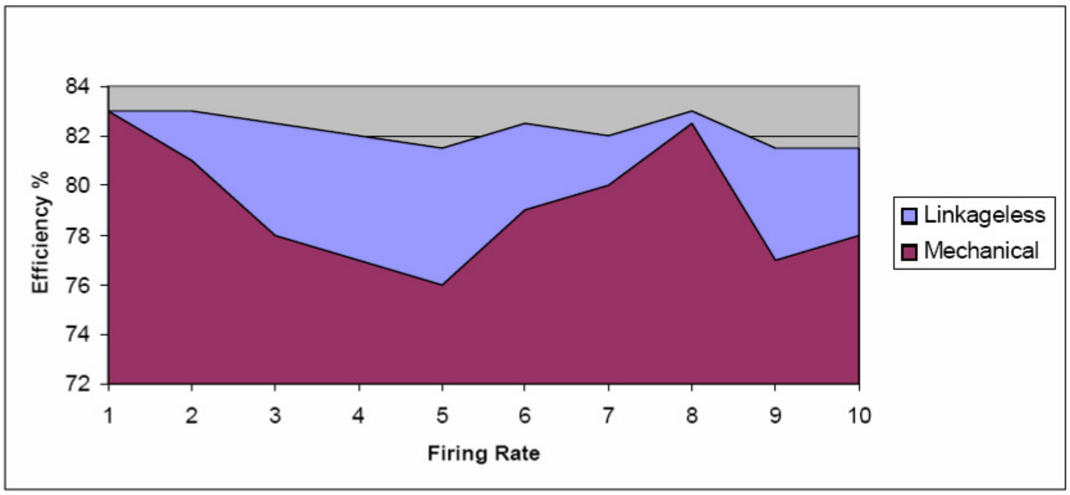
D. LINKAGELESS BURNER CONTROL [94]

This article states that, “there is a tendency to run burners with about 50-percent excess air.” This tendency is due to the inability to tightly control combustion air with a traditional linkage control system.

E. REMOVING GUESSWORK [95]

This article provides a clear picture of how linkageless controls can improve the efficiency of a burner. Figure 4-3 was provided in the article to illustrate that mechanical controls cannot maintain the same efficiency levels as linkageless controls across the firing range.

Figure 4-3. Efficiency versus Firing Rate Based on Control Type



Based on this graphic, the average efficiency gain across the range of firing rates is 3.1 percentage points. We were unable to verify the basis for the figure but the average efficiency gain is consistent with other sources.

F. ENBRIDGE STEAM SAVER PROGRAM, COMMERCIAL/INSTITUTIONAL [96]

The Enbridge Steam Saver Program is an incentive program to promote energy savings for steam systems. The documentation for the program states that, “annual fuel savings compared to mechanical type linkages can be up to 5 percent.”

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[94] Duncan Cairnie. “Linkageless Burner Control, Linkageless control systems help reduce greenhouse gases,” *HPAC Engineering*. http://hpac.com/mag/linkageless_burner_control/index.html. June 2008.

[95] Gary Cellucci, HPAC, Hydronics, *Removing Guesswork* September/October 2005 http://www.bizlink.com/HPAC_articles/September2005/38.pdf.

[96] Enbridge Steam Saver Program, Commercial/Institutional, https://portal-plumprod.cgc.enbridge.com/enbridge/files/comm_steam_saver.pdf.

G. WANT YOUR BURNER TO BE MORE EFFICIENT AND RELIABLE [97]

This document was published by a controls manufacturer to educate boiler system operators on the efficiency gains possible through the use of linkageless controls. The document states that linkageless controls "reduce fuel usage from 2 to 6 percent and beyond."

H. THE NATURAL GAS BOILER BURNER CONSORTIUM [98]

The Natural Gas Boiler Burner Consortium website provides general information on boilers, including conversion factors and efficiencies. According to this site, typical boiler efficiencies will be in the 75 to 85 percent range. However, the site does not indicate whether these efficiencies are for steam or hot water boilers.

4.9.3 Proposed deemed savings basis and estimates

Based on the above research, we recommend that deemed savings estimates be updated as provided in this section.

A. DEVELOPMENT OF PROPOSED VALUES

i. Savings Fraction

The sources that we found provided savings estimates from one to 15 percent. We viewed the data from "Want Your Burner to be More Efficient and Reliable" with skepticism because it was intended to be a marketing tool, but data from this source is consistent with the others consulted for the savings fraction. Most of the sources indicated savings in the range of two to six percent. In absence of solid data, three percent is a reasonable estimate based on the available sources.

ii. Standard Boiler Efficiency

The current deemed savings estimate assumed an efficiency of 80 percent based on the Wisconsin Commercial Code. According to the Natural Gas Boiler Burner Consortium, typical boiler efficiency will be in the 75 to 85 percent range. Since the midpoint of that range agrees with Wisconsin code, the deemed value of 80 percent is reasonable.

iii. Operating Hours

We assume that process boilers will operate year round while heating boilers will only operate during the heating season. The incentive qualifications require that the controlled boiler operate for a minimum of 4,000 hr/yr. Therefore, we recommend annual operating hours of 4,000 hr/yr. This value provides a conservative estimate of energy savings.

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[97] "Want Your Burner to be More Efficient and Reliable? Industrial Insights brochure by Industrial Controls." http://www.industrialcontrolsonline.com/pdf/Industrial%20Insights/ControlLinks%20Article.pdf. March 2007.

[98] http://www.energysolutionscenter.org/boilerburner/Eff_Improve/Primer/Boiler_Introduction.asp. Accessed July 6, 2009.

iv. Boiler Load Factor

The current deemed savings method assumes a boiler load factor value of 50 percent. There was no source provided to support this estimate. During our review, we were unable to find any studies or reports that suggested an appropriate load factor. We feel that the current estimate is reasonable; therefore, we recommend a boiler load factor of 50 percent.

B. PROPOSED EQUATIONS, PARAMETERS, AND DEEMED VALUES

i. Proposed Equations and Parameters

In conclusion, we recommend the following formulas be used to calculate deemed savings for linkageless controls.

Energy savings for this measure is calculated using the following formulas:

$$\frac{\text{Therm}_{\text{savings}}}{BoilerHP} = \left(\frac{33{,}469.8 \times \text{BLF} \times \text{hours}}{\text{Eff}_{\text{Boiler}} \times 100{,}000}\right) * \text{SF}$$

where:

- 33,469.8 = Conversion Factor, Btuh per Boiler HP.
- BLF = Boiler Load Factor, deemed 50 percent
- Hours = Annual boiler operating hours, deemed 4,000 hours
- $\text{EFF}_{\text{Boiler}}$ = Boiler Efficiency, deemed 80 percent
- 100,000 = Conversion factor, BTU per therm
- SF = Savings Fraction due to linkageless controls, deemed 3 percent

Boiler Load Factor, BLF. The boiler load factor is the estimated average percent load on the boiler. It is the average percent of boiler capacity at which the boiler operates.

Operating Hours, Hours. Operating hours refers to the average annual operating hours of the boiler on which linkageless controls are being installed.

Boiler Efficiency, EFF_{Boiler}. Boiler efficiency in this calculation refers to the combustion efficiency of the boiler on which linkageless controls are installed.

Savings Fraction, SF. Savings fraction is the percent of annual consumption that will be saved due to linkageless controls.

ii. Proposed Deemed Values

Substituting the above values into the savings equation yields the proposed deemed savings value for this measure, found in Table 4-138.

Table 4-138. Proposed and Current Deemed Savings Values

Tech Code	Measure Description	Current Deemed Savings (therms per year per HP)	Proposed Deemed Savings (therms per year per HP)
1.0711.085	Linkageless Boiler Control, per hp	27	25

iii. Confidence in Proposed Savings

The deemed savings estimates proposed above are generally based on conservative assumptions. The assumptions for annual operating hours and boiler factors are unsupported but should be conservative estimates based on the operation of most boilers. Therefore, we believe there is a high probability that the Proposed Deemed Savings will be realized.

iv. Recommended Further Research

The sources described in this review are based on unsupported assumptions for operating hours and boiler load factors. We believe these assumptions are conservative but they should be confirmed through a study of participants. A study of this type would provide additional data for both linkageless control and oxygen trim control savings estimates. The study would try to determine:

- The percentage of boilers in Wisconsin that are dedicated to HVAC loads and their associated annual operating hours and load factors
- The percentage of boilers in Wisconsin that are dedicated to process loads and their associated annual operating hours and load factors
- The percentage of boilers in Wisconsin that provide heat to both HVAC and process loads.

In addition, the study could attempt to directly calculate savings attributed to linkageless controls based on a billing analysis.

4.10 BOILER OXYGEN TRIM CONTROLS

Group: Boilers & Burners

Category: Controls

Technology Description: Oxygen Trim Controls

Tech Code: 1.0710.085

Qualifying Equipment: Controls must be installed on a natural gas forced draft boiler 200 hp or greater that operates for a minimum of 4,000 hours per year.

Date Deeming Last Modified: November 2008

Reviewed by: Brian Dunn

Current Deemed Savings: 13 Therms per year per boiler horsepower

Savings Basis: Although boilers require some excess oxygen to ensure the complete combustion of fuel, too much excess oxygen decreases boiler efficiency. An increase in excess oxygen requires an increase in combustion air. The higher volume of combustion air will heat up during combustion and this heat energy is lost up the stack. Installing a system to monitor excess oxygen in the flue allows excess air to be reduced to optimal levels. This improves the efficiency of the boiler.[99]

4.10.1 Existing deemed savings basis and estimates

This section provides a discussion of the measure as it is currently deemed.

A. SAVINGS EQUATIONS AND PARAMETERS

Savings due to the installation of oxygen trim controls are described by the following equations:

$$\frac{\text{Therm}_{\text{savings}}}{BoilerHP} = \left(\frac{33469.8 \times \text{BLF} \times \text{hours}}{\text{Eff}_{\text{Boiler}} \times 100000}\right) * \text{SF}$$

where:

- 33,469.8 = Conversion Factor, Btuh per Boiler HP
- BLF = Boiler Load Factor, deemed 50 percent

[99] Oxygen trim controls are generally an add-on feature to linkageless boiler controls and could be included as part of a linkageless control system. The savings deemed in this document are only for the portion of savings related to oxygen trim control.

- Hours = Annual boiler operating hours, deemed 4,380 hours
- EFF_{Boiler} = Boiler Efficiency, deemed 80 percent
- 100,000 = Conversion factor, Btu per therm
- SF = Savings Fraction due to oxygen trim controls, deemed 1.5 percent.

Boiler Load Factor, BLF. The boiler load factor is the estimated percent load on the boiler in percent of full capacity. It is the average percent of boiler capacity at which the boiler operates.

Operating Hours, Hours. Operating hours refers to the average annual operating hours that the boiler operates.

Boiler Efficiency, EFF_{Boiler}. Boiler efficiency refers to the combustion efficiency of the boiler on which the oxygen trim controls are to be installed.

Savings Fraction, SF. Savings fraction is the percent of annual consumption that will be saved due to installing oxygen trim controls.

B. VALUES, ASSUMPTIONS, AND CALCULATIONS

The values used for each parameter in the current deemed savings calculation are discussed below.

i. Boiler Load Factor

The existing deemed savings calculation assumes that the boiler will operate at an average of 50 percent of rated load. No source is given for this value.

ii. Operating Hours

The boilers that qualify for this measure must operate for a minimum of 4,000 hours per year. The assumed average annual operating hours are 4,380 hours, or one half of the year. Some boilers operate only during the heating season but many other large boilers operate year round.

iii. Boiler Efficiency

The baseline boiler efficiency is 80 percent. This is the minimum efficiency in the Wisconsin Commercial Code and was deemed in the modulating boiler measure review in May 2008.

iv. Savings Fraction

The savings fraction is the percentage of annual usage that is expected to be saved due to the oxygen trim control retrofit, deemed to be 1.5 percent. The example provided in the EPA

Guide estimated possible fuel savings of three percent due to oxygen trim controls. [100] The 1.5 percent savings fraction that was proposed in the deeming calculation was a more conservative estimate, established to accommodate a wider range of boilers. During the deeming process, the evaluators cited two sources that refer to savings fraction estimates of 1 to 2 percent.

Substituting the above values into the savings equation yields a result of 13.7 therms saved per boiler horsepower output. The savings value was rounded down to the deemed value of 13 therm per boiler HP.

4.10.2 Literature review

This section presents the findings of various sources related to boiler oxygen trim controls. Data from all sources is cataloged in the Boiler Controls Review spreadsheet, where the data from each study is combined to make up the final recommended values.

A. GUIDE TO INDUSTRIAL ASSESSMENTS FOR POLLUTION PREVENTION AND ENERGY EFFICIENCY [101]

The Guide to Industrial Assessments for Pollution Prevention and Energy Efficiency describes the effect that excess air has on boiler combustion efficiency. Table 4-139 shows the relationship between oxygen percentage, net stack temperature, and combustion efficiency. Net stack temperature is the difference between the flue gas temperature and the combustion air temperature. This source also states that two percent excess oxygen is the optimal balance point for efficiency and other practical concerns such as pollution.

Table 4-139. Boiler Combustion Efficiency Based on Excess Air and Net Stack Temperature

			Combustion Efficiency by Net Stack Temperature						
Excess Air	O_2 %	CO_2%	220 F	230 F	240 F	246 F	250 F	260 F	270 F
0.0	0.0	11.8	85.3	85.1	84.9	84.8	84.7	84.5	84.2
2.2	0.5	11.5	85.2	85.0	84.8	84.7	84.6	84.4	84.1
4.5	1.0	11.2	85.1	84.9	84.7	84.6	84.5	84.2	84.0
6.9	1.5	11.0	85.0	84.8	84.6	84.5	84.4	84.1	83.9
9.5	2.0	10.7	84.9	84.7	84.5	84.3	84.2	84.0	83.8
12.1	2.5	10.4	84.8	84.6	84.4	84.2	84.1	83.9	83.7
15.0	3.0	10.1	84.7	84.5	84.2	84.1	84.0	83.8	83.5
18.0	3.5	9.8	84.6	84.4	84.1	84.0	83.9	83.6	83.4
21.1	4.0	9.6	84.5	84.2	84.0	83.8	83.7	83.5	83.2
24.5	4.5	9.3	84.3	84.1	83.8	83.7	83.6	83.3	83.1
28.1	5.0	9.0	84.2	83.9	83.7	83.5	83.4	83.2	82.9
31.9	5.5	8.7	84.1	83.8	83.5	83.4	83.3	83.0	82.7
35.9	6.0	8.4	83.9	83.6	83.3	83.2	83.1	82.8	82.5

[100] U.S. EPA: Guide to Industrial Assessments for Pollution Prevention and Energy Efficiency. EPA/625/R-99/003, June 2001. p. 53-54.

[101] Guide to Industrial Assessments for Pollution Prevention and Energy Efficiency, http://www.p2pays.org/ref/19/18351.pdf. Accessed July 7, 2009.

Excess Air	O_2 %	CO_2%	Combustion Efficiency by Net Stack Temperature						
			220 F	230 F	240 F	246 F	250 F	260 F	270 F
40.3	6.5	8.2	83.7	83.4	83.2	83.0	82.9	82.6	82.3
44.9	7.0	7.9	83.5	83.3	83.0	82.8	82.7	82.4	82.1
49.9	7.5	7.6	83.4	83.1	82.8	82.6	82.5	82.2	81.9
55.3	8.0	7.3	83.1	82.8	82.5	82.3	82.2	81.9	81.6
61.1	8.5	7.0	82.9	82.6	82.3	82.1	82.0	81.6	81.3
67.3	9.0	6.7	82.7	82.3	82.0	81.8	81.7	81.4	81.0
74.2	9.5	6.5	82.4	82.1	81.7	81.5	81.4	81.0	80.7
81.6	10.0	6.2	82.1	81.8	81.4	81.2	81.1	80.7	80.3
89.8	10.5	5.9	81.8	81.4	81.1	80.9	80.7	80.3	79.9
98.7	11.0	5.6	81.5	81.1	80.7	80.5	80.3	79.9	79.5
108.7	11.5	5.3	81.1	80.7	80.3	80.1	79.7	79.4	79.0
119.7	12.0	5.1	80.6	80.2	79.8	79.4	79.4	78.9	78.5

Finally, this source states, "in the absence of any reference temperature, it is normally expected that the stack temperature be less than 100°F above the saturated steam temperature at a high firing rate in a saturated steam boiler (this doesn't apply to boilers with economizers and air pre-heaters)." Boilers with economizers and preheaters will have a lower stack temperature and a higher efficiency since more of the heat of combustion is captured.

B. STEAM SYSTEM SURVEY GUIDE [102]

The Steam System Survey Guide provides information for improving steam system efficiency. Like the *Guide to Industrial Assessments*, the Steam System Survey Guide provides a table showing the estimated combustion performance based on excess oxygen and net stack temperature (see Table 4-140). This table is similar to Table 4-139 but has a broader range of net stack temperatures and shows the losses instead of the combustion efficiency. These tables are consistent where they overlap.

Table 4-140. Boiler Combustion Losses Based on Excess Oxygen and Net Stack Temperature

O_2 %	Percent Combustion Losses by Net Stack Temperature														
	230 F	250 F	270 F	290 F	310 F	330 F	350 F	370 F	390 F	410 F	430 F	450 F	470 F	490 F	510 F
1.0	14.49	14.92	15.36	15.79	16.23	16.67	17.11	17.55	17.99	18.43	18.88	19.32	19.77	20.21	20.66
2.0	14.72	15.17	15.63	16.09	16.55	17.01	17.47	17.93	18.39	18.86	19.32	19.79	20.26	20.73	21.20
3.0	14.98	15.46	15.94	16.42	16.90	17.38	17.87	18.36	18.84	19.33	19.82	20.31	20.80	21.30	21.79
4.0	15.26	15.77	16.28	16.79	17.29	17.81	18.32	18.83	19.35	19.86	20.38	20.90	21.41	21.93	22.46
5.0	15.59	16.12	16.66	17.20	17.74	18.28	18.82	19.36	19.91	20.46	21.00	21.55	22.10	22.65	23.20
6.0	15.96	16.52	17.10	17.67	18.24	18.82	19.39	19.97	20.55	21.13	21.71	22.29	22.88	23.46	24.05
7.0	16.38	16.98	17.59	18.20	18.82	19.43	20.04	20.66	21.28	21.90	22.52	23.14	23.77	24.39	25.02
8.0	16.86	17.51	18.16	18.82	19.48	20.14	20.80	21.46	22.12	22.79	23.46	24.12	24.79	25.47	26.14
9.0	17.42	18.13	18.83	19.54	20.25	20.96	21.68	22.39	23.11	23.83	24.55	25.27	25.99	26.72	27.44
10.0	18.09	18.86	19.62	20.39	21.16	21.94	22.71	23.49	24.27	25.05	25.83	26.62	27.41	28.19	28.98
11.0	18.89	19.73	20.57	21.42	22.26	23.11	23.96	24.81	25.67	26.52	27.38	28.24	29.10	29.97	30.83
12.0	19.87	20.80	21.73	22.66	23.60	24.54	25.48	26.43	27.37	28.32	29.27	30.22	31.18	32.13	33.09

[102] Greg Harrell, Ph.D, PE, *Steam System Survey Guide.* Oak Ridge National Laboratory, ORNL/TM-2001/263. May 2002.

In addition to providing the above table, the guide states that a traditional controller should be able to control excess oxygen in the flue gas to between three and seven percent[103]. The guide also describes a method that allows a user to utilize the table to estimate the reduction in combustion losses due to reducing excess oxygen.

C. THE NATURAL GAS BOILER BURNER CONSORTIUM [104]

The Natural Gas Boiler Burner Consortium website provides general information on boilers, including conversion factors and efficiencies. According to this site, typical boiler efficiencies will be in the 75 to 85 percent range. However, the site does not indicate whether these efficiencies are for steam or hot water boilers.

D. BUILDING TUNE-UP AND OPERATIONS PROGRAM EVALUATION[105]

The Building Tune-up and Operations Program Evaluation was performed for the Energy Trust of Oregon and covered a broad spectrum of measures. Of interest to this review is the finding that systems with the potential for the greatest energy savings have already implemented energy conservation measures. This study appeared to be specific to HVAC boilers, though it was never explicitly stated.

4.10.3 Proposed deemed savings basis and estimates

Based on the above research, we recommend that deemed savings estimates be updated as provided in this section.

A. DEVELOPMENT OF PROPOSED VALUES

In order to develop a new deemed savings estimate, we make the following assumptions that may apply to several of the deemed savings parameters:

- If the boiler has been tuned up, the controls savings will interact with boiler tune-up savings. To avoid double counting we assume the boiler is operating at optimal efficiency; that is, that the boiler on which the oxygen trim controls are installed has recently been tuned up.
- The savings estimates are primarily based on operating conditions for HVAC boilers. These boilers may have lower savings than process boilers, but the resulting estimate will be conservative and will likely be achieved regardless of the mix of process and HVAC boilers participating in the program. Also, facilities with large

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[103] Ibid.

[104] http://www.energysolutionscenter.org/boilerburner/Eff_Improve/Primer/Boiler_Introduction.asp. Accessed July 6, 2009.

[105] Linda Dethman and Rick Kunkle for Energy Trust of Oregon, Phil Degens, evaluation manager. *Final Report, Building Tune-Up and Operations Program Evaluation.* *http://www.energytrust.org/library/reports/0705_BTO_ProgramEvaluation.pdf?link_programs_reports_lin1Page=2*. Accessed July 7, 2009.

process boilers are likely to have implemented energy conservation measures already.

i. Efficiency Improvement

We estimate the efficiency improvement that results from this measure by using information from the *Steam Survey Guide.* If the percent excess oxygen and net stack temperature are known then Table 4-140 can be used to provide combustion losses.

An oxygen trim control system should be able to control excess oxygen in the flue gas to a range of 1.5 to 3 percent (2 percent is optimum). A traditional controller should be able to control excess oxygen in the flue gas to a range of 3 to 7 percent. The difference provides the basis for our efficiency improvement estimate. We calculate the efficiency improvement using the following assumptions:

- We assume that the oxygen trim control keeps excess oxygen at the optimum 2 percent and a traditional control keeps excess oxygen at an average of 5 percent, the midpoint of the range cited.
- We use operating pressures consistent with HVAC systems to estimate the flue gas temperatures. HVAC systems generally operate between 5 and 15 pounds per square inch. We assumed the midpoint of the range, 10 pounds per square inch. The temperature of saturated steam at this pressure is 240°F.
- Based on information in the *Guide to Industrial Assessments for Pollution Prevention and Energy Efficiency,* we assume that the flue gas temperature is 100°F greater than the saturated steam temperature. Therefore, the flue gas temperature is 340°F.

The temperature of the combustion air must be known to calculate net stack temperature. Typical HVAC boiler operations use outdoor air for the combustion air. Based on TMY2 data, the average outdoor temperature from October 1 to April 30 is 30.8°F. Subtracting this from the flue gas temperature (340°F) yields a net stack temperature of 309°F[106]. We then used Table 4-140 to find the percent stack losses at 309°F net stack temperature for 2 percent and 5 percent excess oxygen. Stack losses for 2 percent excess oxygen are 16.55 percent and stack losses for 5 percent excess oxygen are 17.74 percent. The improvement in efficiency is 1.19 percent.

Some boilers have economizers or combustion air preheaters installed. These systems capture heat from the flue gas and use it to warm the combustion air, changing the overall combustion efficiency. Therefore, KEMA repeated the estimation method assuming that the net flue gas temperature was 50 degrees lower due to heat recovery, or 259°F. (We used the values for 250°F to match table). For this case, the boiler stack losses at 2 percent excess oxygen are 15.17 percent and the stack losses at 5 percent excess oxygen are 16.12 percent. Therefore, the improvement in efficiency is 0.95 percent when some type of heat recovery is present.

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[106] The combustion air temperature for process boilers will be higher which would result in decreased savings. In this case, the combustion air temperature assumption will result in a less conservative estimate; however the assumption is consistent with basing savings estimates on HVAC boiler operation.

The unweighted average efficiency improvement between standard boilers and boilers with heat recovery is 1.07 percent. However, we believe that more boilers without heat recovery systems will participate than boilers with heat recovery systems. This argues for a weighted average efficiency improvement greater than the unweighted average. In the absence of data indicating the proportion of participating boilers with heat recovery or economizers, KEMA assumed a 1.1 percent efficiency improvement for boilers with oxygen trim controls installed.

Note that this 1.1 percent is not the savings fraction (the fraction of overall consumption saved), but the improvement in efficiency. The form of the energy savings equation must change to accommodate the difference. The savings fraction is a function of the efficiency improvement as shown in this equation:

$$SF = \left(\frac{1}{EFF_{Boiler}} - \frac{1}{EFF_{Boiler} + EI} \right)$$

where:

- EFF_{Boiler} = efficiency of the boiler before oxygen trim controls, proposed 80 percent
- EI = efficiency improvement, proposed 1.1 percent.

Substituting the above values yields a savings fraction of 1.7 percent.

ii. Standard Boiler Efficiency

The current deemed savings estimate assumes an efficiency of 80 percent based on the Wisconsin Commercial Code. According to the Natural Gas Boiler Burner Consortium, the typical boiler efficiency will be in the 75 to 85 percent range. It is not known whether this range includes steam boilers or only hot water boilers. Many steam boilers will be at the lower end of this range but they are offset by some high efficiency hot water boiler models which have efficiencies of greater than 90 percent. Since there are outliers above and below the cited range, and since the midpoint of that range agrees with the Wisconsin code, the deemed value of 80 percent is reasonable.

iii. Operating Hours

We assume that process boilers will operate year round while heating boilers will only operate during the heating season. The incentive qualifications require that the controlled boiler operate for a minimum of 4,000 hr/yr. Therefore, we recommend annual operating hours of 4,000 hr/yr. This value provides a conservative estimate of energy savings.

iv. Boiler Load Factor

The current deemed savings method assumes a boiler load factor value of 50 percent. There was no source provided to support this estimate. During our review, we were unable to find any studies or reports that suggested an appropriate load factor. We feel that the current estimate is reasonable; therefore, we recommend a boiler load factor of 50 percent.

B. PROPOSED EQUATIONS, PARAMETERS, AND DEEMED VALUES

i. Proposed Equations and Parameters

The form of the savings equation is different from the current equation because our analysis is in terms of the efficiency improvement and not the savings fraction. We recommend that energy savings for this measure be calculated using the following formula:

$$\frac{Therm_{savings}}{BoilerHP} = \left(\frac{33{,}469.8 \times BLF \times hours}{100{,}000}\right) * \left(\frac{1}{EFF_{Boiler}} - \frac{1}{EFF_{Boiler} + EI}\right)$$

where:

- 33,469.8 = Conversion Factor, BtuH per Boiler HP
- BLF = Boiler Load Factor, deemed 50 percent
- Hours = Annual boiler operating hours, deemed 4,000 hours
- EFF_{Boiler} = Boiler Efficiency, deemed 80 percent
- EI = Efficiency Improvement, deemed 1.1 percent
- 100,000 = Conversion factor, BTUs per therm.

Boiler Load Factor, BLF. The boiler load factor is the estimated percent load on the boiler in percent of full capacity. It is the average percent of boiler capacity at which the boiler operates.

Operating Hours, Hours. Operating hours refers to the average annual operating hours that the boiler operates.

Boiler Efficiency, EFF_{Boiler}. Boiler efficiency refers to the combustion efficiency of the boiler on which the oxygen trim controls are to be installed.

Efficiency Improvement, EI. The efficiency improvement is the change in combustion efficiency due to installing oxygen trim controls.

ii. Proposed Deemed Values

Substituting the above values into the savings equation yields the proposed deemed savings value for this measure, found in Table 4-141.

Table 4-141. Proposed and Current Deemed Savings Values

Tech Code	Measure Description	Current Deemed Savings (therms per year per HP)	Proposed Deemed Savings (therms per year per HP)
1.0710.085	Boiler Oxygen Trim Controls, per hp	13	11.3

iii. Confidence in Proposed Savings

The deemed savings estimates proposed above are generally based on conservative assumptions. The assumptions for annual operating hours and boiler factors are unsupported but should be conservative estimates based on the operation of most boilers. Therefore, we believe there is a high probability that the Proposed Deemed Savings will be realized.

iv. Recommended Further Research

The sources described in this review are based on unsupported assumptions for operating hours and boiler load factors. We believe these assumptions are conservative but they should be confirmed through a study of participants. A study of this type would provide additional data for both linkageless control and oxygen trim control savings estimates. The study would try to determine:

- The percentage of boilers in Wisconsin that are dedicated to HVAC loads and their associated annual operating hours and load factors
- The percentage of boilers in Wisconsin that are dedicated to process loads and their associated annual operating hours and load factors
- The percentage of boilers in Wisconsin that are provide heat to both HVAC and process loads.

In addition, the study could try to directly calculate savings attributed to oxygen trim controls based on a billing analysis.

5. RECOMMENDATIONS

5.1 PROPOSED DEEMED SAVINGS VALUES

The following tables contain proposed updates to deemed savings values resulting from the DSPD analysis. KEMA recommends these deemed savings estimates be adopted in January 2010 along with the deemed savings measures that are currently being reviewed as part of the deemed savings review task. The proposed lighting hours of use and coincidence factor values are shown in Table 5-1. The current lighting hours of use and coincidence factor values are shown in Table 5-2.

Table 5-1. Proposed Deemed Parameters, Lighting Hours and Coincidence Factor

Building Use	Hours	CF
Food Sales	5,544	92%
Food Service	4,482	84%
Health Care	3,677	78%
Hotel/Motel	3,356	35%
Office	3,526	77%
Public Assembly	2,729	67%
Public Services	3,425	64%
Retail	4,226	84%
Warehouse	3,464	79%
School	2,302	52%
College	3,900	68%
Dormitory	986	7%
Industrial	4,745	77%
Agricultural	4,698	67%
Other	3,672	67%

Table 5-2. Existing Deemed Parameters, Lighting Hours, and Coincidence Factor

Sector	Hours	CF
Agriculture	4,368	90%
Commercial	3,680	90%
Industrial	4,576	90%
Schools & Government	3,230	71%

The PSC may decide that the proposed building use definition cannot be implemented at this time. Appendix A contains an alternative, sector-level review of lighting hours and coincidence factor. If the building use definition is rejected at this time, KEMA recommends using the values in Appendix A.

The proposed deemed values by building use for replacing 8 foot T12 fluorescent lighting fixtures with T8 fixtures are shown in Table 5-3. Alternative, sector-level savings can be found in Appendix B. The alternative savings use the hours and coincidence factors suggested in Appendix A. The current savings for these measures are shown in Table 5-4.

Table 5-3. Proposed Deemed Savings Values by Measure, T8 Replacing 8' T12

Building Use	Hours	CF	Proposed Deemed Savings 2.0810.170 kW	Proposed Deemed Savings 2.0810.170 kWh	Proposed Deemed Savings 2.0811.170 kW	Proposed Deemed Savings 2.0811.170 kWh
Food Sales	5,544	92%	0.0214	129	0.1095	661
Food Service	4,482	84%	0.0196	104	0.1001	534
Health Care	3,677	78%	0.0182	86	0.0931	438
Hotel/Motel	3,356	35%	0.0081	78	0.0416	400
Office	3,526	77%	0.0178	82	0.0912	420
Public Assembly	2,729	67%	0.0155	64	0.0794	325
Public Services	3,425	64%	0.0148	80	0.0757	408
Retail	4,226	84%	0.0197	99	0.1006	503
Warehouse	3,464	79%	0.0184	81	0.0941	413
School	2,302	52%	0.0122	54	0.0625	274
College	3,900	68%	0.0159	91	0.0810	465
Dorms	986	7%	0.0016	23	0.0083	117
Industrial	4,745	77%	0.0180	111	0.0918	565
Agricultural	4,698	67%	0.0156	110	0.0797	560
Other	3,672	67%	0.0155	86	0.0794	438

Table 5-4. Current Deemed Savings Values, T8 Replacing 8' T12

Tech Code	Measure Description	Ag kW	Ag kWh	Com kW	Com kWh	Ind kW	Ind kWh	S-G kW	S-G kWh
2.0810.170	T8 4L-4ft High Performance Replacing T12 2L-8 ft	0.0234	114	0.0234	96	0.0234	119	0.0185	83
2.0811.170	T8 4L-4ft High Performance Replacing T12HO/VHO 2L-8 ft	0.1008	489	0.1008	412	0.1008	513	0.0795	358

The proposed deemed savings by building use for replacing high intensity discharge lighting with fluorescent lighting are shown in Table 5-5. Alternative, sector-level savings can be found in Appendix C. The alternative savings use the hours and coincidence factors suggested in Appendix A. The current savings for these measures are shown in Table 5-6.

Table 5-5. Proposed Deemed Savings by Measure, T8 or T5 Replacing HID

Building Use	2.5170.170		2.5180.170		2.5182.170		2.5185.170		2.5186.170	
	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Food Sales	0.1388	837	0.2265	1,366	0.0952	574	0.6592	3,975	0.5016	3,025
Food Service	0.1269	677	0.2070	1,104	0.0870	464	0.6025	3,214	0.4584	2,445
Health Care	0.1180	555	0.1925	906	0.0809	381	0.5604	2,636	0.4264	2,006
Hotel/Motel	0.0528	507	0.0861	827	0.0362	347	0.2505	2,406	0.1906	1,831
Office	0.1156	532	0.1886	869	0.0793	365	0.5489	2,528	0.4177	1,923
Public Assembly	0.1006	412	0.1641	672	0.0690	283	0.4776	1,956	0.3634	1,489
Public Services	0.0959	517	0.1564	844	0.0657	355	0.4552	2,456	0.3464	1,869
Retail	0.1275	638	0.2081	1,041	0.0875	438	0.6055	3,030	0.4608	2,305
Warehouse	0.1192	523	0.1945	853	0.0818	359	0.5661	2,484	0.4308	1,890
School	0.0792	347	0.1292	567	0.0543	238	0.3760	1,650	0.2861	1,256
College	0.1026	589	0.1675	961	0.0704	404	0.4875	2,796	0.3710	2,128
Dormitory	0.0106	149	0.0172	243	0.0072	102	0.0502	707	0.0382	538
Industrial	0.1163	716	0.1898	1,169	0.0798	491	0.5523	3,402	0.4203	2,589
Agricultural	0.1010	709	0.1648	1,157	0.0693	486	0.4797	3,368	0.3650	2,563
Other	0.1006	554	0.1641	905	0.0690	380	0.4776	2,633	0.3634	2,003

Table 5-6. Current Deemed Savings Values, T8 or T5 Replacing HID

Tech Code	Measure Description	Agriculture		Commercial		Industrial		Schools-Government	
		kW	kWh	kW	kWh	kW	kWh	kW	kWh
2.5170.170	T8 4 lamp or T5HO 2 lamp Replacing 250-399 W HID	0.1345	653	0.1345	550	0.1345	684	0.1061	478
2.5180.170	T8 6 lamp or T5HO 4 lamp Replacing 400-999 W HID	0.2120	1,029	0.2120	867	0.2120	1,078	0.1672	754
2.5182.170	T8 8 lamp or T5HO 6 lamp Replacing 400-999 W HID	0.1437	697	0.1437	587	0.1437	731	0.1133	511
2.5185.170	T8/T5HO <= 500 Watts Replacing >=1000 W HID	0.5589	2,713	0.5589	2,285	0.5589	2,842	0.4409	1,987
2.5186.170	T8 or T5HO <= 800W, Replacing >=1000 W HID	0.4244	2,060	0.4244	1,735	0.4244	2,158	0.3348	1,509

The proposed deemed values for high bay occupancy sensors are shown in Table 5-7. Alternative, sector-level savings can be found in Appendix D. The alternative savings use the hours and coincidence factors suggested in Appendix A. The existing deemed savings values are found in Table 5-8.

Table 5-7. Proposed Deemed Savings, High Bay Occupancy Sensors

Building Type	Hours	kWh Savings by Space Type					
		Gymnasium	Industrial	Retail	Warehouse	Public Assembly	Other
Food Sales	5,544	517	591	197	701	618	525
Food Service	4,482	418	478	159	567	499	424
Health Care	3,677	343	392	131	465	410	348
Hotel/Motel	3,356	313	358	119	424	374	318
Office	3,526	329	376	125	446	393	334
Public Assembly	2,729	254	291	97	345	304	258
Public Services	3,425	319	365	122	433	382	324
Retail	4,226	394	451	150	534	471	400
Warehouse	3,464	323	370	123	438	386	328
School	2,302	215	246	82	291	256	218
College	3,900	364	416	139	493	434	369
Dormitory	986	92	105	35	125	110	93
Industrial	4,745	442	506	169	600	529	449
Agriculture	4,698	438	501	167	594	523	445
Other	3,672	342	392	131	464	409	348
Percent Off		39%	45%	15%	53%	47%	40%
Coincidence Factor		15%	18%	6%	18%	12%	14%
kW Savings		**0.034**	**0.043**	**0.014**	**0.043**	**0.028**	**0.032**

Table 5-8. Existing Deemed Savings, High Bay Occupancy Sensors

Tech. Code	Measure Description	Watt-age	CF	Agriculture		Commercial		Industrial		Schools-Government	
				kW	kWh	kW	kWh	kW	kWh	kW	kWh
2.5192.085	Occupancy sensor for high bay fluorescent fixtures, per fixture controlled	247	0%	0.00	5.5438	0.00	4.6706	0.00	5.8078	0.00	2.8204
Percent Off				62.5%		62.5%		62.5%		43.0%	
Hours of Use				4,368		3,680		4,576		3,230	

The proposed deemed values for CFLs are shown in Table 5-9. Alternative, sector-level savings can be found in Appendix E. The alternative savings use the hours and coincidence factors suggested in Appendix A. The existing deemed savings values are found in Table 5-10.

Table 5-9. Proposed Deemed Savings, CFLs

Building Use	Hours	CF	Savings by Measure			
			CFL <32 W		CFL Reflector Flood	
			kW	kWh	kW	kWh
Food Sales	5,544	92%	0.0512	309	0.0449	271
Food Service	4,482	84%	0.0468	250	0.0410	219
Health Care	3,677	78%	0.0435	205	0.0382	180
Hotel/Motel	3,356	35%	0.0195	187	0.0171	164
Office	3,526	77%	0.0426	196	0.0374	172
Public Assembly	2,729	67%	0.0371	152	0.0325	133
Public Services	3,425	64%	0.0354	191	0.0310	167
Retail	4,226	84%	0.0470	235	0.0412	206
Warehouse	3,464	79%	0.0440	193	0.0386	169
School	2,302	52%	0.0292	128	0.0256	112
College	3,900	68%	0.0379	217	0.0332	190
Dormitory	986	7%	0.0039	55	0.0034	48
Industrial	4,745	77%	0.0429	264	0.0376	2132
Agricultural	2,450	67%	0.0373	136	0.0327	120
Other	3,672	67%	0.0371	205	0.0325	179

Table 5-10. Existing Deemed Savings, CFLs

Tech Code	Measure Description	Delta Watts				Agriculture		Commercial		Industrial		Schools-Government	
		Ag.	Com.	Ind.	S&G	kW	kWh	kW	kWh	kW	kWh	kW	kWh
2.0300.1650	CFL <= 32W, replacing incandescent <=100W	57.0	56.0	53.0	53.0	0.051	199	0.050	178	0.048	323	0.038	171
		New Watts		Old Watts									
2.0307.1650	CFL reflector flood lamps <=30W replacing incandescent reflector flood lamps <=100W	20.0		75.0		0.05	131	0.05	173	0.05	336	0.039	178
					Coincidence Factor	90%		90%		90%		71%	
					Hours of Use	3,490		3,130		6,100		3,230	

The existing and proposed deemed values for Agriculture ventilation fans are shown in Table 5-11.[107]

[107] The measure descriptions have been changed at the request of the program to distinguish them from new measures for circulation fans.

Table 5-11. Existing and Proposed Deemed Savings, Ag Exhaust Fans

Tech Code	Measure Description	Current Deemed Savings		Proposed Deemed Savings	
		kW	kWh/yr	kW	kWh/yr
4.0736.150	Agricultural Exhaust Fan, High Efficiency - 36"	0.322	1,094	0.206	700
4.0742.150	Agricultural Exhaust Fan, High Efficiency - 42"	0.396	1,483	0.240	815
4.0748.150	Agricultural Exhaust Fan, High Efficiency - 48"	0.470	1,872	0.274	930
4.0750.150	Agricultural Exhaust Fan, High Efficiency - 50"	0.664	2,553	0.305	1,037
4.0751.150	Agricultural Exhaust Fan, High Efficiency - 51"	0.664	2,553	0.305	1,037
4.0752.150	Agricultural Exhaust Fan, High Efficiency - 52"	0.664	2,553	0.305	1,037
4.0754.150	Agricultural Exhaust Fan, High Efficiency - 54"	0.664	2,553	0.305	1,037
4.0755.150	Agricultural Exhaust Fan, High Efficiency - 55"	0.664	2,553	0.305	1,037
4.0760.150	Agricultural Exhaust Fan, High Efficiency - 60"	0.664	2,553	0.305	1,037
4.0772.150	Agricultural Exhaust Fan, High Efficiency - 72"	0.664	2,553	0.305	1,037

The existing and proposed deemed savings values for natural gas measures are shown in Table 5-12.

Table 5-12. Existing and Proposed Deemed Savings, Natural Gas Measures

Tech Code	Measure Description	Current Deemed Savings (per year)	Proposed Deemed Savings (per year)
4.1000.390	Repair leaking steam trap, building space conditioning system	718	910
1.1300.430	Boiler Tune-up - service buy-down, per MBh	0.679	0.356
1.0711.085	Linkageless Boiler Control, per hp	27	25
1.0710.085	Boiler Oxygen Trim Controls, per hp	13	11.3

KEMA looked at each measure to determine our confidence that the estimated deemed savings would be realized. Table 5-13 summarizes our degree of confidence in each of the measure bins reviewed.

Table 5-13. Confidence that Deemed Savings Will Be Realized

Measure Description	Confidence Savings Will Be Realized		
	High	Medium	Low
Lighting Hours of Use and Coincidence Factor	X		
T8 replacing 8 foot T12HO or T12VHO	X		
High bay fluorescent fixture replacing HID	X		
Occupancy sensor for high bay fluorescent fixtures		X	
CFL replacing incandescent		X	
High efficiency Ag ventilation fans		X	
Leaking steam trap			X
Boiler tune-up	X		
Linkageless boiler controls	X		
Oxygen trim boiler controls	X		

5.2 FURTHER RESEARCH

We recommend that the following future research be performed.

- **Lighting Hours of Use and Coincidence Factor.** The Agriculture sector hours of use and coincidence factor values are based on a review of only six projects installed during the 18MCP.[108] Since there are no secondary sources that provide values for agriculture, it may be up to Focus on Energy to strengthen the parameter estimates through program data collection and tracking or primary research. By requiring and tracking lighting use profiles for projects in the Agriculture sector, the program could increase the sample size used to determine lighting hours and CF and thereby increase the accuracy of the savings estimate. A metering study of Agriculture sector lighting use would provide a more accurate estimate but also increase the cost.

  The hours of use value for Colleges is based on one source and is the least supported value outside of the Agriculture sector. The hours of use and CF values for Dormitories are also based on single sources, as provided by Focus Residential Programs. The program may also decide to track lighting use profiles for projects in colleges and dormitories to further strengthen these estimates.

- **Interactive Factor.** The program may want to consider including an Interactive Factor in lighting savings estimates to account for savings resulting from reducing the cooling load on buildings in which lighting projects are completed. We cannot formally recommend including an Interactive Factor in the lighting savings equation at this time for a number of reasons. First, we must know the percentage of buildings that are air conditioned before applying the interactive factor. That data is not currently available. Second, the Interactive Factor is weather dependent, so primary metered sources for Interactive Factor would have to be adjusted for Wisconsin's climate. Finally, only one primary source is available for Interactive Factor, so the current research does not provide strong support for the values that should be used. Since including an interactive factor may yield a more accurate savings estimate, we recommend further research into this matter.

- **T8 Replacing T12 Fluorescents.** The parameter estimates for the 8 foot T12 replacement measures are straightforward and accurately obtained but improvements can always be made. One way to increase confidence in the old and new wattage estimates is to better track both the ballast factors of the installed fixtures and a basic description of what was removed in WISeerts. Ballast factors are normally available on invoices and/or cut sheets, but removed fixtures are not often described. This would allow a larger sample of installed projects to be reviewed, and would provide direct data on which to base energy savings estimates.

- **High Bay Fluorescent Installations.** The parameter estimates for the high bay fluorescent installations are straightforward and accurately obtained but improvements can always be made. One way to increase confidence in the old and new wattage estimates is to better track in WISeerts data for installed fixtures (fixture

[108] Hours of use for CFLs in the Agriculture sector are calculated by a different method and are discussed below.

type, number of lamps, and ballast factor) and a basic description of what was removed. Ballast factors are normally available on invoices and/or cut sheets, but removed fixtures are not often described. This would allow a larger sample of installed projects to be reviewed, and would provide direct data on which to base energy savings estimates.

The current and proposed calculation for this measure assumes that the operating hours of the fixtures remain constant before and after the fluorescent fixture installation. This is likely not the case, as HID lights require an extensive warm-up period which often causes operators to turn the lights on early in the operating period and only turn them off when they are guaranteed to no longer be needed. Fluorescent lights can be turned on and off at will and are more likely to be operated only when necessary. We were unable to find any sources that specifically addressed this issue. Therefore, we recommend that a pre- and post- installation metering study be conducted to improve the estimates for hours of use and coincidence factor for high bay applications.

- **High Bay Fluorescent Occupancy Sensors.** One way to increase confidence in the estimate of the fixture wattage controlled is to record data for the fixture (number of lamps, fixture type, and ballast factor) in WISeerts as part of the occupancy sensor measure. This data is not currently available as invoices do not often indicate which fixtures are controlled by which occupancy sensors.

  Due to the lack of significant study data available in the industry, values for percent off, hours of use, and coincidence factor could be improved through a metering study of customer installations. This would be a simple study to execute and should include metering data from high bay fluorescent fixtures that are controlled by occupancy sensors as well as those that are not.

- **CFLs.** The wattage estimates for all building uses and the hours of use for the Agricultural building use are based on data from surveys with Focus on Energy participants. This is a telephone survey that collects customer-reported data. While it has been suggested in a number of studies that customers do not consistently over or under-report wattages or hours of use, the estimates that they provide are not necessarily accurate. One way to improve the wattage estimate is to collect this data on the application and to record it in the tracking database. This would allow for a very large sample and more accurate data. For the hours of use and coincidence factor estimates, the quality of the data could be improved by conducting a metering study of the various types of CFLs in the non-residential sector. The study results would increase the accuracy of the parameter estimates using the building type definition, and provide CFL-specific data for the non-Agriculture building types. The study should meter pre- and post- installation operating hours and coincidence factor.

- **Ag Ventilation Fans.** There are many relevant agricultural ventilation fan sources to inform the deemed savings. However, there were also several assumptions that were made with limited information.

  While the estimates for annual runtime hours are probably conservative, future research could improve accuracy. The research could involve collecting detailed information from participating Ag ventilation projects or fielding a metering study of fan operating run times.

The accuracy of the transition rate from smaller to larger fans is difficult to gauge. Future research should be conducted on the proportion of projects that include a size transition and how it compares to the market as a whole.

Poorly maintained fans will get soiled and their effectiveness will be reduced. With limited market data, it is difficult to assess the potential impacts that soiling and poor maintenance will have. Further research should address this issue.

- **Leaking Steam Traps.** The sources described in the review are based on theoretical estimates of leakage rates, assumed operating hours, and expert opinions on market prevalence of steam system pressures and trap types and sizes. We were unable to find empirical research demonstrating savings due to steam trap repairs in an HVAC system. A study that examined the actual realized savings throughout the state of Wisconsin would provide a more accurate statement of expected savings.
- **Boiler Tune-Up.** Two of the sources described in the review are based on empirical research to determine actual savings due to boiler tune-ups. These studies were not performed in a climate identical to Wisconsin's and actual savings in Wisconsin could vary somewhat. However, we do not believe that any improvements in accuracy would be substantial. The climate in one study was warmer than Wisconsin's while the climate for the other study was colder. Regardless, performing research in Wisconsin on boiler combustion efficiency may provide improved accuracy since the types and efficiencies of boilers in the population could differ from the two empirical studies.
- **Boiler Controls.** The sources described in the review are based on unsupported assumptions for operating hours and boiler load factors. We believe these assumptions are conservative but they should be confirmed through a study of participants. A study of this type would provide additional data for both linkageless control and oxygen trim control savings estimates. The study would try to determine the percentage of boilers in Wisconsin that are dedicated to HVAC loads, the percentage of boilers in Wisconsin that are dedicated to process loads, and the percentage of boilers in Wisconsin that provide heat to both HVAC and process loads. The study would also look at the annual operating hours and load factors associated with each group. In addition, the study could attempt to directly calculate savings attributed to linkageless controls based on a billing analysis.

APPENDIX A: ALTERNATIVE LIGHTING HOURS OF USE AND COINCIDENCE FACTOR

In the main body of the report, KEMA recommended that lighting hours of use and coincidence factor be defined by building type, not sector as it was in the past. Changing to building type would require an investment by the program and the PSC to implement the new methodology. Therefore, KEMA has also provided this section of review that develops lighting hours of use and coincidence factor at the sector level. If the PSC rejects the building type definition for lighting hours and coincidence factor, KEMA recommends that the values developed in this section be used for sector-level savings calculations.

Group: Lighting

Category: N/A

Technology Description: Lighting hours of use and coincidence factor (CF) values for all lighting measures.[109]

Qualifying Equipment: N/A

Date Deeming Last Modified: Pre-2006 (exact date unclear)

Summarized by: Jeremiah Robinson

A.1 EXISTING DEEMED SAVINGS BASIS AND ESTIMATES

Lighting hours of use and coincidence factor are not, in and of themselves, an energy savings measure. However, they are parameters which are used to calculate deemed savings for all lighting measures except low-wattage CFLs. Each sector has its own value for hours of use and coincidence factor.

A.1.1 Definitions and existing values

Hours of Use, Hours. Hours of use refers to the average annual operating hours of the light fixture and is measured in hour/year. The current values are shown in Table A-1.

Coincidence Factor, CF. Coincidence factor refers to the average percentage of total system wattage that is operating during the peak period and is measured in percent. The peak period is defined as weekdays, 1 pm to 4 pm, June through August. The values are shown in Table A-1.

[109] The recommended hours of use value for CFLs in the Agriculture Sector is not covered in this section of the report; that value is developed in Section 4.5.

Table A-1. Existing Deemed Lighting Operating Hours and Coincidence Factors

Sector	Hours	CF
Agriculture	4,368	90%
Commercial	3,680	90%
Industrial	4,576	90%
Schools-Government	3,230	71%

A.1.2 Discussion of existing values

a. HOURS OF USE

The existing values for hours of use have been used in prescriptive and deemed estimates for a number of years. The origin of the existing hours of use is unknown and no source can be found either by personnel at Focus on Energy or in documentation maintained by KEMA.

The logic behind the hours for use for each sector is as follows:

- Agriculture sector hours are based on 12 hours per day, 7 days per week (4,368 hr/yr)
- Commercial sector hours are based on the average of eight different industries per the statewide database. (3,680 hr/yr)
- Industrial sector hours are based on 16 hours per day, 5.5 days per week (4,576 hr/yr)
- School and Government sector hours are based on 12 hours per day, 5 days per week, 12 months per year (3,200 hr/yr)

b. COINCIDENCE FACTOR

It is not clear when the values currently used for coincidence factor first came to be used. However, the justification for the 90 percent factor used for Agriculture, Commercial, and Industrial, was presented in March 2005 in the CFL deemed savings calculations. This report claims that the data was based on a suggestion by the Edison Electric Institute (EEI). We have not been able to track down this source, and the single value of 90 percent across different sectors suggests that it was not a thoroughly researched value.

We could not find the source of the 71 percent value used for the Schools & Government sector. The 2005 CFL deemed savings document suggests a value of 63 percent, which was abandoned at some indeterminate point in time.

A.2 LITERATURE REVIEW

Here we present the findings of various sources related to lighting hours of use and coincidence factors. Data from the various studies are categorized in many different ways. This data is presented in this review as it was presented in the various sources. In the final recommendations, a weighting scheme will be suggested and used to combine the data and apply it to the Focus on Energy program.

It should be noted that no sources were found for agricultural lighting hours of use or coincidence factor. This will be addressed in a later section.

A.2.1 PG&E 1996 evaluation [110]

The *Evaluation of Pacific Gas & Electric Company's 1996 Commercial Energy Efficiency Incentives Program: Lighting Technologies* was performed by Quantum Consulting in 1998. It studied lighting hours and coincidence factors in the California commercial sector, and included a billing analysis of 413,035 sites, 1,270 telephone surveys, and 351 engineering reviews over the course of two years. Though it is an older study, it is included here because it was large and comprehensive. Table A-2 shows the CF and hours of use values determined by this study.

Table A-2. PG&E 1996 Hours & CF Values

Building Use	Hours	CF
College/University	3,900	68%
School	2,150	42%
Office	4,000	81%
Retail	4,450	88%
Grocery	5,800	81%
Restaurant	4,600	68%
Health Care/Hospital	4,400	74%
Hotel/Motel	5,500	67%
Warehouse	3,550	84%
Personal Service	4,100	79%
Community Service	2,700	48%
Miscellaneous	4,500	76%

The table shows that the building use with the highest operating hours is grocery stores with 5,800 hours/year. The lowest hours of use belongs to schools, with 2,150 hours/year. It is apparent that coincidence factor does not seem to correspond to hours of use in this study, which is due to the fact that the sectors with the most hours of use may not be the most heavily used in the afternoon summer peak hours. For instance, Restaurants have a 68 percent CF while Retail has an 88 percent CF even though the hours of use for Restaurants is higher than for Retail.

The peak demand period used in the PG&E 1996 Evaluation is defined as May through October, 12-6 pm, Monday through Friday.

A.2.2 Department of Energy study [111]

The *U.S. Lighting Market Characterization – Volume 1: National Lighting Inventory and Energy Consumption Estimate* was performed by Navigant Consulting in 2002. It was an

[110] Quantum Consulting. *Evaluation Of Pacific Gas & Electric Company's 1996 Commercial Energy Efficiency Incentives Program: Lighting Technologies.* March 1, 1998.

[111] Navigant Consulting. *U.S. Lighting Market Characterization – Volume 1: National Lighting Inventory and Energy Consumption Estimate*. September 2002.

attempt at a comprehensive cataloging of installed lighting throughout the U.S, and consisted of telephone surveys of 5,430 commercial and 17,877 industrial buildings. It includes data on the square-footage and installed lighting wattage in the various building types, and hours of use weighted both by building type and lamp type.

Table A-3 shows the hours of use and sector weighting for commercial buildings and Table A-4 shows the hours of use and sector weighting for industrial buildings. The column labeled "% Ltg. Usage" in these tables refers to the percentage of total national lighting kWh by building type within the commercial and industrial sectors. So, for example, referring to Table A-3, offices use 20.6 percent of the total national kWh used by commercial buildings, according to this study.

It should be noted that, in this study, "commercial" includes both government and education buildings.

Table A-3. DOE Study Commercial Hours of Use

Building Use	Hours	% Ltg. Usage
Vacant	3,577	3.9%
Office/ Professional	3,760	20.6%
Laboratory	5,074	1.0%
Warehouse (non-refrigerated)	3,541	11.8%
Food sales	5,256	2.9%
Public order/safety	3,504	1.0%
Health Care (outpatient)	3,395	2.0%
Warehouse (refrigerated)	3,869	1.0%
Religious Worship	1,825	2.0%
Public Assembly	2,665	3.9%
Food Service	4,599	2.9%
Health Care (inpatient)	5,840	4.9%
Skilled Nursing	4,380	1.0%
Hotel/Motel/Dorm	3,687	4.9%
Strip Shopping	4,052	7.8%
Enclosed Retail	5,001	2.9%
Retail (excluding enclosed)	3,723	8.8%
Service (excluding food)	3,431	4.9%
Other	3,723	1.0%
Education	2,774	10.8%

The table shows that Office/Professional is the largest commercial building use with 20.6 percent of total commercial lighting kWh usage. Inpatient Health Care has the highest hours of use with 5,840 hours/year and Religious Worship the lowest with 1,825 hours/year.

Table A-4. DOE Study Industrial Hours of Use

Building Use	Hours	% Ltg. Usage
Food and Kindred Products	5,913	8.1%
Tobacco Products	5,001	0.0%
Textile Mill Products	4,928	8.1%
Apparel and Other Textile Products	3,687	2.0%
Lumber and Wood Products	5,731	4.0%
Furniture and Fixtures	3,942	3.0%
Paper and Allied Products	5,913	4.0%
Printing and Publishing	5,329	3.0%
Chemicals and Allied Products	5,293	10.1%
Petroleum and Coal Products	5,293	1.0%
Rubber and Miscellaneous Plastics	5,512	6.1%
Leather and Leather Products	4,417	0.0%
Stone, Clay, and Glass Products	5,402	4.0%
Primary Metal Industries	5,731	6.1%
Fabricated Metal Products	4,125	8.1%
Industrial Machinery and Equipment	5,183	7.1%
Electronic and Other Electric Equipment	4,526	4.0%
Transportation Equipment	6,059	12.1%
Instruments and Related Products	3,650	7.1%
Miscellaneous Manufacturing Industries	2,920	2.0%

The table shows that Transportation Equipment is the largest industrial building use with 12.1 percent of total industrial lighting kWh usage, and also has the highest hours of use at 6,059 hours/year.

A.2.3 New England Schools study [112]

The *CT & MA Utilities 2004-2005 Lighting Hours of Use for School Buildings Baseline Study* was performed by RLW Analytics. It was a direct metering study done on school buildings in New England, and involved installing 600 lighting loggers in schools during 2006. This study did not include data from universities or any other building use. Therefore, data from this study will inform only the final recommended values for the Schools & Government sector buildings. Table A-5 shows the hours of use and CF values for lighting in schools.

[112] RLW Analytics. *CT & MA Utilities 2004-2005 Lighting Hours of Use for School Buildings Baseline Study*. September 7, 2006.

Table A-5. RLW School Hours of Use Study Values

Space	Hours	CF
Auditorium	1,667	35%
Cafeteria	2,196	32%
Classroom	1,844	16%
Gymnasium	2,076	33%
Hallway	3,129	58%
Kitchen	1,625	16%
Library	2,087	27%
Locker Room	2,198	84%
Mechanical Room	940	28%
Office	2,236	35%
Other	1,826	16%
Restroom	2,380	43%
Storage Closet	800	26%
Teacher Lounge	1,879	21%

The table shows that, in schools, hallways show the highest hours of use with 3,129 hours/year. Locker Rooms show the highest coincidence factor with 84 percent.

The peak demand period for the New England Schools Study is defined as June-September, 3-5 pm, Monday through Friday.

A.2.4 New England coincidence factor study [113]

The *New England Coincidence Factor Study* was performed by RLW Analytics. It was a direct metering study that involved the installation of 1,415 meters throughout New England on buildings in 10 different building use categories. Table A-6 shows the coincidence factor results of this study.

Table A-6. RLW Coincidence Factor Study Values

Building Use	CF
Grocery	95%
Manufacturing	73%
Medical (Hospital)	77%
Office	75%
Other	54%
Restaurant	81%
Retail	82%
University/College	68%
Warehouse	78%
School	63%

[113] RLW Analytics. *Coincidence Factor Study - Residential and Commercial Industrial Lighting Measures*. Spring 2007.

The table shows that grocery stores have the highest coincidence factor with 95 percent and schools the second-lowest coincidence factor at 63 percent. There is also a catch-all building use for “Other” with a low CF value.

The peak demand period for the New England Coincidence Factor study is defined as June-August, 1-5 pm, Monday through Friday.

A.2.5 PG&E Rightlights program evaluation[114]

The *Evaluation of the 2004-2005 RightLights Program* is an impact evaluation done of a California program by Quantec in 2006. The RightLights program is a commercial and industrial lighting rebate program. The impact evaluation included telephone surveys with 100 program participants and 75 non-participants supplemented by 136 site visits for measure verification, a participant billing analysis, and the installation of 184 meters at 60 participant sites. Table A-7 shows a summary of hours of use determined through this impact evaluation.

Table A-7. PG&E RightLights Program 2004–2005 Evaluation Values

Building Use	Hours
Process Industrial	3,547
Grocery	4,636
Office	2,558
Restaurant	4,278
Retail	1,621

The table shows that Grocery has the highest hours of use with 4,636 hours/year and Retail the lowest with 1,621 hours/year.

A.2.6 SDG&E Time of Use Study [115]

The *SDG&E 2004-05 Express Efficiency Lighting Program Time of Use Study* is a metering study done by RLW Analytics in 2007. It included the installation of meters at 122 customer sites in southern California.[116] Table A-8 shows a summary of the results of this study.

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[114] Quantec. *Evaluation of the 2004-2005 RightLights Program*. April 21, 2006.

[115] RLW Analytics. *SDG&E 2004-05 Express Efficiency Lighting Program Time of Use Study* February 15, 2007.

[116] The report also included 281 meters installed on CFLs. The fluorescent and metal halide values are presented here, since the lighting hours and coincidence factors in question do not currently apply to CFL measures.

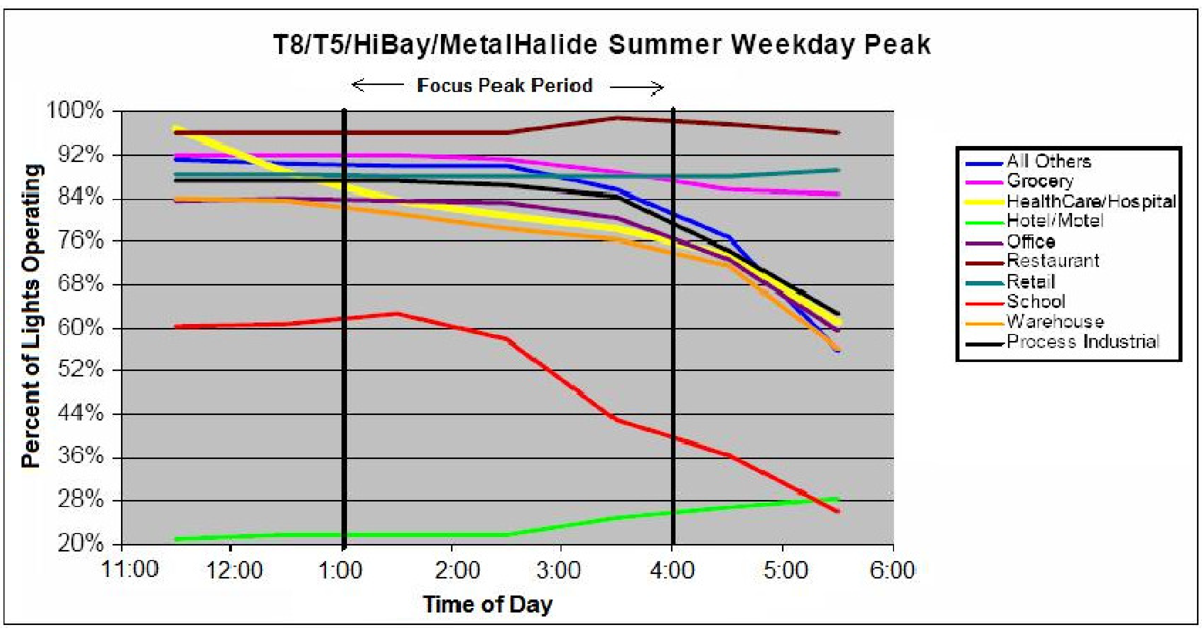
Table A-8. SDG&E 2004–2005 Hours of Use

Building Use	Hours	CF
Grocery	6,390	90%
Health Care	2,689	82%
Hotel	2,307	23%
Office	3,792	78%
Process	5,512	96%
Restaurant	4,450	88%
Retail	5,435	53%
School	1,795	79%
Warehouse	3,211	85%
Others	3,667	88%

The table shows that grocery stores have the highest hours of use at 6,390 hours/year and schools the lowest with 1,795 hours/year.

Coincidence factors were reported for the peak demand period of 11-6 pm, Monday through Friday, May through September. However, they were also reported graphically by time of day as shown in Figure 5-1. This allowed the values for the Focus peak hours of 1 to 4 pm to be read from the graph and averaged to yield the values reported in Table A-8. Therefore, the coincident factor values in Table A-8 represent a peak period of 1-4 pm, Monday through Friday, May through September.

Figure 5-1. SDG&E 2004-2005 Peak Demand Period Graph (Other Lighting)



A.2.7 SDG&E Hours of Operation Study [117]

The *Small Business Super Saver Program Hours of Operation Study* was a metering study done by KEMA Services, Inc. in 2006. It was similar to the study above, except in that it did not look at coincidence factor and included other technologies. The study involved installing 150 meters at 60 small businesses and institutions in southern California. Table A-9 shows a summary of the lighting results of this study.

Table A-9. SDG&E 2006 Study Values

Building Use	Hours
Assembly	2,961
Grocery	5,058
Healthcare	2,504
Office	2,698
Process	2,895
Restaurant	4,305
Retail	3,640
School	2,795
Warehouse	3,250
All Other	2,804

The table shows that Grocery had the highest hours of use at 5,058 hours/year and Health Care the lowest at 2,504 hours/year.

A.3 PROPOSED DEEMED SAVINGS BASIS AND ESTIMATES

A.3.1 Development of proposed values

a. HOURS OF USE

There are six studies cited that provide hours of use values or one or more building type. These sources are not equal in their value to the Focus program. Each has a different sample size and some are based on surveys, while others are based on metering. A larger sample size or number of data points translates into greater accuracy.

Surveys often result in inaccurate self-reported values, which may lead one to disregard survey data entirely. However, many surveys can be completed at a similar cost as relatively few metering installations so survey studies tend to contain more data points. The size of these studies makes them important even though the values tend to be less accurate than metering. In order to use all of the cited studies and to assign them value based on their size and data collection method, we have developed a weighting system to average the hours of use in the cited studies.

Two of the studies are based on surveys; they are PG&E 1996 and DOE. The other four studies are based on metering. Some of these four also include surveys but the values reported from the studies are the metered values. In order to compare studies based on

[117] KEMA Services, Inc. *Small Business Super Saver Program Hours of Operation Study*. September 2006.

metering with those based on surveys, we must determine the relative weight or value of a metered sample as compared to a survey sample.

Unfortunately, there is no standard rule of thumb to suggest the worth of a survey compared to a metered data point. In order to include the large PG&E and DOE surveys in our weighting analysis, we propose to weight them at ten percent of a metered study with the same number of data points. To put this more simply, a meter is worth ten surveys in this analysis. Putting a value on this relationship is somewhat arbitrary, but it is necessary, and it reflects the reality that metering is much more reliable than self-reports.

Table A-10 shows the number of meters or surveys used in each cited study. When applicable, the number of surveys is then divided by 10 to yield the value in the "meter equivalent sample size" row, with the number of meters from the other studies transferred to that row. The "weight" column represents the percent of the total sample size contributed by each study.

Table A-10. Hours of Use Study Weighting by Sample Size

Study	Meters	Surveys	Meter Equivalent Sample Size	Weight
PG&E 1996	0	1,270	127	6%
DOE	0	5,430	543	27%
RLW Schools	600	0	600	29%
PG&E RightLights	184	0	184	9%
SDG&E TOU	431	0	431	21%
SDG&E 2006	150	0	150	7%
Total	**1,365**	**6,700**	**2,035**	**100%**

If all building types had values reported for all six sources, the weights above would be the relative weight of each survey, across all building types. However, none does. Each building type has values from between one and five sources. So, the weights presented above act as relative weights between the applicable sources by building type.

Table A-11 shows the hours of use values cited for each study for each building type, the weighting factors determined using the method described above, and the resulting weighted average Hours of Use by building type.

Table A-11. Hours of Use Values and Weighted Averages

Building Use	PG&E 1996	DOE	RLW Schools	PG&E RightLights	SDG&E TOU	SDG&E 2006	Weighted Average
Food Sales	5,800	5,256	-	4,636	6,390	5,058	5,544
Food Service	4,600	4,599	-	4,278	4,450	4,305	4,482
Health Care	4,400	4,617	-	-	2,689	2,504	3,677
Hotel/Motel	5,500	3,687	-	-	2,307	-	3,356
Office	4,000	3,760	-	2,558	3,792	2,698	3,526
Public Assembly	-	2,665	-	-	-	2,961	2,729
Public Services (non-food)	3,400	3,431	-	-	-	-	3,425
Retail	4,450	4,258	-	1,621	5,435	3,640	4,226
Warehouse	3,550	3,705	-	-	3,211	3,250	3,464
School	2,150	2,774	2,147	-	1,795	2,795	2,302
College	3,900	-	-	-	-	-	3,900
Industrial	-	5,054	-	3,547	5,512	2,895	4,745
Other	4,500	3,723	-	-	3,667	2,804	3,672
Weight	6%	27%	29%	9%	21%	7%	100%

All building categories have at least two sources except for “College” with only one citation based on surveys. However, we would expect the value for college buildings to be greater than that for schools, and on the order of that for offices, and it is. Therefore, the College estimate appears reasonable.

Once the average hours of use were determined for each building type, KEMA combined the building types into the four sectors using more weighting systems. The weighting systems were determined by the percentage of lighting kWh used by each building type, in each Focus sector, in Wisconsin where possible or nationally where not. The two sectors where this type of weighting system is required are the Commercial and Schools & Government sectors.

We were unable to find a source for data on the percentage of lighting kWh used by the various building types in Wisconsin for the Commercial sector. Therefore, we turned to the national DOE Study, which includes the percentage of lighting kWh used by each building type nationally, as shown in Table A-4.

For the Commercial sector, we determined hours of use from each source as shown below in Table A-12. This table shows the average values for each building use in the Average Hours column. These values are then weighted and combined to create the overall average.

Table A-12. Commercial Hours of Use

Building Use	Weight	Average Hours
Food Sales	3.6%	5,544
Food Service	3.6%	4,482
Health Care	8.5%	3,677
Hotel/Motel	6.0%	3,356
Office	25.3%	3,526
Public Assembly	7.3%	2,729
Public Services (non-food)	6.0%	3,425
Retail	24.0%	4,226
Warehouse	15.7%	3,464
Average	100%	3,730

The overall average commercial hours of use across all sources and all building uses is 3,730 hours/year.

For the Schools & Government sector, sources typically have building uses for "k-12 school," "college/university," and "office" but nothing resembling "school & government." We considered using a similar method as was described for the Commercial sector, but determined that a more accurate Wisconsin-specific approach was possible based on the data tracked in the WISeerts database.

We reviewed the WISeerts database to determine the percentage of Focus on Energy Schools & Government sector lighting savings which could be categorized as "k-12 school," "college/university," and "office." This involved categorizing projects based on the name of the institution. We assumed that any institution with "university" in the name is college/university. Likewise, "school" would indicate a k-12 school project and "city," "police," or "municipal" would likely indicate office space. Some outliers, such as "Potawatomi Bingo and Casino" occurred, as well as city garages or warehouses, but they are a small minority.

We used this analysis to produce a kWh-weighted average of Schools & Government lighting projects that fall into the three building use types and used the results to determine the weighted average hours of use for the sector. Table A-13 shows the results.

Table A-13. Schools & Government Hours of Use

Building Use	Weight	Average Hours
Office	23%	3,526
School	36%	2,302
College	41%	3,900
Average	100%	3,239

For the Industrial sector, no weighting system was necessary as the sources generally included "industrial" as a building use. The average hours of use for Industrial are 4,745 hours/year.

The hours of use for the Agriculture sector are discussed in a later section.

b. COINCIDENCE FACTOR

Coincidence factor refers to the percentage of total system wattage that is operating during the peak demand period, and is deemed for each sector.

In the previous method of deeming, a value of 90 percent was used for commercial, industrial, and agriculture. A value of 71 percent was used for schools & government. Sources for these values are not available or have been lost. Because these sources are not available, we recommend developing new values based on the sources cited above in the literature review and the analysis below.

There are four sources that provide coincidence factor values for at least one building type, with most providing values for approximately ten building types. Again, not all of these surveys are of equal value to the program. The same considerations for sampling method (survey or meter) and sample size discussed for hours of use above apply to coincidence factors as well. These factors are dealt with in the same way for coincidence factor as they were for hours of use. A meter is considered to be worth ten surveys, and sample sizes are weighted accordingly.

However, in addition to these factors, another very important consideration is the peak periods used by each study. Each study cited uses a different definition for peak period. Since coincidence factor is defined as the percent of total system wattage on during the peak period, when the peak period occurs may have a significant effect on the coincidence factor value for that study. Thus, a weighting system was developed to include both sample size and the degree to which the peak periods for each study overlap with the Focus peak period.

All cited studies define peak period in the summer, Monday through Friday, mostly in the afternoon. This is consistent with the program's definition. However, the months and hours included is different for each. The peak months and hours for each cited study are presented in Table A-14 below.

Table A-14. Coincidence Factor Study Weighting by Sample Size and Peak Period Overlap

	PG&E 1996	RLW Schools	RLW CF	SDG&E Time of Use	Focus	Total
Peak Months	May-Oct	Jun-Sept	Jun-Aug	May-Sept	Jun-Aug	
Peak Hours	12 - 6 pm	3 - 5 pm	1 - 5 pm	1 - 4 pm	1 - 4 pm	
Total Peak Hours	1,104	244	368	459	276	
Hours In Focus Peak	276	92	276	276	276	
Percent in Focus Peak	25%	38%	75%	60%	100%	
Peak Period Weighting Factor	13%	19%	38%	30%	-	100%
Sample Size	127	600	1,415	431	-	-
Sample Size Weighting Factor	5%	23%	55%	17%	-	100%
Overall Weighting Factor	9%	21%	46%	24%	-	100%

The total peak hours for each program were calculated, as were the number of these hours that are contained in the Focus peak period. A ratio of the former to the latter is reported in the "Percent in Focus Peak" row in the above table. Each of these "Percent in Focus Peak" values was divided by the sum of the percentages to yield Peak Period Weighting Factors that sum to 100 percent.

Then, Sample Size Weighting Factors were developed using the method described for hours of use. The two weighting factors, Peak Period and Sample Size, were given equal importance and averaged to yield the Overall Weighting Factor of each study. For each building type, these act as relative weights of the values reported by each study for that building type.

The CF values reported by each study by building type are reported in Table A-15 along with their relative weights and the resulting weighted average.

Table A-15. Coincidence Factor Values and Weighted Averages

Building Use	PG&E 1996	RLW Schools	RLW CF	SDG&E Time of Use	Weighted Average
Food Sales	81%	-	95%	90%	92%
Food Service	68%	-	81%	96%	84%
Health Care	74%	-	77%	82%	78%
Hotel/Motel	67%	-	-	23%	35%
Office	81%	-	75%	78%	77%
Public Services (non-food)	64%	-	-	-	64%
Retail	88%	-	82%	88%	84%
Warehouse	84%	-	78%	79%	79%
School	42%	33%	63%	53%	51%
College	68%	-	68%	-	68%
Industrial	-	-	73%	85%	77%
Other	76%	-	54%	88%	67%
Weighting Factor	**9%**	**21%**	**46%**	**24%**	**100%**

Note that there is only one cited value for Public Services (non-food) buildings, so that one value is the “weighted average” value even though no actual weighting has occurred.

Once the average coincidence factor was determined by building type, KEMA combined the building types into sector-level estimates using the method outlined in the Hours of Use section. Table A-16 shows the coincidence factor from each building use, the weighting factor used, and the overall weighted average coincidence factor for the Commercial sector.

Table A-16. Commercial Coincidence Factor Weighting by Building Use

Building Use	Weight	Average CF
Food Sales	3.9%	92%
Food Service	3.9%	84%
Health Care	9.2%	78%
Hotel/Motel	6.5%	35%
Office	27.3%	77%
Public Services (non-food)	6.5%	64%
Retail	25.9%	84%
Warehouse	16.9%	79%
Average	**100%**	**77%**

For the Schools & Government sector, we determined coincidence factors based on the results from each source as shown below in Table A-17.

Table A-17. Schools & Government Coincidence Factor

Building Use	Weight	Average CF
Office	23%	77%
School	36%	52%
College	41%	68%
Average	100%	64%

For the Industrial sector, no weighting system was necessary as the sources generally included “industrial” as a building use. The average coincidence factor for the Industrial sector is 77 percent

c. THE AGRICULTURAL SECTOR

After a thorough but unsuccessful search for studies on lighting usage in the agricultural sector, we decided to look through the existing engineering reviews that were performed on installed projects during Focus on Energy’s 18-month Contract Period (18MCP). Though hours of use were mostly not used in calculations because most lighting measures were deemed, diligent engineers often collected self-reported hours of use data anyway. There were six engineering reviews done of lighting projects during the 18MCP in which hours of use was collected, representing 362 light fixtures of various types. This is a small sample but, unfortunately, the only data available to us.

Proposed agriculture lighting hours is based on a weighted average of this sample, based on the number of fixtures installed. Coincidence factor is determined using a weighting system based on both hours of use and whether the respondents indicated that the lights were on during the day or during the night. These results are shown below in Table A-18.

Table A-18. Agricultural Hours of Use and Coincidence Factor

Sector	Hours	CF
Agriculture	4,698	67%

A.3.2 Equations, definitions, and proposed values

In conclusion, we recommend the values in Table A-19 as the final deemed savings values for lighting hours of use and coincidence factor.

Hours of Use, Hours. Hours of use refers to the average annual hours that light fixtures operate in each sector, and is measured in hours/year. Values are shown in Table A-19.

Coincidence Factor, CF. Coincidence factor refers to the percentage of total system wattage operating during the peak demand period, is deemed for each sector, and is measured in percent. Values are shown in Table A-19.

Table A-19. Recommended Deemed Lighting Hours of Use and Coincidence Factor Values

Sector	Hours	CF
Agriculture	4,698	67%
Commercial	3,730	77%
Industrial	4,745	77%
Schools-Government	3,239	64%

APPENDIX B: ALTERNATIVE SAVINGS FOR T8 REPLACING 8' T12

This appendix contains alternative savings values for the "T8 Replacing 8' T12" measure group. If the PSC chooses not to accept the building type definition for hours of use and coincidence factor, then KEMA recommends that these sector-level savings be adopted. The savings are shown in Table B-1.

Table B-1. Alternative Savings for T8 Replacing 8' T12

			Proposed Deemed Savings			
			2.0810.170		2.0811.170	
Sector	Hours	CF	kW	kWh	kW	kWh
Agriculture	4,698	67%	0.0156	110	0.0797	560
Commercial	3,730	77%	0.0179	87	0.0912	444
Industrial	4,745	77%	0.0180	111	0.0918	565
Schools-Government	3,238	64%	0.0150	75	0.0767	386

APPENDIX C: ALTERNATIVE SAVINGS FOR HIGH BAY FLUORESCENT REPLACING HID

This appendix contains alternative savings values for the "High Bay Fluorescent Replacing HID" measure group. If the PSC chooses not to accept the building type definition for hours of use and coincidence factor, then KEMA recommends that these sector-level savings be adopted. The savings are shown in Table C-1.

Table C-1. Alternative Savings for High Bay Fluorescent Replacing HID

			2.5170.170		2.5180.170		2.5182.170		2.5185.170		2.5186.170	
Sector	Hours	CF	kW	kWh	kW	kWh	kW	kWh	kW	kWh	kW	kWh
Agriculture	4,698	67%	0.1010	709	0.1648	1,157	0.0693	486	0.4797	3,368	0.3650	2,563
Commercial	3,730	77%	0.1156	563	0.1886	919	0.0793	386	0.5490	2,674	0.4178	2,035
Industrial	4,745	77%	0.1163	716	0.1898	1,169	0.0798	491	0.5523	3,402	0.4203	2,589
Schools-Government	3,238	64%	0.0972	489	0.1586	798	0.0666	335	0.4615	2,322	0.3512	1,767

APPENDIX D: ALTERNATIVE SAVINGS FOR OCCUPANCY SENSORS FOR HIGH BAY FLUORESCENT FIXTURES

This appendix contains alternative savings values for the "Occupancy Sensors for High Bay Fluorescent Fixtures" measure group. If the PSC chooses not to accept the building type definition for hours of use and coincidence factor, then KEMA recommends that these sector-level savings be adopted. The savings are shown in Table D-1.

Table D-1. Alternative Savings for Occupancy Sensors for High Bay Fluorescent Fixtures

		Space Type					
		kWh Savings					
Sector	**Hours**	**Gymnasium**	**Industrial**	**Retail**	**Warehouse**	**Public Assembly**	**Other**
Agriculture	4,698	438	501	167	594	523	445
Commercial	3,730	348	398	133	472	416	353
Industrial	4,725	441	504	168	597	526	447
Schools- Government	3,239	302	346	115	409	361	307
Percent Off		39%	45%	15%	53%	47%	40%
Coincidence Factor		15%	18%	6%	18%	12%	14%
kW Savings		0.0344	0.0427	0.0142	0.0427	0.0284	0.0325

APPENDIX E: ALTERNATIVE SAVINGS FOR SCREW-IN CFL ≤32W AND CFL REFLECTOR FLOOD LAMP ≤30W

This appendix contains alternative savings values for the "Screw-in CFL ≤32W and CFL Reflector Flood Lamp ≤30W" measure group. If the PSC chooses not to accept the building type definition for hours of use and coincidence factor, then KEMA recommends that these sector-level savings be adopted. The savings are shown in Table E-1.

Table E-1. Alternative Savings for Screw-in CFL ≤32W and CFL Reflector Flood Lamp ≤30W

Building Use	Hours	CF	Savings by Measure			
			CFL <32 W		CFL Reflector Flood	
			kW	kWh	kW	kWh
Agriculture	2,450	67%	0.0373	136	0.0327	120
Commercial	3,730	77%	0.0427	208	0.0374	182
Industrial	4,745	77%	0.0429	264	0.0376	232
Schools-Government	3,238	64%	0.0359	180	0.0314	158

If the PSC chooses not to accept the building type definition for hours of use and coincidence factor, we recommend that the hours of use and CF values proposed in Appendix A be applied to all measures in which compact fluorescent lamps replace incandescent lamps. The resulting savings are shown in Tables E–2 and E–3.

Table E-2. Alternative kW Savings for Other Measures Impacted by Changes to CFL Analysis

<table>
<tr><th>WISeerts Tech Code</th><th>Measure Description</th><th>New Watts</th><th>Old Watts</th><th>Agriculture</th><th>Commercial</th><th>Industrial</th><th>Schools and Government</th></tr>
<tr><td>2.0301.165</td><td>CFL High Wattage 31-115 Watts, replacing incandescent</td><td>65.0</td><td>200.0</td><td>0.090</td><td>0.103</td><td>0.104</td><td>0.087</td></tr>
<tr><td>2.0305.060</td><td>CFL Cold Cathode Screw-In, replacing incandescent</td><td>4.0</td><td>25.0</td><td>0.014</td><td>0.016</td><td>0.016</td><td>0.014</td></tr>
<tr><td>2.0310.165</td><td>CFL Direct Install, replacing incandescent, WPS Hometown Checkup</td><td rowspan="6">20.0</td><td rowspan="6">75.7</td><td rowspan="6">0.037</td><td rowspan="6">0.043</td><td rowspan="6">0.043</td><td rowspan="6">0.036</td></tr>
<tr><td>2.0400.165</td><td>CFL Fixture, replacing incandescent fixture</td></tr>
<tr><td>n/a</td><td>Replace incandescent lamps with 14 Watt compact fluorescent lamps, WPS Hometown Checkup</td></tr>
<tr><td>n/a</td><td>Replace incandescent lamps with 20 Watt compact fluorescent lamps, WPS Hometown Checkup</td></tr>
<tr><td>n/a</td><td>Replace incandescent lamps with 23 Watt compact fluorescent lamps, WPS Hometown Checkup</td></tr>
<tr><td>n/a</td><td>Replace incandescent spotlight lamps with 16 Watt spotlight compact fluorescent lamps, WPS Hometown Checkup</td></tr>
<tr><td colspan="4">Coincidence Factor</td><td>67%</td><td>77%</td><td>77%</td><td>64%</td></tr>
</table>

Table E-3. Alternative kWh Savings for Other Measures Impacted by Changes to CFL Analysis

WISeerts Tech Code	Measure Description	New Watts	Old Watts	Agriculture	Commercial	Industrial	Schools and Government
2.0301.165	CFL High Wattage 31-115 Watts, replacing incandescent	65.0	200.0	331	504	641	437
2.0305.060	CFL Cold Cathode Screw-In, replacing incandescent	4.0	25.0	51	78	100	68
2.0310.165	CFL Direct Install, replacing incandescent, WPS Hometown Checkup	20.0	75.7	136	208	264	180
2.0400.165	CFL Fixture, replacing incandescent fixture						
n/a	Replace incandescent lamps with 14 Watt compact fluorescent lamps, WPS Hometown Checkup						
n/a	Replace incandescent lamps with 20 Watt compact fluorescent lamps, WPS Hometown Checkup						
n/a	Replace incandescent lamps with 23 Watt compact fluorescent lamps, WPS Hometown Checkup						
n/a	Replace incandescent spotlight lamps with 16 Watt spotlight compact fluorescent lamps, WPS Hometown Checkup						
Hours of Use				2,450	3,730	4,745	3,238