New Jersey's Clean Energy Program Energy Impact Evaluation and Protocol Review

SmartStart Program Protocol Review

FINAL

July 10, 2009

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1. Executive Summary

1.1 Overview

KEMA has been contracted by the New Jersey Board of Public Utilities' Office of Clean Energy (OCE) to perform an evaluation of energy impacts of New Jersey's Clean Energy Program's (NJCEP) energy efficiency and renewable programs. The results of this impact evaluation will assist OCE in determining the net and gross energy impacts of the programs. The results will also help the OCE update and modify the *Protocols to Measure Resource Savings* (Protocols)[1].

KEMA submitted the *New Jersey's Clean Energy Program Energy Impact Evaluation Final Work Plan* (Final Work Plan)[2] to OCE on October 8, 2007. The Final Work Plan as specified in the RFP mirrors the information provided in the bid proposal modified to reflect adjustments discussed at the kick-off meeting and subsequent discussions with OCE, the BPU Program Coordinator, the market managers and the utilities. The Final Work Plan presents individual research plans for the following six program areas.

1. Residential Electric and Gas HVAC Programs (Cool Advantage and Warm Advantage)
2. Residential New Construction Programs
3. ENERGY STAR Products Program
4. Commercial and Industrial Programs (SmartStart)[3]
5. Combined Heat and Power Program
6. Customer On-site Renewable Energy Program (CORE)[4]

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[1] *New Jersey's Clean Energy Program, Protocols to Measure Resource Savings,* Revisions to September 2004 Protocols, December 2007.

[2] *New Jersey's Clean Energy Program Energy Impact Evaluation Final Work Plan.* Prepared by KEMA for New Jersey Board of Public Utilities, Office of Clean Energy. October 8, 2007.

[3] The SmartStart work plan was updated and approved by OCE in May 2008.
New Jersey's Clean Energy Program Energy Impact Evaluation Updated SmartStart Work Plan. Prepared by KEMA for New Jersey Board of Public Utilities, Office of Clean Energy. May 2, 2008.

[4] The comprehensive CORE work plan was updated and approved by OCE in November 2008.
New Jersey's Clean Energy Program Energy Impact Evaluation CORE Work Plan. Prepared by KEMA for New Jersey Board of Public Utilities, Office of Clean Energy. November 14, 2008.

This report presents the results of KEMA's review of the *Protocols to Measure Resource Savings* for measures supported by the SmartStart Buildings Program. KEMA's retrospective assessment of energy savings reported by the SmartStart Program was provided in a separate document[5].

1.2 Approach

The NJCEP energy impact evaluation has two broad objectives:

1. To revise the savings calculation Protocols so that going forward the calculations using these Protocols provide (more) accurate statements of savings accomplishments.
2. To provide a retrospective assessment of program accomplishment, as part of a due diligence review of past utility program effectiveness on behalf of ratepayers.

The first of these objectives, KEMA's prospective assessment (review of savings protocols) is the topic of this report. The second objective, KEMA's retrospective assessment (review of reported savings) was reported in a separate reported submitted on July 10, 2009.

The Protocols were developed to accurately and consistently determine energy and resource savings for measures supported by the NJCEP. The document is periodically updated as new programs are added, existing programs are modified, and new information becomes available. The Protocols were most recently updated in December 2007. KEMA conducted a detailed assessment of the Protocols and recommends updates to the Protocols based on:

- a review of the December 2007 version;
- a review of sources and data cited in the protocols;
- a review of similar "deemed savings" documents prepared in other jurisdictions and other secondary sources;
- knowledge gained from the retrospective review of track savings currently underway; and
- application of these data and sources to the measures supported by NJCEP.

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[5] *New Jersey's Clean Energy Program Energy Impact Evaluation SmartStart Program Impact Evaluation.* Prepared by KEMA for New Jersey Board of Public Utilities, Office of Clean Energy. July 10, 2009.

1.3 Summary of Findings and Recommendations

This section presents KEMA's key findings and recommendations for the Protocol Review, Protocol use of Time Period Allocation Factors, a process for estimating savings for custom projects, an on-going process for updating the Protocols, and tracking data and hard-copy documentation.

1.3.1 Protocol Review

This report provides a review of the savings algorithms for the SmartStart Program. The review assesses the appropriateness of the savings equations and the input parameters provided in the 2007 Protocols. A detailed review of the following Protocols is included in this report:

- Lighting Equipment
    - Performance Lighting
    - Prescriptive Lighting
- Lighting Controls
- Motors
- Electric HVAC Systems
- Electric Chillers
- Variable Frequency Drives
- Air Compressors with Variable Frequency Drives
- Gas Chillers (Absorption Chillers)
- Gas Fired Desiccants
- Gas Booster Water Heaters
- Gas Water Heaters
- Furnaces and Boilers
- Compressed Air System Optimization

First, we address the use of key terms used in the Protocols. Then we provide a table containing KEMA's key recommendations for each SmartStart protocol.

1.3.1.1 Key Protocol Terms

Key variables (e.g., Coincidence Factor, Equivalent Full Load Hours, kW savings) in the Protocols are defined differently, depending on the Protocol. To remove confusion regarding these definitions, KEMA provides a Glossary of Key Terms and Variables as they are used in this report. KEMA recommends consistent use of key terms in the Protocols.

1.3.1.2 Key Protocol Recommendations

Table 1-1 presents a summary of KEMA's key recommendations for each of the fourteen Protocols reviewed. This summary of recommendations is provided at a high and general level; for a more detailed explanation of each recommendation refer to the full body of the report.

Table 1-1
Summary of Protocol Recommendations

Protocol	Number	Page	Recommendation
Performance Lighting	PL-1	3-15	**Revise algorithm inputs for Equivalent Full Load Hours (EFLH), Coincidence Factor (CF), and Interactive Factor (IF) based on the values provided, which are based on secondary sources and are differentiated by building type.**
	PL-3	3-18	**Record lighting control type on the application. When lighting is controlled by something other than a simple switch, use savings factors provided in the Lighting Controls section to adjust for savings based on those controls.**
	PL-4	3-18	**Provide a list of building types, space types, and a standard lighting wattage table either on the application or on a separate downloadable document.**
	PL-5	3-18	**Clarify whether the wattage data from the application is used in savings calculations, or whether the wattages are based on a standard wattage table. We recommend that a standard wattage table be used, and have provided California's Standard Performance Contract (SPC) table for that purpose.**
	PL-6	3-18	**Record on the application information on which building spaces are conditioned and which are not, so that interactive savings are not claimed for unconditioned spaces.**
	PL-7	3-18	**In calculating energy savings, use all building spaces, even if the lighting densities from some spaces do not meet the qualifying requirements for the program. This will provide a more accurate estimate of energy savings.**
Prescriptive Lighting	PrL-1	3-21	**Replace the existing wattages from the Prescriptive Lighting Savings Table with updated wattages from California's Standard Performance Contract (SPC) table.**
	PrL-2	3-21	**Use the same inputs for CF, EFLH, and IF as provided in the Performance Lighting protocol review.**
	PrL-3	3-21	**Account for interactive energy savings realized under this**

Protocol	Number	Page	Recommendation
			protocol by including Interactive Factor (IF) in the savings calculation.
	PrL-4	3-21	**Record lighting control type on the application. When lighting is controlled by something other than a simple switch, use savings factors provided in the Lighting Controls section to adjust savings based on those controls.**
Lighting Controls	LC-1	3-24	**Coordinate this measure with Performance and Prescriptive Lighting, such that savings are not double-counted for customers who apply for Lighting Controls and one of the other lighting measures.**
	LC-2	3-24	**Use the same values for EFLH, CF, and IF as are recommended for Performance Lighting.**
Motors	M-1	3-34	**Base energy savings calculations on the horsepower of the qualifying unit, rather than on both the qualifying and replaced unit.**
	M-2	3-34	**Fully articulate the algorithms such that commonly used factors as Load Factor and Duty Cycle are apparent in the algorithm, rather than subsumed under the Rated Load Factor, a term that is not commonly used in the industry.**
	M-3	3-34	**Include in the algorithm a factor to account for the interaction motor between two sometimes concurrent measures: Motors and Variable Frequency Drives (VFDs).**
	M-4	3-34	**Conduct a survey to gather motor operating hours by climate zone and by sector. Until that has been completed, base operating hours on those provided.**
	M-5	3-34	**Include in the protocols the provided tables which establish baseline and qualifying premium motor efficiencies.**
Electric HVAC System	ES-1	3-47	**Adjust the baseline energy efficiency values to fit those provided by the Consortium of Energy Efficiency (CEE) Tier 1.**
	ES-2	3-47	**Consider including a factor in the algorithm to account for over sizing of equipment.**
	ES-3	3-48	**Consider allowing variation in CF and EFLH based on building type, building vintage, and climate zone. Further research is warranted to determine these values. The variation could be estimated by adjusting variability information for California for the New Jersey climate, or by carrying out rigorous DOE 2 (computer based) building simulation.**
Electric Chillers	EC-1	3-58	**Use IPLV (Integrated Part Load Value) for efficiency in the algorithm rather than full load efficiency, which is currently used.**

Protocol	Number	Page	Recommendation
	EC-2	3-59	**Adjust baseline efficiency values based on equipment type and size as provided in the full body of the report.**
	EC-3	3-59	**Limit qualifying equipment such that the qualifying chiller must be at least 5% more efficient than the baseline chiller. A list of qualifying efficiencies is provided.**
	EC-4	3-59	**Use a custom approach for very large chillers.**
	EC-5	3-59	**Conduct market research into the installed baseline of chillers in New Jersey, including size, age, efficiency, and operational hours, which will help determine the importance of this measure and establish appropriate benchmarks.**
	EC-6	3-59	**Investigate and provide more accurate values for EFLH and CF.**
Variable Frequency Drives	VFD-1	3-70	**Undertake a metering study to determine accurate values for Demand Savings Factor (DSF) and Energy Savings Factor (ESF). Since HVAC motors are highly dependent upon weather, it will be important to use data that are collected within New Jersey.**
	VFD-2	3-70	**Create a lookup table of DSF and ESF values based on the type of fan or pump application. This will require updating the application to collect this information from the customer.**
	VFD-3	3-70	**Until a metering study is complete, use values for DSF and ESF based on those used by Connecticut Light and Power, as provided.**
Air Compressors with Variable Frequency Drives	ACVFD-1	3-77	**Proceed conservatively with the promotion of VFDs on air compressors unless there is confidence that the compressor regularly operates at 30%-70% load. Within that window, VFDs can provide significant savings, but for compressors which typically operate outside that window, savings will be minimal or negative.**
	ACVFD-2	3-77	**Limit this prescriptive measure to facilities with a single operating compressor who are either replacing their existing compressor with a new single compressor of the same size, or are installing a retrofit VFD on the existing compressor. For multiple-compressor systems, it is much more difficult to determine whether a VFD would save energy, and the customer and program may receive greater benefit by treating multiple-compressor systems as a custom measure.**
	ACVFD-3	3-77	**Fully articulate in the protocol the algorithms provided for Yearly, Peak, and Maximum kW/HP savings and their inputs, as provided.**
	ACVFD-4	3-77	**Change and expand values used for key variables in the protocol based on secondary sources and our engineering review, as provided.**

Protocol	Number	Page	Recommendation
Gas Chillers (Absorption Chillers)	GC-1	3-82	**Treat Gas Chillers as a custom measure. Gas absorption chiller energy use is extremely site-specific.**
	GC-2	3-82	**In the custom calculation, we suggest using a temperature bin calculation method both for the baseline chiller and for the new proposed chiller. At minimum, the load profile must be based on operating hours during peak times and operating hours during off-peak times. As an alternative, SmartStart may create a complete building simulation using energy modeling software. Various simulation tools like DOE-2, HAP, Trace and e-Quest have in built performance simulation modules for gas absorption chillers.**
Gas Fired Desiccants	GFD-1	3-87	**Treat Gas Fired Desiccants as a custom measure. Energy savings are highly variable based on many factors, including the design and efficiency of the existing cooling equipment.**
	GFD-2	3-87	**One possible approach to determine savings for gas fired desiccants is to use existing modeling software. There are several models that are currently available, including TRACE, DOE-2, and DesiCalc. Another option is to conduct further research by measurement and verification of SmartStart customers who are installing the technology.**
Gas Booster Water Heaters	GBWH-1	3-96	**Consider treating Gas Booster Water Heaters as a custom measure. Booster heater energy use will vary greatly, depending upon whether they are installed on commercial dishwashers or elsewhere. Even amongst commercial dishwasher installations, energy use variability is considerable based on dishwasher type.**
	GBWH-2	3-96	**KEMA provides a prescriptive methodology for booster heater installations on a great majority of commercial dishwashers. The following recommendations apply to these installations.** **a.) Use the provided algorithms, which are based on the sensible heat equation, rather than estimating EFLH.** **b.) Ask for the racks of dishes washed per day on the application and obtain gallons per rack from the provided lookup table. The values are used in the algorithm to estimate the amount of water heated.** **c.) Use the values provided for other algorithm variables.**
	GBWH-3	3-97	**Conduct further research into dishwasher use with respect to time and typical booster water heater input temperatures.**
Gas Water Heaters	GWH-1	3-103	**Use the algorithm provided, which is based on energy use density by building type, rather than a fixed value for baseline energy usage. The fixed baseline is currently based on residential water heating energy, not commercial.**
	GWH-2	3-103	**Require that the application collect the square footage served by the water heater and use the value with the appropriate energy use density to determine hot water energy use.**

Protocol	Number	Page	Recommendation
	GWH-3	3-103	**Use Energy Factor (EF) for efficiency values for small water heaters (less than 50 gallons or 75,000 BtuH). Use Thermal Efficiency (TE) for efficiency values for larger water heaters.**
Furnaces and Boilers	FB-1	3-114	**Use the provided algorithm to calculate energy savings. It is based on heating degree days from four New Jersey climate zones and twelve building types, rather than on a single fixed value for EFLH.**
Compressed Air System Optimization	CASO-1	3-103	**Take advantage of the DOE Compressed Air Challenge (CAC), which provides training and other services regarding compressed air systems. Following CAC guidelines will help to provide a more thorough and standardized approach to compressed air systems and give more confidence and authority to the SmartStart Program's energy savings recommendations.**
	CASO-2	3-103	**Maintain both options for rebates under Compressed Air System Optimization: Compressed Air System Analysis and Pay for Performance. Below we discuss recommendations for these measures separately.**
	Compressed Air System Analysis Recommendations		
	CASO-3	3-119	**Require any auditor providing this analysis to have attended the CAC two-part training series and not be under the employ of a company which also sells compressed air products.**
	CASO-4	3-119	**Refer to the main body of the report for an extensive list of potential compressed air system improvements.**
	Pay for Performance Recommendations		
	CASO-5	3-121	**Make sure not to offer this option to a customer who has already begun installation of a product. This type of project would have occurred without the program and program dollars could be better spent elsewhere.**
	CASO-6	3-121	**Promote the systems approach to air compressor energy savings for multiple-compressor systems, even under the Pay for Performance option.**
	CASO-7	3-121	**Encourage customers to take CAC training.**
	CASO-8	3-121	**Continue to require that Measurement and Verification (M&V) plans follow the International Performance Measurement and Verification Protocol (IPMVP). This protocol offers two options and we recommend that the program generally promote Option B, the system-wide M&V approach. We recommend that the program also consider the Compressed Air Supply Efficiency**

Protocol	Number	Page	Recommendation
			method as promoted by California as a simple standardized M&V method.
	CASO-9	**3-122**	**Rebate ultrasonic leak detectors or create a tool library where customers can borrow ultrasonic leak detectors. Ultrasonic leak detectors are an essential tool for checking leaks in air lines.**

1.3.2 Time Period Allocation Factors

Time Period Allocation Factors are an important component of determining the cost-effectiveness of program measures from a utility perspective.

The time periods are defined as follows:

- Electricity (kWh) savings across summer peak, summer off-peak, winter peak, and winter off-peak
- Gas (therm) savings across summer and winter periods

KEMA does not recommend changes to the Time Period Allocation Factors for electricity most measures. However for several technologies, including control measures that save energy at specific times, rather than over the normal course of equipment operations KEMA recommends additional research. In such cases, the measure savings shape (energy savings) is expected to be different from the end use load shape (energy consumption). Unfortunately, most load shape research to date has focused on end use load shapes.

Table 1-2 below summarizes the recommendations for improving Time Period Allocation Factors for electric measures.

Table 1-2
Summary of Recommendations (Electric Measures)

Measure	Recommendations
Lighting Equipment	No changes currently recommended.
Lighting Controls	Use current Time Period Allocation Factors until additional research and possible on-site metering surveys yield more appropriate data on measure shape of lighting controls.
High Efficiency Motors	Time Period Allocations should utilize the specific end-use load shapes. Since most motor applications are for HVAC systems, the HVAC system Time Period allocation Factors should suffice.
High Efficiency HVAC	No changes currently recommended.
High Efficiency Chillers	No changes currently recommended.
VFDs	Use equipment specific Time Period Allocation Factors, per Efficiency Vermont Technical Reference User Manual (TRC) No. 2005-37.
VFD air compressors	Use current Time Period Allocation Factors until additional analysis of business and application types inform more appropriate hours of operation.

Gas efficiency measures only have Time Period Allocation Factors associated with summer and winter use. The Protocols stipulate that the summer and winter periods are six months each. Therefore, for any efficiency measure to operate at a constant rate year round, the Time Period Allocation Factor is expected to be roughly 50/50 for summer and winter periods.

Some of the measures in the C&I Gas Protocols result primarily in electric savings, rather than gas savings. Although they are being recommended as custom savings measures, estimated Time Period Allocation Factors for gas chillers and gas fired desiccants have been provided in this analysis. Table 1-3 summarizes the Time Period Allocation Factor recommendations for measures in the Gas Protocols.

Table 1-3
Summary of Recommendations (Gas Protocols)

Measure	Recommendations
Gas Chillers	Revise Time Period Allocation Factors to reflect zero electric savings in the winter, and zero gas savings in the summer.
Gas Fired Desiccants	Use HVAC system Time Period Allocation Factors for electric savings. No gas savings are associated with this measure.
Gas Booster Water Heaters	No changes currently recommended.
Water Heaters	Use current Time Period Allocation Factors until additional research on seasonal variation in water delivery temperature can be completed.
Furnaces and Boilers	Minor changes to the Time Period Allocation Factors are recommended, based on climate zone.

1.3.3 Estimating Savings for Custom Projects

Custom measures allow customers to qualify for and receive an incentive for energy efficiency measures that are not on the Prescriptive Equipment incentive list. Custom measures are site and end-use specific, and require a detailed analysis to qualify for incentives. The following is a brief synopsis of key considerations and recommendations for estimating savings for custom projects. For a more complete discussion of these topics, please refer to Section 4 of the full body of this report.

1.3.3.1 Key Questions and Concerns

The following is a summary of general issues and recommendations regarding custom savings calculations.

- KEMA recommends SmartStart develop a standard method for handling energy savings calculations and measurements from various sources. We recommend that the program carefully review all calculations. For calculations provided by manufacturers, vendors, or contractors, we recommend that the program perform separate calculations using standard methods for comparison.
- KEMA recommends that the program establish a standard method for determining whether a project is an early or natural replacement installation. This distinction determines which baseline condition is used and can have a significant impact on the energy savings calculated. We recommend that the program ask for the reason equipment is being replaced on the application and use the answer to make this determination. If the answer is not clear or it is otherwise difficult to determine, we recommend that the program assume natural replacement as the default
- SmartStart currently accounts for interactive effects for some prescriptive lighting measures. KEMA recommends that the program develop a standard regarding whether interactive effects should be considered for custom projects. Since interactive effects are often difficult to determine and verify, we recommend that the program, by default, excludes interactive effects from custom projects. Exceptions can be made for unusual projects.

1.3.3.2 Methods for Determining Savings

Savings for custom measures may be determined by:

Engineering Estimates. This is the most common method for determining savings. It involves applying well-established engineering algorithms to estimate baseline and qualifying energy use.

Building or Process Simulation Modeling. For measures that have building-wide impacts or impacts across a number of systems, building or process simulation modeling using public domain software may be acceptable to document savings.

Metering. Whole-building metering may be used to determine savings if savings are a significant fraction of the total monthly or annual energy usage. When measures are installed that affect a large and distinct system, sub-metering may be the best way to document the savings. The program may wish to require metering for measurement and verification (M&V) in order for a project to qualify for an incentive, or to gain a greater understanding of energy savings for planning purposes. In such cases, the International Performance Measurement and Verification Protocol[6] (IPMVP) should be followed to develop an M&V plan. Documentation of the method used and assumptions made should be a program requirement.

1.3.4 Tracking Data and Hard-Copy Documentation

Consistent and complete program tracking data is a fundamental requirement for a statewide energy efficiency program such as SmartStart. Program tracking data can be used for program operations, program planning, and reporting and verification of accomplishments. KEMA understands that OCE has implemented a statewide tracking database and process for archiving hard-copy project documentation subsequent to the time period covered by this evaluation (2001-2006).

1.3.4.1 Electronic Data

During the period under review (2001-2006), the program relied on policies and procedures to ensure consistency and quality control. The application, technical information, savings and incentive calculations, and supporting documents were reviewed upon receipt to verify eligibility. However the data was not collected and stored in a consistent electronic format across the state. Statewide energy efficiency and renewable programs, such as SmartStart, should have an electronic tracking database to facilitate consistent and accurate measure level energy savings calculations and therefore reporting of overall program impacts. The database should

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[6] 1.2.3 International Performance Measurement and Verification Protocol (IPMVP) - Efficiency Valuation Organization, April 2007

contain the following categories: customer information, contractor/vendor information, measure and project-specific data.

The database should contain measure specific energy and demand savings values. These values should be hand entered (with supporting hard-copy documentation or electronic PDFs) for custom projects and officially calculated by the database for non-custom projects.

The database should be as detailed as possible. All measure specific information on the program application should be entered into the database. Electronic tracking of this information will enable the OCE greater flexibility in monitoring and researching its programs. It will also minimize demands on the program for data requests for program impact evaluations, benefit-cost studies, and other research studies. The accuracy of these studies will also improve with better program tracking data.

KEMA understands that OCE has created a statewide database subsequent to the time period covered by this impact evaluation (2001-2006).

1.3.4.2 Hard-Copy Documentation

Following data entry into the program tracking database, all project application and supporting documentation should be filed in a dedicated location for the program. Each file should consist of:

- Application form
- Invoices, or other information submitted by the customer or their contractor
- Supporting calculations (e.g. prescriptive lighting worksheet, lighting controls worksheet, etc.)
- Any internal procedural application processing forms (e.g. payment release forms, internal check-in forms, etc.)

1.3.5 On-going Protocol Updates

The Protocols to Measure Resource Savings (Protocols) is updated and modified periodically in order to ensure that the savings calculation methodologies are accurate and relevant. KEMA recommends that OCE update the Protocol document on an annual basis to coincide with the annual program planning process. The Protocol update process should also include the results and recommendations of any independent third-party program evaluations of the SmartStart program. Table 1-4 shows a selection of regulations, federal and state policies, and studies which may inform updates to the Protocol.

Table 1-4
Selection of Sources for Protocol Updates

Source	Description
Federal policy	Federal policies such as the EISA 2007 will set new federal efficiency standards for certain motors and lighting
New Jersey building codes	New commercial buildings are required to show compliance to ASHRAE 90.1-2004.
NJCEP Impact Evaluations	Third party evaluations of the SmartStart program can provide important data on the accuracy of key assumptions used in the Protocols.
Regional or New Jersey specific metering studies	Other metering studies may provide improved values for operating hours and equivalent full load hours, across different business types.
Other industry studies	The results and findings of other industry studies may also inform revisions to New Jersey operating hours and savings calculations.

2. Introduction

KEMA has been contracted by the New Jersey Board of Public Utilities' Office of Clean Energy (OCE) to perform an evaluation of energy impacts of the New Jersey Clean Energy Program's (NJCEP) energy efficiency and renewable programs. The results of this impact evaluation will assist OCE in determining the net and gross energy impacts of the programs. The results will also help the OCE update and modify the *Protocols to Measure Resource Savings* (Protocols)[7].

KEMA submitted the *New Jersey's Clean Energy Program Energy Impact Evaluation Final Work Plan* (Final Work Plan)[8] to OCE on October 8, 2007. The Final Work Plan as specified in the RFP mirrors the information provided in the bid proposal modified to reflect adjustments discussed at the kick-off meeting and subsequent discussions with OCE, the BPU Program Coordinator, the market managers and the utilities. The Final Work Plan presents individual research plans for the following six program areas.

1. Residential Electric and Gas HVAC Programs (Cool Advantage and Warm Advantage)
2. Residential New Construction Programs
3. ENERGY STAR Products Program
4. Commercial and Industrial Programs (SmartStart)[9]
5. Combined Heat and Power Program
6. Customer On-site Renewable Energy Program (CORE)[10]

This report presents the results of KEMA's review of the Protocols to Measure Resource Savings for measures supported by the SmartStart Buildings Program. KEMA's retrospective

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[7] *New Jersey's Clean Energy Program, Protocols to Measure Resource Savings,* Revisions to September 2004 Protocols, December 2007.

[8] *New Jersey's Clean Energy Program Energy Impact Evaluation Final Work Plan.* Prepared by KEMA for New Jersey Board of Public Utilities, Office of Clean Energy. October 8, 2007.

[9] The SmartStart work plan was updated and approved by OCE in May 2008.
New Jersey's Clean Energy Program Energy Impact Evaluation Updated SmartStart Work Plan. Prepared by KEMA for New Jersey Board of Public Utilities, Office of Clean Energy. May 2, 2008.

[10] The comprehensive CORE work plan was updated and approved by OCE in November 2008.
New Jersey's Clean Energy Program Energy Impact Evaluation CORE Work Plan. Prepared by KEMA for New Jersey Board of Public Utilities, Office of Clean Energy. November 14, 2008.

assessment of energy savings reported by the SmartStart Program will be provided in a separate document in January 2009.

2.1 Program Overview

The NJCEP Commercial and Industrial programs have been marketed under the umbrella of the SmartStart Buildings Program. This program offers design support, technical assistance, financial incentives, and additional services for qualifying projects and equipment. The SmartStart Program is organized into three sectors: Retrofit, Schools (New Construction and Retrofit), and New Construction. There is also a Combined Heat and Power (CHP) component of this program that was evaluated separately.

Table 2-1 provides a summary of the Commercial and Industrial New Construction, Retrofit and School Retrofit Programs' overall budget, program expenditure and tracked savings for the evaluation period of analysis (2001-2006).

Table 2-1

Commercial and Industrial New Construction, Retrofit and School Retrofit Program Summary from 2001-2006[11]

Commercial & Industrial Programs						
	2001	**2002**	**2003**	**2004**	**2005**	**2006**
C&I New Construction						
Program Budget (in 000's of $)			$3,145	$3,317	$3,300	$3,811
Actual Expenditures (in 000's of $)			$3,832	$3,902	$3,730	$1,422
Participants			188	176	198	187
Tracked KW Savings			1,935	6,380	3,548	3,861
Tracked MWh Savings			11,760	31,538	13,851	17,351
Tracked Dtherms Savings			8,246	4,576	12,335	2,855
C&I Retrofit						
Program Budget (in 000's of $)			$24,089	$21,773	$20,900	$25,180
Actual Expenditures (in 000's of $)			$25,095	$22,686	$17,347	$16,973
Participants			3,818	3,563	1,923	1,798
Tracked KW Savings			34,659	33,751	28,478	21,539
Tracked MWh Savings			179,679	163,631	260,238	78,194
Tracked Dtherms Savings			70,277	40,439	175,613	171,062
C&I New School Construction & Retrofit						
Program Budget (in 000's of $)			$6,670	$5,109	$3,500	$3,872
Actual Expenditures (in 000's of $)			$1,628	$3,073	$3,360	$1,672
Participants			203	244	266	109
Tracked KW Savings			1,561	3,199	4,356	901
Tracked MWh Savings			5,908	8,975	13,583	2,832
Tracked Dtherms Savings			9,482	9,629	2,053	27,913
C&I Total						
Program Budget (in 000's of $)	$21,551	$28,353	$33,904	$30,199	$27,700	$32,863
Actual Expenditures (in 000's of $)	$12,346	$38,271	$30,555	$29,661	$24,437	$20,067
Participants	1,632	9,070	4,209	3,983	2,387	2,094
Tracked KW Savings	6,364	26,750	38,155	43,330	36,382	26,301
Tracked MWh Savings	30,943	144,635	197,347	204,144	287,672	98,377
Tracked Dtherms Savings	33,802	33,504	88,005	54,644	190,001	201,830

2.2 Approach

The NJCEP energy impact evaluation has two broad objectives:

1. To revise the savings calculation Protocols so that going forward the calculations using these Protocols provide (more) accurate statements of savings accomplishments.
2. To provide a retrospective assessment of program accomplishment, as part of a due diligence review of past utility program effectiveness on behalf of ratepayers.

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[11] New Jersey Clean Energy Program. *New Jersey's Clean Energy Program Report submitted to the New Jersey Board of Public Utilities*. Reports from 2001-2006.

The first of these objectives, KEMA's prospective assessment (review of savings protocols) is the topic of this report. The second objective, KEMA's retrospective assessment (review of reported savings) will be reported in January 2009.

The Protocols were developed to accurately and consistently determine energy and resource savings for measures supported by the NJCEP. The document is periodically updated as new programs are added, existing programs are modified, and new information becomes available. The Protocols were most recently updated in December 2007. KEMA conducted a detailed assessment of the Protocols and recommends updates to the Protocols based on:

- a review of the December 2007 version;
- a review of sources and data cited in the protocols;
- a review of similar "deemed savings" documents prepared in other jurisdictions and other secondary sources;
- knowledge gained from the retrospective review of track savings currently underway; and
- application of these data and sources to the measures supported by NJCEP.

2.3 Overview of Report

Remainder of the report is organized as follows: *Section 2, Protocol Reviews,* provides KEMA's assessment and recommended updates to the existing SmartStart Protocols; and *Section 3, Estimating Savings for Custom Projects,* outlines our recommended process for estimating energy savings for custom projects. *Section 4, On-going Protocol Updates,* provides KEMA's recommendations for Protocol updates and third party evaluations to ensure the accuracy and relevancy of methodologies; and the report concludes with a discussion of tracking data and hard copy project documentation to ensure adequate records are available for future research and program planning (*Section 5, Tracking Data and Hard-Copy Documentation).*

Appendix A provides the *2008 Standard Performance Contract*, which is a comprehensive list of fixture wattages, in PDF format.

3. Protocol Reviews

This section provides KEMA's review of the SmartStart Protocols. First, KEMA provides a summary of key terms used in the Protocols followed by a detailed review of each commercial and industrial technology in the Protocols. This section concludes with a review of Time Period Allocation Factors.

KEMA reviewed the Protocols for the following technologies:

- Lighting Equipment
    - Performance Lighting
    - Prescriptive Lighting
- Lighting Controls
- Motors
- Electric HVAC Systems
- Electric Chillers
- Variable Frequency Drives
- Air Compressors with Variable Frequency Drives
- Gas Chillers (Absorption Chillers)
- Gas Fired Desiccants
- Gas Booster Water Heaters
- Gas Water Heaters
- Furnaces and Boilers
- Compressed Air System Optimization

The Protocol review for each of the aforementioned technologies includes:

- **Review of the 2007 Protocols Document** – The review of the savings Protocols began with a review of energy savings calculations, input assumptions, and baseline estimates. KEMA engineers identified:
    - measures/assumptions/definitions of key factors (e.g. coincidence factor, load factor, equivalent full load hours, etc.)/etc. that merited further research;
    - cited sources and data to be reviewed; and
    - key factors in savings algorithms that could be updated and/or refined with applicable secondary sources (studies and data).

- **Review of the Sources/Data cited in the Protocols, if available** – The savings Protocols reference underlying studies and data that are used to determine energy savings. The introduction to the Protocols states:

  > *The standard values for most commercial and industrial (C&I) measures are supported by end use metering for key parameters for a sample of facilities and circuits, based on the metered data from past programs. These C&I standard values are based on five years of data for most measures and two years of data for lighting. Some electric and gas input values were derived from a review of literature from various industry organizations, equipment manufacturers, and suppliers. These input values are updated to reflect changes in code, federal standards and recent program evaluations.*[12]

  The document also refers to "5 year metering data" or "utility or consulting studies" as the basis for many key parameters without specifically citing the source data and literature. A review of these source data and studies was included as part of the review of the Protocols, subject to availability. Available sources were reviewed for statistical validity, appropriate application, and whether or not more current data are available.

  First, KEMA obtained all publicly available sources cited in the Protocols. Then KEMA requested all remaining underlying studies and data cited in the Protocols in a June 18, 2008 memo to OCE titled *New Jersey SmartStart Protocol Sources Request*. OCE and the utilities were not able to locate some of the requested studies and data. KEMA did receive other key sources, such as the *Energy Efficient Market Assessment of New Jersey Clean Energy Programs*[13] prepared for OCE by Summit Blue, and the New Jersey Comprehensive Resource Analysis Market Assessment prepared for New Jersey Utilities Working Group by Xenergy.[14] KEMA reviewed the available sources and data; then used additional secondary sources to inform its recommendations.

- **Review of Secondary Sources** – Following the review of sources and data cited in the Protocols, KEMA reviewed other studies and data collected in other regions applicable

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[12] *New Jersey Clean Energy Program Protocols to Measure Resource Savings. Revisions to September 2004 Protocols.* December 2007. Page 1.

[13] Summit Blue. *Energy Efficient Market Assessment of New Jersey Clean Energy Programs, Book III – Commercial and Industrial Programs*. July 20, 2006.

[14] *New Jersey Comprehensive Resource Analysis Market Assessment*. Prepared by Xenergy, August 19, 1999.

to New Jersey. These sources were incorporated directly or indirectly into the Protocols recommendations.

- **Application of Engineering Review to Protocols** – KEMA applied its review of applicable studies and data to the measures and technologies reported in the Protocols. Additional research is recommended if it is outside the scope of this impact evaluation.

- **Recommended updates to the Protocols** – KEMA recommends updates to the existing Protocols based on its comprehensive assessment. Recommendations include: standard definitions of key factors; updates to key factors, assumptions, and inputs; and updated studies or source data currently used in the Protocol.

3.1 Definitions of Key Terms and Variables

Certain key variables in the Protocols are defined differently, depending on the Protocol. To remove confusion regarding these definitions, we begin the review with a glossary of commonly used terms. These terms are used consistently in KEMA's review of the Protocols.

Annual operating hours. The number of hours that a given piece of equipment operates in a year.

Capacity. Rated power input of equipment in kW or Btu/hr. Usually found on equipment nameplate or in manufacturer's data.

Coincidence Factor, CF. The fraction of full load capacity (kW) used on average during the peak demand period. In other words, the average kW used during the peak demand period divided by the kW used at full or maximum load.

Duty Cycle, DC. Average percent of time that a lamp or other equipment is on.

Electric On-Peak/Off-Peak. Allocation periods for electric consumption (kWh) by time and day of the week.

On-Peak – Monday-Friday, 8 am – 8 pm

Off-Peak – Weekends, holidays, and 8 pm – 8 am weekdays

Energy Savings. General term to describe any type of energy savings: kW, kWh, or gas therm savings.

Equivalent Full Load Hours, EFLH. Total energy consumption (kWh or gas therms) of a given piece of equipment per year divided by the full load capacity (kW) of the equipment.

Interactive Factor, IF. For indoor lighting measures, the fraction of the lighting energy savings that is equivalent to the secondary energy savings resulting from reduced HVAC consumption due to lesser internal heat load.

kW Savings. Peak electrical demand savings, equivalent to the average kW saved during the Peak Demand Period. Or, the average kWh used per day during the Peak Demand Period divided by 8 hr.

kWh Savings. Annual electric energy savings. The actual units of this value are kWh/yr, but the divisor is assumed to be understood.

Latent Heat Load. The portion of the cooling load that is due to dehumidification by condensing water vapor from the supply air.

Load Factor, LF. The average fraction of full load capacity at which equipment operates over a given time period.

Peak Demand Period. The coincident peak electric demand (kW) period is 12 pm – 8 pm, non-holiday weekdays, Monday through Friday, June through August.

Peak Duty Cycle, PDC. Average percent of time that a lamp or other equipment is on during the peak demand period.

Sensible Heat Load. The portion of the cooling load due to reducing the temperature of the supply air.

Summer. For electric energy, summer is defined as May through September. For gas energy, summer is defined as April through September.

Therms. Measurement of natural gas, defined as 100 ft^3 of natural gas or 100,000 Btu of heat energy.

Winter. For electric energy, winter is defined as October through April. For gas energy, winter is defined as October through March.

3.2 Lighting Equipment

This Lighting Equipment protocol review section includes Performance Lighting and Prescriptive Lighting. The Performance Lighting measure provides incentives for new construction projects or for renovation projects where all the fixtures are replaced. The Prescriptive Lighting measure provides incentives for any lighting retrofit project where qualifying fixtures are used. The following sections review the Protocols for these measures and make recommendations for changes.

3.2.1 Performance Lighting Protocol

This protocol is applicable in new construction projects and renovations where 100% of the fixtures are replaced. Outdoor lighting is not covered by this measure, except fixtures that are attached to a building. To qualify, the whole project must achieve an average lighting power density (LPD) that is at least 20% lower than the code-required LPD (ASHRAE 90.1-2004). LPD is calculated using the Performance Lighting Worksheet. Minimum lighting levels must comply with New Jersey's non-residential construction code. Publicly supported schools may instead comply with New Jersey administrative Code Title 6-NJAC 6:22-5.4, g1- h1.

3.2.1.1 Algorithms and Variable Definitions

The existing protocols calculate kWh and kW savings using the following equations:

$$kW_{base} = \sum_{space}\left[(LPD_{ASHRAE90.1-2004})*\left(\frac{SquareFootage*(1-0.05)}{1{,}000}\right)\right] \quad \text{Equation 3.2-1}$$

$$\Delta kW = (kW_{base} - kW_{inst}) \quad \text{Equation 3.2-2}$$

$$kW\ Savings = (\Delta kW)*(CF)*(1+IF) \quad \text{Equation 3.2-3}$$

$$kWh\ Savings = (\Delta kW)*EFLH*(1+IF) \quad \text{Equation 3.2-4}$$

where:

kW_{base} = baseline lighting power
kW_{inst} = installed lighting power
LPD = lighting power density for a given space, W/ft^2 (ASHRAE 90.1-2004)
Square Footage = The area of a given space
ΔkW = reduction in lighting power due to measure installation.
CF = Coincident Factor

IF = Interactive Factor, reduced air-conditioning load due to decreased lighting wattage (interior lighting only).
EFLH = Equivalent Full Load Hours

Table 3-1
Summary of Algorithm Inputs

Component	Type	Value		Source
kW_{inst}	Fixed	Total new/replaced lighting load		standard wattage tables
kW_{base}	Fixed	5% Lower LPD than Code		ASHRAE 90.1 2004, pg 64-66, table 9.6.1
CF	Fixed	Large Office	65%	JCP&L metered data and Cost effectiveness study Estimate
		Large Retail	81%	
		Large Schools	41%	
		Large All Other	63%	
		All Hospitals	67%	
		All Other Office	71%	
		All Other Retail	84%	
		Other Schools	40%	
		All Other	69%	
		Industrial	71%	
		Continuous	90%	
IF	Fixed	5%		From Previous Protocols
EFLH	Fixed	Large Office	3309	JCP&L metered data and Cost Effectiveness Study Estimate
		Large Retail	5291	
		Large Schools	2289	
		Large All Other	3677	
		All Hospitals	4439	
		All Other Office	2864	
		All Other Retail	4490	
		Other Schools	2628	
		All Other	2864	
		Industrial	4818	
		Continuous	7000	

3.2.1.2 2008 Performance Lighting Incentive Worksheet Summary

The Performance Lighting Worksheet is shown in Table 3-2. The upper section of the worksheet, labeled Code and Program Limits, is used to calculate a qualifying installed lighting wattage equal to 80% of that allowed by ASHRAE 90.1-2004.[15] The actual installed lighting

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[15] This value is used to determine whether a project qualifies, and should not be confused with the baseline energy density value used in savings calculations, which is 95% of the ASHRAE LPD's.

wattage is calculated in the lower section of the worksheet, labeled Installed Lighting Levels. In order for a project to qualify, the lighting wattage calculated in the lower section of the worksheet must be less than that allowed by the upper section.

Table 3-2

Performance Lighting Worksheet

Building Type	

Code and Program Limits					
A	B	C	D	E	F
Space Type	Gross Lighted Area (sq. ft.)	Unit Lighting Power Allowance (Watts/sq. ft.)	New Construction/ Major Renovation Program Limit (Watts/ sq. ft.) [C x 0.80]	Lighting Power Limit (W) [B x D]	Composite Program Limit [∑E/∑B]
	∑			∑	

Installed Lighting Levels					
G	H	I	J	K	L
Space ID	Luminaire Tag	Luminaire Description	Number of Luminaires	Watts per Luminaire	Connected Watts [K x J]
			∑		∑

M. Composite Connected Watts/ sq. ft. [∑L/∑B]	

3.2.1.3 Review of Protocol

The existing protocols have several areas that need clarification. These items are discussed in this section.

Use of Standard Wattage Table: The Protocol describes a standard lighting table that is used to look up standard fixture wattages for installed lighting. It is unclear how the table is being used since the worksheet also collects Watts/luminaire in the installed lighting section.

ASHRAE 90.1-2004 LPD Methods: ASHRAE 90.1-2004 outlines two lighting wattage calculation approaches: the Building Area Method and the Space-by-Space Method. The Building Area Method uses a single value for LPD for the whole building, while the Space-by-Space method provides values separately for each individual space and adds them.

According to the instructions on the worksheet, the building type should be based on the list from table 9.5.1, the Building Area Method table. The values from this table are not used, however, and the remainder of the form leads the customer through a Space by Space Method calculation based on table 9.6.1, the Space-by-Space Method table. This is confusing. Confusion could be avoided by providing lists of both building and space types either directly on the worksheet or in another downloadable worksheet.

3.2.1.4 Discussion of Key Protocol Algorithm and Inputs

Standard lighting wattage tables are generally more reliable than customer reports of watts/luminaire. The customer-reported luminaire description and watts/luminaire are valuable to determine the type of lighting installed, and can be used to look up wattages from a standard wattage table. We expect that the program is currently doing this, rather than using customer reported luminaire wattages in savings calculations, but the protocol is not entirely clear on this matter.

Even if the program does use standard lighting tables in all calculations, it would be helpful to the customer to explain that watts/luminaire refers to the entire fixture (ballast input wattage), not the sum of lamp wattages. It may also be helpful to provide the standard wattage table being used in the calculations as a downloadable document.

Also, it appears that many of the fixture wattages listed in the protocol are outdated. In general, these input values should be replaced by values from current and verifiable sources.

The program was unable to provide KEMA with the JCP&L metering data used to determine CF and EFLH, or a source for the IF value. We evaluated secondary sources for these factors, which are discussed in Section 3.2.1.5.

EFLH values in the protocol do not account for automatic lighting controls. If controls are pre-existing, then the savings factor (SVG), from Table 3-5 in Lighting Controls Section 3.3.1 should be used. This value represents the fraction of the time that lights are off because of the automatic lighting controls. In this case, Equation 3.2-5 below should be substituted for Equation 3.2-2 above. To use this value, however, the program would have to ask for lighting controls information on the application, which it currently does not do.

$$\Delta kW = (kW_{base} - kW_{inst}) * (1 - SVG) \qquad \text{Equation 3.2-5}$$

If the controls are new and also being incentivized as a Lighting Controls Measure, care should be taken to avoid double counting savings. Savings due to the reduction in EFLH will be accounted for in the lighting controls measure, therefore no adjustment to EFLH is needed. However the Lighting Controls measure should use the new fixture wattage, to avoid double-counting savings.

The requirements for Performance Lighting state that the project must be new construction or renovations where 100% of fixtures are replaced. However, the worksheet states that if any space exceeds the program LPD limit, that space should be removed from the worksheet. This violates the intent of requiring that 100% of fixtures be replaced. Any space with lighting that does not meet program limits should still be listed on the application, as it will give a more accurate estimate of energy savings for the whole building. If only part of the building is included in the project, then the Prescriptive Lighting measure should be used.

The protocol states that the interactive factor (IF) are applied only to lighting in conditioned spaces. However, the application does not collect information on whether the space is conditioned. It is unclear if this is accounted for in some other way, or if IF is currently applied to all lighting.

3.2.1.5 Review of Industry Practice

In this section we review other energy efficiency programs and several secondary sources. For consistency and ease of reading, we changed the variable names from the original documents to provide uniformity throughout this section.

3.2.1.5.1 Efficiency Vermont and Connecticut Light & Power

Efficiency Vermont and Connecticut Light & Power both use the same method, which is similar to that of the New Jersey Protocol. A LPD baseline is determined based on ASHRAE 2001. Operating hours are collected from customers, and default values are listed by building type where not provided by the customer. IF is included, and is based on a methodology outlined by the 1993 ASHRAE Journal article: “Calculating Lighting and HVAC Interactions,” which suggests an IF of 0.34.

3.2.1.5.2 Evaluation of 2004-2005 San Diego City Schools Retrofit & Partnership Program (KEMA, Inc, 2008)

This evaluation was conducted for San Diego Gas & Electric and San Diego City Schools. This report contains useful data with regards to CF and EFLH, but is only applicable to schools and from a different region with potentially different usage patterns and daylighting conditions.

3.2.1.5.3 Calculating Lighting and HVAC Interactions, ASHRAE Journal, November 1993

This article provides a method for estimating the interactive factor (IF). The method assumes values for the percent of lighting heat that must be offset by cooling and the efficiency of cooling equipment. The method is a simplified approach and does not vary based on different building types.

3.2.1.5.4 New Jersey Electric & Gas Utilities: Commercial Energy Efficient Construction Baseline Study (RLW Analytics, Inc, 2000)

This study determined baseline conditions in the commercial sector for HVAC, lighting, and building shell. On-site audits were conducted in new construction and renovated buildings for several building types. LPDs were determined for a variety of building types and spaces. It is difficult to make a direct comparison between the LPDs found in this study and the baseline used by the SmartStart program, as most of the space descriptions do not directly translate. When comparable space types are compared, the baseline LPD values in this study are slightly less (meaning more efficient) than the SmartStart baseline.

3.2.1.5.5 Coincident Factor Study, Residential and Commercial & Industrial Lighting Measures (RLW Analytics, Inc, 2007)

This study, conducted by RLW Analytics for the New England State Program Work Group (SPWG),[16] included a comprehensive lighting metering study. The study provided the percentage of lights that are on, for each hour, for an average 24-hour period across a number of building types. A comparable CF for New Jersey's peak period can be calculated by averaging the hourly values that correspond to New Jersey's peak period. We estimated hourly values using the figure titled "C&I Lighting Profiles: No Occupancy Sensors" on p. 32. The CF values in Table 3-3 are based on this estimate.

3.2.1.5.6 2008 Standard Performance Contract (SPC), California Investor Owned Utilities

The SPC provides a comprehensive list of standard fixture wattages. This list considers fixture type, ballast type, lamp length, lamp wattage, and fixture configuration.

3.2.1.5.7 Database for Energy Efficient Resources, DEER 2005

This database provides energy and demand savings for a variety of energy efficiency measures. With regard to lighting measures, DEER provides values for EFLH and IF based on building type and vintage, and climate zone. These values come from a lighting measurement and evaluation study performed for PG&E by Quantum Consulting, Inc.[17]. The EFLH and IF values in Table 3-3 are based on this data.

3.2.1.6 Recommendations

3.2.1.6.1 Variable Inputs

As described above, we recommend that EFLH, CF, and IF inputs be revised. All recommended values are provided by building type in Table 3-3 below. These values are based data from New England and California, and have not been adjusted for New Jersey; we do not expect lighting use to vary significantly between these locations. Note that the table offers more building types

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[16] "Coincident Factor Study, Residential and Commercial & Industrial Lighting Measures", prepared by RLW Analytics, Inc, 2007

[17] "Evaluation of Pacific Gas & Electric Company's 1997 Commercial Energy Efficiency Incentives Program: Lighting Technologies", prepared by Quantum Consulting, Inc., for Pacific Gas & Electric Company, March 1, 1999

than those currently used by SmartStart; education, medical, restaurants, and retail are subdivided and lodging and storage have been added.

EFLH: While many of the efficiency programs have defined EFLH, there was limited information about the source of these values. DEER 2005 provides the best-documented data, and so we recommend that DEER values be used for EFLH, as provided in Table 3-3.

IF: The existing protocol uses an IF of 5% for all lighting. When compared to savings values identified in secondary sources, this value seems to underestimate savings. We recommend that data from DEER 2005 be used for IF. We made one change was to DEER 2005 values in reducing the “Storage – Unconditioned” value from 0.06 to 0, as unconditioned storage buildings cannot have interactive effects.

CF: We recommend using the CF values shown below in Table 3-3. These are calculated for New Jersey’s peak demand period based on data in the RLW report.

Table 3-3
Recommended Key Variable Values, by Building Type

Building Type	EFLH[18]	CF[19]	IF[20]
Education – Primary School	1,440	0.57	0.15
Education – Secondary School	2,305	0.57	0.15
Education – Community College	3,792	0.64	0.15
Education – University	3,073	0.64	0.15
Grocery	5,824	0.88	0.13
Medical – Hospital	8,736	0.72	0.18
Medical – Clinic	4,212	0.72	0.18
Lodging Hotel (Guest Rooms)	1,145	0.67	0.14
Lodging Motel	8,736	1.00	0.14
Manufacturing – Light Industrial	4,290	0.63	0.04
Office- Large	2,808	0.68	0.17
Office-Small	2,808	0.68	0.17
Restaurant – Sit-Down	4,368	0.76	0.15
Restaurant – Fast-Food	6,188	0.76	0.15
Retail – 3-Story Large	4,259	0.78	0.11
Retail – Single-Story Large	4,368	0.78	0.11
Retail – Small	4,004	0.78	0.11
Storage Conditioned	4,290	0.69	0.06
Storage Unconditioned	4,290	0.69	0.00
Warehouse	3,900	0.69	0.06
Average = Miscellaneous	4,242	0.72	0.13

kW_{inst}: We recommend that the protocol clearly state that a standard wattage lighting table, not customer-reported luminaire wattages, are used to determine installed kW. We recommend using the table in California's Standard Performance Contracting Program (SPC), Appendix A.

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[18] "Evaluation of Pacific Gas & Electric Company's 1997 Commercial Energy Efficiency Incentives Program: Lighting Technologies", prepared by Quantum Consulting, Inc., for Pacific Gas & Electric Company, March 1, 1999

[19] "Coincident Factor Study, Residential and Commercial & Industrial Lighting Measures", prepared by RLW Analytics, Inc, 2007

[20] "Evaluation of Pacific Gas & Electric Company's 1997 Commercial Energy Efficiency Incentives Program: Lighting Technologies", prepared by Quantum Consulting, Inc., for Pacific Gas & Electric Company, March 1, 1999

3.2.1.6.2 Algorithms

We do not recommend any changes to the basic algorithms used for Performance Lighting.

However, we do recommend that SmartStart collect lighting control type on the application. When applicable, we recommend that SVG values from Table 3-5 be used to adjust savings for these controls based on the following equation.

$$\Delta kW = (kW_{base} - kW_{inst}) * (1 - SVG) \qquad \text{Equation 3.2-6}$$

3.2.1.6.3 Additional Recommendations

We recommend that the program provide the following information directly on the application or on another downloadable companion document:

- A list of building types based on Table 3-3.
- A list of space types with LPD from ASHRAE 90.1-2004 table 9.6.1.
- A statement that watts/luminaire on the application refers to the entire fixture wattage (ballast input wattage), not the sum of lamp wattages.
- Standard Wattage Table (as provided in Appendix A).

We recommend that the program ask for which spaces are conditioned on the application, to avoid applying IF to unconditioned spaces.

We also recommend that the program use all building spaces in the calculation, even if the lighting from that space does not meet the requirements. This will provide a more accurate estimate of energy savings.

3.2.2 Prescriptive Lighting Protocol

This measure applies to replacement of existing light fixtures with more efficient lighting in commercial or industrial facilities. Manufacturer's specification sheets must be provided in addition to the prescriptive lighting incentive application.

In order to qualify for the incentive, fixture types must meet the following conditions:

- CFL fixtures must be new and Energy Star qualified. Fixtures must have replaceable electronic ballasts. Power factor must be no less than 90%. Manufacturers must provide a minimum of a 3 year warranty on the fixture, and the installer must provide a minimum of 1 year warranty.

- Pulse start Metal Halide fixtures must have a minimum of 12% wattage reduction over previously installed fixtures.
- T5 fixtures replacing T12 fluorescent or incandescent fixtures greater than 250 watts or any HID fixture must have a ballast factor greater than or equal to 1.0, have a reflectance greater than or equal to 91%, have a minimum of 2 lamps, and be designated as F54T5 HO.
- Four foot T8 fixtures replacing T12 fluorescent or incandescent fixtures greater than 250 watts or any HID fixture must have a ballast factor greater than or equal to 1.14, have a reflectance greater than or equal to 91%, have a minimum of 4 lamps, and be designated as F32T8.
- Eight foot T8 fixtures replacing T12 fluorescent or incandescent fixtures greater than 250 watts or any HID fixture must have a ballast factor greater than or equal to 0.80, have a reflectance greater than or equal to 91%, have a minimum of 2 lamps, and be designated as F96T8 HO.
- T8 to T8 replacement requires de-lamping and adding new reflectors, resulting in maintained lighting levels with a more efficient system.

3.2.2.1 Algorithms and Variable Definitions

The existing Protocol calculates energy savings and demand reduction using the following equations:

$$kW\ Savings = (\Delta kW) * (CF)$$ Equation 3.2-7

$$kWh\ Savings = (\Delta kW) * (EFLH)$$ Equation 3.2-8

$$\Delta kW = fixtures\ installed * kW/fixture_{base} - fixtures\ removed * kW/fixture_{inst}$$ Equation 3.2-9

Where:

$kW/fixture_{base}$ = power used by baseline fixture
$kW/fixture_{inst}$ = power used by new fixture
fixtures replaced = number of existing fixtures removed
fixtures installed = number of new fixtures installed
ΔkW = reduction in electrical demand based on measure installation
CF = Coincidence Factor

EFLH = Equivalent Full Load Hours

Table 3-4

Values and Sources of Key Protocol Variables

Component	Type	Value	Source
kW_{inst}	Fixed	From Prescriptive Lighting Savings table	New Jersey lighting Table
kW_{base}	Fixed		
CF	Fixed	77.50%	JCP&L metered data and Cost effectiveness study Estimate (Average of small retail and office from lighting verification summary)
EFLH	Fixed	3,677	

3.2.2.2 Review of Protocol

The protocol has a calculation error. Values in the current ΔkW algorithm are transposed, and it should be corrected such that it reads:

$$\Delta kW = fixtures\ replaced * kW/fixture_{base} - fixtures\ installed * kW/fixture_{inst} \qquad \text{Equation 3.2-10}$$

This measure also has a discrepancy between the application and the protocol. The application suggests a one-to-one replacement of one fixture with another fixture, but the protocol includes the potential that a different number of fixtures may be installed from the number removed. We recommend that the application be updated to collect both the number and type(s) of fixtures removed and installed.

The current wattage table assigns baseline wattage for a given newly installed fixture. The customer provides information about both the installed and replaced lighting.

CF and EFLH are based on data for small retail and offices. However, greater accuracy could be achieved by applying specific values by building type. As is done for the Performance Lighting Application, building type could be collected on the application and EFLH determined from a lookup table. Special consideration should be given to exit signs, which typically operate 8,760 hrs/yr.

Interactive Factor (IF) is not included in Prescriptive Lighting savings calculations. Interactive savings are achieved by this measure in the same way that they are for Performance Lighting. Credit for those savings could be claimed. The same IF values as outlined for Performance Lighting in Table 3-3 apply.

Similar to Performance Lighting, the EFLH values do not account for lighting with automatic controls. See 3.2.1.6.2 for further discussion. The existing applications do not collect lighting controls data; this data would have to be collected to account for lighting controls in this way. The following algorithm would apply if a lighting control savings factor (SVG) were used.

$$\Delta kW = SVG * (\text{fixtures replaced} * \text{kW/fixture}_{base} - \text{fixtures installed} * \text{kW /fixture}_{inst})$$

Equation 3.2-11

3.2.2.3 Recommendations

We recommend that the program replace the existing wattages from the Prescriptive Lighting Savings Table with updated wattages from California's Standard Performance Contract (SPC) table.

We recommend that the program use the same inputs for CF, EFLH, and IF as provided in the Performance Lighting Section in Table 3-3. These inputs are building type specific. Therefore we recommend that the application be updated to ask for building type. We did not adjust the parameters for New Jersey because we do not expect lighting use to vary significantly between New Jersey and other areas.

We recommend that Interactive Factor (IF) be included in the savings calculation for lighting in conditioned spaces, and existing algorithms be replaced with the following:

$$\text{kW Savings} = (\Delta kW) * (CF)(1 + IF)$$

Equation 3.2-12

$$\text{kWh Savings} = (\Delta kW) * (1 + IF) * (EFLH)$$

Equation 3.2-13

$$\Delta kW = \text{fixtures replaced} * \text{kW/fixture}_{base} - \text{fixtures installed} * \text{kW /fixture}_{inst}$$

Equation 3.2-14

We recommend that the application be updated to ask whether lighting controls are installed and what type. If automatic lighting controls are present but not part of the lighting controls measure, energy savings should be calculated by:

$$\Delta kW = SVG * (\text{fixtures replaced} * \text{kW/fixture}_{base} - \text{fixtures installed} * \text{kW /fixture}_{inst})$$

Equation 3.2-15

3.3 Lighting Controls Protocol

Lighting controls include occupancy sensors, daylight dimmer systems, and occupancy controlled hi-low controls for fluorescent and HID fixtures. The manufacturer's specification sheet must be included with the Lighting Controls Incentive worksheet in the application. All lighting controls must be UL listed and must be installed on eligible energy efficient lighting.

This is related to Performance and Prescriptive lighting. In the event that both measures are applied for, they should be coordinated to avoid double-counting savings.

3.3.1 Overview of Protocol

The existing protocols calculate energy savings and demand reduction using the following equations:

$$kW\ Savings = (\Delta kW_c) * (SVG) * (EFLH) * (1 + IF) \qquad \text{Equation 3.3-1}$$

$$kWh\ Savings = (\Delta kW) * EFLH * (1 + IF) \qquad \text{Equation 3.3-2}$$

where:

SVG = % of annual lighting energy saved by lighting control
kW_c = kW of lighting controlled
IF = Interactive Factor – reduction in A/C usage due to lower lighting heat production
CF = Coincident Factor
EFLH = Equivalent Full Load Hours

Table 3-5 shows the input values for the variables in the algorithm above. For SVG, the baseline is a manual toggle switch.[21]

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[21] New Jersey Electric & Gas Utilities: Commercial Energy Efficient Construction Baseline Study (RLW Analytics, Inc, 2000)

Table 3-5

Summary of Lighting Controls Protocol Values and Sources

Variable	Type	Value		Source
kW_c	Variable	Load connected to control		Application
SVG	Fixed	Occupancy sensors, Hi-Low Control, controlled HID	30%	*Determination of Energy Savings*, Northeast Utilities, 1992; Electricity Energy Use and Efficiency: Experience with Technologies, Markets and Policies, ACEEE, 1999 ; Comparison between Protocols (National Grid, Northeast Utilities, Long Island Power Authority, NYSERDA, and Energy Efficient Vermont.)
		Daylighting Dimmer System	50%	
IF	Fixed	Interior Lighting Only	5%	Not Given
CF	Fixed	Large Office	65%	JCP&L metered data and Cost effectiveness study Estimate
		Large Retail	81%	
		Large Schools	41%	
		Large All Other	63%	
		All Hospitals	67%	
		All Other Office	71%	
		All Other Retail	84%	
		Other Schools	40%	
		All Other	69%	
		Industrial	71%	
		Continuous	90%	
EFLH	Fixed	Large Office	3309	
		Large Retail	5291	
		Large Schools	2289	
		Large All Other	3677	
		All Hospitals	4439	
		All Other Office	2864	
		All Other Retail	4490	
		Other Schools	2628	
		All Other	2864	
		Industrial	4818	
		Continuous	7000	

3.3.2 Review of Industry Practice

In this section we review other energy efficiency programs and several secondary sources. For consistency and ease of reading, we changed the variable names from the original documents to provide uniformity throughout this section.

3.3.2.1 Efficiency Vermont

Efficiency Vermont uses a similar savings calculation method to the New Jersey protocol. Default SVG values are identical to New Jersey, though the source of these values is not specified. Vermont's application is confusing, but it appears that they provide the option for a operating hours value to be provided by the customer.

3.3.2.2 Wisconsin Focus on Energy Program

This program uses a 37.5% SVG value for the use of occupancy sensors in commercial and industrial buildings, and 40% for daylighting controls with either dimmable or step ballast. An additional fixture position adjustment factor of 0.85 is introduced in daylighting applications, to account for fixtures that are not positioned in ideal locations and therefore cannot dim to their minimum output.

3.3.2.3 California Database for Energy Efficient Resources (DEER), 2005

DEER uses a 20% SVG value for the use of occupancy sensors in high-occupancy areas (offices, retail, etc.), and 50% for low-use areas (warehouses, etc.).

3.3.3 Recommendations

The SVG values used by the program are similar to that used by other efficiency programs; no update to these values is needed.

We recommend that this measure be coordinated with Performance and Prescriptive lighting, in the event that both measures are applied for, to avoid double-counting savings. We recommend that the Performance and Prescriptive lighting measures remain as they are, and all calculations under Lighting Controls use the wattage of the new rebated fixtures.

We recommend that the same values for EFLH, CF, and IF be used in this protocol as were recommended for Performance Lighting in 3.2.1.6, provided again here in Table 3-6 below. These parameters are not adjusted for the New Jersey climate, because we do not expect lighting use to vary significantly according to climate.

As an alternative option, SmartStart could allow customers the option to provide estimated pre-installation and post-installation hours associated with controls. In some cases lighting contractors may conduct a feasibility study to determine the impact efficient controls will have. If so, the results from these studies can be used rather than the default SVG and EFLH values. It should be noted that the application would need to be updated to collect this information.

Table 3-6
Recommended Key Variable Values

Building Type	EFLH[22]	CF[23]	IF[24]
Education – Primary School	1,440	0.57	0.15
Education – Secondary School	2,305	0.57	0.15
Education – Community College	3,792	0.64	0.15
Education – University	3,073	0.64	0.15
Grocery	5,824	0.88	0.13
Medical – Hospital	8,736	0.72	0.18
Medical – Clinic	4,212	0.72	0.18
Lodging Hotel (Guest Rooms)	1,145	0.67	0.14
Lodging Motel	8,736	1.00	0.14
Manufacturing – Light Industrial	4,290	0.63	0.04
Office- Large	2,808	0.68	0.17
Office-Small	2,808	0.68	0.17
Restaurant – Sit-Down	4,368	0.76	0.15
Restaurant – Fast-Food	6,188	0.76	0.15
Retail – 3-Story Large	4,259	0.78	0.11
Retail – Single-Story Large	4,368	0.78	0.11
Retail – Small	4,004	0.78	0.11
Storage Conditioned	4,290	0.69	0.06
Storage Unconditioned	4,290	0.69	0.00
Warehouse	3,900	0.69	0.06
Average = Miscellaneous	4,242	0.72	0.13

3.4 Motors

This measure pertains to either a new or replacement motor that meets the minimum efficiency requirements to qualify as a NEMA Premium motor. It applies to all motors up to and including

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[22] “Evaluation of Pacific Gas & Electric Company’s 1997 Commercial Energy Efficiency Incentives Program: Lighting Technologies”, prepared by Quantum Consulting, Inc., for Pacific Gas & Electric Company, March 1, 1999

[23] “Coincident Factor Study, Residential and Commercial & Industrial Lighting Measures”, prepared by RLW Analytics, Inc, 2007

[24] “Evaluation of Pacific Gas & Electric Company’s 1997 Commercial Energy Efficiency Incentives Program: Lighting Technologies”, prepared by Quantum Consulting, Inc., for Pacific Gas & Electric Company, March 1, 1999

200 HP. As is typical, the base-case assumption is a NEMA energy efficient motor and the qualifying assumption is a NEMA premium efficiency motor. For consistency throughout the discussion regarding this measure, we standardized and made uniform variable names across all program citations.

3.4.1 Premium Efficiency Motor Energy and Peak Demand Impact Algorithm

The annual energy savings and demand savings due to the installation of a NEMA Premium motor are presently calculated using the following equations:

$$\Delta kW = 0.746 * [(HP_{base} * RLF_{base})/h_{base} - HP_{prem} * RLF_{prem})/h_{prem}]$$

Equation 3.4-1

$$kW\ Savings = \Delta kW * CF$$

Equation 3.4-2

$$kWh\ Savings = \Delta kW * EFLH$$

Equation 3.4-3

where:

HP_{base} = Rated horsepower of the baseline motor
HP_{prem} = Rated horsepower of the energy-efficient motor
RLF_{base} = Rated load factor of the baseline motor
RLF_{prem} = Rated load factor of the energy-efficient motor
h_{base} = Efficiency of the baseline motor
h_{prem} = Efficiency of the energy-efficient motor
ΔkW = kW savings at full load
CF = Coincidence Factor
EFLH = Equivalent Full Load Hours

Table 3-7
Variables for Motor Savings used in Equation 3.4-1, Equation 3.4-2 and Equation 3.4-3

Component	Type	Value	Source
Motor kW	Variable	Based on horsepower and efficiency	Application
EFLH	Fixed	Commercial 2,502	JCP&L metered data and PSEG audit data for indiustrial
		Industrial 4,599	
HP_{base}	Fixed	Comparable EPACT Motor	EPACT Directory
HP_{prem}	Variable	Nameplate	Application
RLF_{base}	Fixed	0.70-0.80	Industry Data
RLF_{prem}	Variable	Nameplate	Application
Efficiency - h_{base}	Fixed	Comparable EPACT Motor	From EPACT directory
Efficiency – h_{prem}	Variable	Nameplate	Application
CF	Fixed	35%	JCP&L metered data

3.4.2 Discussion of Key Protocol Algorithm and Inputs

The current protocols are comprised almost entirely of the recommendations provided in the Market Assessment conducted by Summit Blue[25]. There are, however, some artifacts from the "New Jersey Clean Energy Program Protocols" of September 2004 that are no longer used. As the following variable is no longer used, it should be removed from the current protocols as follows:

> *Motor kW*: While this variable is listed in Table 3-7 as coming from the application, we find no mention of this metric on the 2008 Premium Motors Application for New Jersey's Clean Energy Program™. Furthermore, this variable is not used in any of the equations in the current protocol.

A discussion follows regarding the variables and algorithms of the current protocols that require modifications:

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[25] Energy Efficiency Market Assessment of New Jersey Clean Energy Programs, Book III—Commercial and Industrial Programs (Summit Blue Consulting, LLC, July 2006).

Resizing of Motor: Given that it has historically been common for motors to be somewhat oversized, it is noteworthy that the recommendations include consideration for a baseline motor to be replaced with a NEMA Premium motor of a smaller capacity. Summit Blue's recommendations may have been intended to capture the possibility that a given motor might have been replaced with a premium efficiency motor of a more appropriate horsepower rating. Hence, Equation 3.4-1 accounts for the resulting change to the load factor that would result both from the increased efficiency and the decreased motor size.

We could find no other program that attempted to capture the savings associated with re-sizing a motor in addition to claiming savings resulting from upgrading its efficiency. It is difficult to claim savings associated with having selected a motor of decreased capacity since that would likely have happened, upon burnout, independent from upgrading to a premium motor. Instead, we recommend using the NEMA Premium motor capacity in the savings calculation as shown in the recommended algorithm below.

Equivalent Full Load Hours: The naming of this variable, Equivalent Full Load Hours as used in the calculation of the energy savings per Equation 3.4-3, is flawed given that the load factor is already taken into consideration as an independent variable in Equation 3.4-1. To remedy this discrepancy, two options exist:

- Replace EFLH with Operating Hours. As provided by the 2008 Premium Motors Application for New Jersey's Clean Energy Program™, the annual run hours are sought. This figure could be used in the savings calculation, instead.
- Eliminate Load Factor from the equation.

Rated HP's: The HP_{base} variable should be eliminated since it is difficult to claim savings associated with re-sizing the motor at the time of replacement. Instead, only the HP_{ee} should be used in the savings calculation.

Rated Load Factor: There is no widely accepted definition for the term "Rated Load Factor." Nor is the term "Rated Load Factor" ever indicated on the nameplates of motors, as suggested in Table 3-7. Instead, a load factor is typically reported as a percentage of the rated Full Load at a given operating condition, e.g. 75% of Full Load. Most motors do not operate at full load capacity and the load factor quantifies this underutilization. Other programs typically assume that the Load Factor is unchanged between the baseline motor and the qualifying motor and that percentage is based upon industry data and is typically between 0.70 and 0.80.

Coincidence Factor: The Coincidence Factor, CF, is said to have been determined from the JCP&L metered data. Further investigation is warranted to assess the appropriateness of the selected value of 35%.

3.4.3 Review of Industry Practices

We reviewed the practices of a number of other programs and used them to develop a recommended motor protocol provided. It is worth mentioning that the motor protocol in the 2004 New Jersey Clean Energy Protocols was much more similar to that of quite a few other programs prior to incorporating the changes recommended by Summit Blue. For consistency and ease of reading, the variable names have been changed from the original documents to provide uniformity throughout this section.

3.4.3.1 Efficiency Vermont

The Efficiency Vermont protocols use the following algorithms to estimate the impact of installing a NEMA Premium Efficiency motor:

$$\mathbf{\Delta kW = 0.746 * HP * LF * (1/h_{base} - 1/h_{prem})} \qquad \text{Equation 3.4-4}$$

$$\mathbf{kW\ Savings = \Delta kW} \qquad \text{Equation 3.4-5}$$

$$\mathbf{kWh\ Savings = \Delta kW * HRS} \qquad \text{Equation 3.4-6}$$

where:

HP = Rated horsepower of motor
LF = Load factor of motor (default = 0.75)
h_{base} = Efficiency of the baseline motor
h_{prem} = Efficiency of the energy-efficient motor
HRS = Annual hours of operation, per application or default to Table below.

Table 3-8
Annual Motor Operating Hours[26], HRS

Building Type	HVAC Pump (heating)	HVAC Pump (cooling)	HVAC Pump (unknown use)	Ventilation Fan
Office	2,186	2,000	2,000	6,192
Retail	2,000	2,000	2,000	3,261
Manufacturing	3,506	2,000	2,462	5,573
Hospitals	2,820	2,688	2,754	8,374
Elem/Sec Schools	3,602	2,000	2,190	3,699
Restaurant	2,348	2,000	2,000	4.155
Warehouse	3,177	2,000	2,241	6,389
Hotels/Motels	5,775	2,688	4,231	3,719
Grocery	2,349	2,000	2,080	6,389
Health	4,489	2,000	2,559	2,000
College/Univ	5,716	2,000	3,641	3,361
Miscellaneous	2,762	2,000	2,000	3,720

The Efficiency Vermont motor protocol is rather similar to the 2004 New Jersey Clean Energy Protocols except for the following:

- New Jersey used only two levels of equivalent full load hours: 2,502 hours for Commercial installations and 4,599 hours for Industrial, where Efficiency Vermont relied on either application information or those values provided in Table 3-8.
- New Jersey claimed only 35% of the demand savings that Efficiency Vermont claimed by using a Coincident Factor of 0.35. In effect, Efficiency Vermont used a Coincident Factor of 1.0.

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[26] Adapted from Southeastern NY audit data, adjusted for climate variations. Motors must operate a minimum of 2000 hours to qualify.

- The Vermont program appears to assume that all motors are HVAC related. The New Jersey program is both Commercial and Industrial, and is not limited to HVAC applications.

3.4.3.2 Connecticut Light & Power/The United Illuminating Co.

The Program Savings Documentation for 2008 Program Year indicates calculating the savings in a manner very similar to the Efficiency Vermont Program except that the following table is used for the Coincident Factor:

Table 3-9
Default C&I Peak Coincident Factors

Season	Efficient HVAC Motors	
	Cooling	Heating
Summer	0.73	0
Winter	0.6	0.8

3.4.3.3 We Energies

The We Energies Energy Efficiency Procurement Plan of 2005 calculates the savings in a similar manner except that the savings for ODP and TEFC motors are not differentiated and, hence, are assumed to yield equal savings. The kW Savings algorithm is also slightly different in that

- the Load Factor is assumed to be 0.70 whereas other programs assume 0.75;
- a variable is introduced to account for the duty cycle of the motors;
- another variable is introduced to account for the simultaneous operation of motors as follows:

$$\Delta kW_{nc} = 0.746 * HP * LF * DC * (1/h_{base} - 1/h_{prem}) \quad \text{Equation 3.4-7}$$

$$kW\ Savings = \Delta kW_{nc} * CF \quad \text{Equation 3.4-8}$$

$$kWh\ Savings = \Delta kW_{nc} * HRS \quad \text{Equation 3.4-9}$$

where:

HP = Rated horsepower of motor
LF = Average loading of motor (Default = 0.70)

DC = Duty Cycle, percent of typical hour that motor is operating, 0.70 for low use, 0.95 for high use
HRS = Annual Operating Hours provided to We Energies by Franklin Energy, 1000 hours for low use, 7,500 hours for high use.

On a measure-wide, aggregated basis, a demand diversification factor (DDF) is later applied to the demand savings to account for the coincidence of multiple motors operating at the same time.

3.4.3.4 Arkansas

The Arkansas Deemed Savings Quick Start Program Draft Report, Commercial Measures, of March 29, 2007, calculates the savings in a very similar manner to other programs except that, for the kW savings, no coincidence factor is used; hence, the coincidence factor is presumed to be 1.0.

$$\Delta kW = 0.746 * HP * LF * (1/h_{base} - 1/h_{prem})$$

Equation 3.4-10

$$kW\ Savings = \Delta kW$$

Equation 3.4-11

$$kWh\ Savings = \Delta kW * HRS$$

Equation 3.4-12

where:

HP = Rated horsepower of motor
LF = Average loading of motor (Default = 0.70)
h_{base} = Efficiency of the baseline motor, either per application or table
h_{prem} = Efficiency of the energy-efficient motor, either per application or table.
HRS = Annual Operating Hours

3.4.3.5 California Investor Owned Utilities

As per the California 2004-2005 Impact Evaluation Upstream HVAC and Motors Program, savings for installation of premium efficiency motors are calculated as follows:

$$\Delta kW = 0.746 * HP * LF * (1/h_{base} - 1/h_{prem})$$

Equation 3.4-13

$$kW\ Savings = \Delta kW * CF$$

Equation 3.4-14

$$\textbf{kWh Savings} = \boldsymbol{\Delta}\textbf{kW} * \textbf{HRS} \qquad \text{Equation 3.4-15}$$

where:

HP = Rated horsepower of motor from nameplate

LF = Average loading of motor (Default = 0.75 per work papers and DEER)

h_{base} = Efficiency of the baseline motor, per table

h_{prem} = Efficiency of the energy-efficient motor, either per table.

CF = Coincident Factor (Default = 0.74 per work papers and DEER).

HRS = Annual Operating Hours, assumed to be 4,700[27], independent of motor size or application (per work papers).

While the three Investor Owned Utilities (IOUs) have very similar programs, a few differences were observed across the state:

- Southern California Edison motor savings in the Program Implementation Plans and database differ from those defined in their work papers.
- Pacific Gas & Electric offers a Savings By Design discount whereas San Diego Gas & Electric does not.

3.4.3.6 DEER Analysis

The Database for Energy Efficiency Resources (DEER) is regulated by the California Public Utility Commission (CPUC) and the California Energy Commission (CEC). It provides energy estimates and peak demand savings values for variety of measures based on modeling. DEER provides the following values for operating hours of motors by motor size.

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[27] The hours of operation vary dramatically between applications and customers. A study done by the New England Power Service Company (1989) on hours of operation for commercial and industrial motors found median use of 4,000-5,000 hours per year. In the early 1990s, the PG&E Express Efficiency Program used 4,100 annual operating hours for the energy and economic analysis. This number was considered conservative and in the absence of other data, was a good approximation of the operating patterns. The 1994 program year measurement and evaluation studies for motors in the commercial and industrial sectors found that this number was indeed much lower than actual practice (Xenergy 1996B). Given that the study did not provide a new figure for motor operating hours (possibly because of small sample size) and to retain a conservative but more realistic estimate, the annual operating hours for motors was increased by 15% to 4,700 hours per year.

Table 3-10

Annual Operating Hours per 2005 DEER

Motor Horsepower	Operating Hours, HRS
1 to 5 HP	2,745
6 to 20 HP	3,391
21 to 50 HP	4,067
51 to 100 HP	5,329
101 to 200 HP	5,200

3.4.4 Recommended Motor Protocol Algorithm and Inputs

The recommended algorithm includes a factor to account for the interaction between two sometimes concurrent measures: NEMA Premium motor and Variable Frequency Drive (VFD). When a VFD controls a NEMA Premium motor, the motor is often operating at a lower rotational speed where the improved efficiency margin is diminished relative to that at full speed. Hence, the savings that result from the upgrade to a NEMA premium motor are deemed to be approximately 6% lower than for a NEMA Premium motor without a VFD when comparing the energy consumption with that using baseline motors.

The recommended algorithm is used to calculate ΔkW as follows (replacing Equation 3.4-1):

$$\Delta kW = 0.746 * HP * VF * \left(\frac{1}{\eta_{base}} - \frac{1}{\eta_{prem}}\right)$$ Equation 3.4-16

kW Savings = ΔkW * CF Equation 3.4-17

kWh Savings = ΔkW * HRS * LF Equation 3.4-18

where:

ΔkW = kW Savings at full load
HP = Rated horsepower of qualifying motor
LF = Load Factor, percent of full load at typical operating condition
DC = Duty Cycle, percent of time motor is operating on average
VF = VFD Interaction Factor
η_{base} = Baseline motor efficiency
η_{prem} = Qualifying motor efficiency
HRS = Annual operating hours
CF = Coincidence Factor

Table 3-11
Variables for Motor Savings Algorithms

Component	Type	Value	Source
HP	Variable	Nameplate	Application
LF	Fixed	0.75	California DEER 2005
VF	Fixed	1.0 (no VFD)	California DEER 2005
		0.94 (with VFD)	
h_{base}	Fixed	EPAct Baseline Efficiency Table	EPAct
h_{prem}	Variable	Nameplate	Application
CF	Fixed	0.74	California DEER 2005
HRS	Fixed	Annual Operating Hours Table	California DEER 2005

The value of VF shown above is estimated based on a limited sampling of motors. We recommend conducting a more complete analysis to determine whether this value should differ for varying motor sizes and applications. The accuracy of this factor will improve as the collection of tracking data improves, thereby allowing increasingly detailed analysis.

We also recommend improving the accuracy of the deemed savings calculation by conducting a survey or metering to gather the operating hours by climate zone and by sector. Until that has been completed, we recommend using the 2005 DEER values for CF, as shown in Table 3-11, and operating hours as shown in Table 3-12.

Table 3-12
Annual Operating Hours per 2005 DEER

Motor Horsepower	Operating Hours, HRS
1 to 5 HP	2,745
6 to 20 HP	3,391
21 to 50 HP	4,067
51 to 100 HP	5,329
101 to 200 HP	5,200

We did not adjust these values for the New Jersey climate. Many motors are used for space conditioning, and energy use of those will vary by climate. However, the protocol applies to motors for industrial processes, as well, which will not vary significantly by climate. For this reason, we have recommended a survey or metering to determine values for EFLH and CF. Such is survey is beyond the scope of this report.

We also recommend that Table 3-14 be included in the protocols to establish the baseline and qualifying premium efficiencies as per NEMA.

Table 3-13

EPAct Baseline Motor Efficiency Table

Motor Horsepower	1200 RPM (6 pole)		1800 RPM (4 pole)		3600 RPM (2 pole)	
	ODP	TEFC	ODP	TEFC	ODP	TEFC
1	0.8	0.8	0.825	0.825	na	0.755
1.5	0.84	0.855	0.84	0.84	0.825	0.825
2	0.855	0.865	0.84	0.84	0.84	0.84
3	0.865	0.875	0.865	0.875	0.84	0.855
5	0.875	0.875	0.875	0.875	0.855	0.875
7.5	0.885	0.895	0.885	0.895	0.875	0.885
10	0.9002	0.895	0.895	0.895	0.885	0.895
15	0.902	0.902	0.91	0.91	0.895	0.902
20	0.91	0.902	0.91	0.91	0.902	0.902
25	0.917	0.917	0.917	0.924	0.91	0.91
30	0.924	0.917	0.924	0.924	0.91	0.91
40	0.93	0.93	0.93	0.93	0.917	0.917
50	0.93	0.93	0.93	0.93	0.924	0.924
60	0.936	0.936	0.936	0.936	0.93	0.93
75	0.936	0.936	0.941	0.941	0.93	0.93
100	0.941	0.941	0.941	0.945	0.93	0.936
125	0.941	0.941	0.945	0.945	0.936	0.945
150	0.945	0.95	0.95	0.95	0.936	0.945
200	0.945	0.95	0.95	0.95	0.945	0.95

Table 3-14

NEMA Premium Efficiency Motors

Motor Horsepower	1200 RPM (6 pole)		1800 RPM (4 pole)		3600 RPM (2 pole)	
	ODP	TEFC	ODP	TEFC	ODP	TEFC
1	0.825	0.825	0.855	0.855	0.77	0.77
1.5	0.865	0.875	0.865	0.865	0.84	0.84
2	0.875	0.885	0.865	0.865	0.855	0.855
3	0.885	0.895	0.895	0.895	0.855	0.865
5	0.895	0.895	0.895	0.895	0.865	0.885
7.5	0.902	0.91	0.91	0.917	0.885	0.895
10	0.917	0.91	0.917	0.917	0.895	0.902
15	0.917	0.917	0.93	0.924	0.902	0.91
20	0.924	0.917	0.93	0.93	0.91	0.91
25	0.93	0.93	0.936	0.936	0.917	0.917
30	0.936	0.93	0.941	0.936	0.917	0.917
40	0.941	0.941	0.941	0.941	0.924	0.924
50	0.941	0.941	0.945	0.945	0.93	0.93
60	0.945	0.945	0.95	0.95	0.936	0.936
75	0.945	0.945	0.95	0.954	0.936	0.936
100	0.95	0.95	0.954	0.954	0.936	0.941
100	0.95	0.95	0.954	0.954	0.941	0.95
150	0.954	0.958	0.958	0.958	0.941	0.95
200	0.954	0.958	0.958	0.962	0.95	0.954

3.5 Electric HVAC Systems

This measure involves the installation of high efficiency HVAC units. It includes Unitary HVAC/Split systems, Air-to-Air Heat Pump Systems, Packaged Terminal Systems, Water Source Heat Pumps and Central DX air conditioning (A/C) systems.

3.5.1 Overview of Existing Protocol

Existing savings protocols for commercial & industrial HVAC measures are presented in this section. First we define the variables used in the protocol are and then discuss assumptions.

3.5.1.1 Overview of Protocol

The existing protocols use the following algorithms to calculate energy and demand savings.

kW Savings = $(BtuH_c/1000) * (1/EER_b – 1/ EER_q) * CF$ Equation 3.5-1

kWh Savings = $(BtuH_c/1000) * (1/EER_b – 1/ EER_q) * EFLH_c$ Equation 3.5-2

In addition, for Heat Pumps:

Heating Energy Savings = $(BtuH_h/1000) * (1/EER_b – 1/ EER_q) * EFLH_h$ Equation 3.5-3

where:

$BtuH_h$ = Heating capacity in Btu/Hour
$BtuH_c$ = Cooling capacity in Btu/Hour
EER_b = Efficiency rating of baseline unit
EER_q = Efficiency rating of energy efficient unit
CF = Coincidence factor
$EFLH_h$ = Equivalent Full Load Heating Hours
$EFLH_c$ = Equivalent Full Load Cooling Hours

Table 3-15-
NJ Protocol Variables and Sources

Variable	Type	Value	Source
BtuH	Variable	ARI, AHAM, or Manufacturer Data	Application
EER_b	Variable	HVAC Baselines Table Below	Baseline C/I study
EER_q	Variable	ARI or AHAM values	Application
CF	Fixed	67%	Engineering estimate
EFLH	Fixed	A/C: 1131	JCP&L metered data
		HP Cooling 381	
		HP Heating 800	

The program was not able to provide us with the JCP&L metered data used for EFLH or the source of the engineering estimate used for CF. The “Baseline C/I Study” refers to the NJ Commercial Energy-Efficient Construction Baseline Study, completed for New Jersey in 2000. However, the EER values which are actually used for the baseline are from ASHRAE 90.1-2004, as shown below in Table 3-16. The efficiency assumptions for qualifying equipment are taken from the Air Conditioning and Refrigeration Institute (ARI), the Association of Heating and Association of Home Appliance Manufacturers (AHAM), or the rebate application.

Table 3-16
HVAC Baselines

Equipment Type	Size	Baseline (ASHRAE 90.1-2004)
Unitary HVAC & Split Systems	≤5.4 tons	13 SEER
	>5.4 to 11.25 tons	10.1 EER
	>11.25 to 20 tons	9.5 EER
	>21 to 30 tons	9.3 EER
Air-Air Heat Pump Systems	≤ 5.4 tons	13 SEER
	>5.4 to 11.25 tons	9.9 EER
	>11.25 to 20 tons	9.1 EER
	>21 to 30 tons	9.0 EER
Packaged Terminal Systems	≤0.74 ton	10.6 EER
	0.75 to 1 ton	10.2 EER
	>1 ton	9.9 EER

3.5.1.2 Review of Protocol

The kW and kWh savings calculation methods for are quite common and have been found to be used in other protocols developed for a variety of jurisdictions as explained in Section 3.5.2.

A coincidence factor of 67% is reasonable when compared to other studies, but could yield more accurate savings values if broken out for various building types and vintages, and climate zones.

The existing protocols use a single EFLH value across all building types. Increased accuracy can be achieved if EFLH is defined based on building type and vintage, and climate zone.

3.5.2 Review of Industry Practices

Various studies and work papers are reviewed in light of New Jersey HVAC protocols. A variety of considerations were explored such as algorithms, assumptions, and variables.

3.5.2.1 Efficiency Vermont

Efficiency Vermont provides savings guidelines for split systems, single package air conditioners, and water and air source heat pumps.

Energy and demand savings are calculated using following algorithms

$\Delta kWh_c = kBTU/hr*[(1/SEER_{base} - 1/SEER_{ee})]*FLH_s$ **Equation 3.5-4**

$\Delta kWh_h = kBTU/hr*[(1/HSPF_{base} - 1/HSPF_{ee})]*FLH_w$ **Equation 3.5-5**

$\Delta kW_c = kBTU/hr*[(1.1/SEER_{base} – 1.1/SEER_{ee})]$ **Equation 3.5-6**

$\Delta kW_h = kBTU/hr*[(1.1/HSPF_{base} – 1.1/HSPF_{ee})]$ **Equation 3.5-7**

where:

ΔkWh_c = Gross customer annual cooling kWh savings
ΔkWh_h = Gross customer annual heating kWh savings
ΔkW_c = Gross customer connected load cooling kW savings
ΔkW_h = Gross customer connected load heating kW savings
KBtu/hr = System capacity, (1 ton = 12 KBtu/hr)
$SEER_{base}$ = Cooling seasonal energy efficiency rating for the baseline equipment
$SEER_{ee}$ = Cooling seasonal energy efficiency rating for the energy efficient equipment
FLH_s = Cooling full load hours per year
FLH_w = Heat pump heating full load hours
$HSPF_{base}$ = Heating seasonal performance factor for baseline equipment

$HSPF_{ee}$ = Heating seasonal performance factor for energy efficient equipment

The savings for larger air conditioners (> 65,000 Btuh), all packaged terminal air conditioners (PTAC), packaged terminal heat pumps (PTHP), water source heat pumps, and room air conditioners are calculated by substituting cooling EER efficiencies for SEER in the above algorithms.

The Efficiency Vermont protocol differs from the current NJ protocol in the following ways:

- In the absence of a qualifying heat pump efficiency value, Efficiency Vermont uses the following algorithm to calculate qualifying efficiency: *HSPF = 0.65*SEER*. The New Jersey protocol does not have any such provision.
- Efficiency Vermont defines operating hours differently for different equipment types as shown in Table 3-17 below.

Table 3-17
Full Load Operating Hours

Equipment Type	Full Load Operating Hours	
	Heating	Cooling
Split systems & single-package rooftop units	2200 (< 65,000 Btuh) 1600 (> 65,000 Btuh)	800
PTAC	1640	830
Water source heat pumps	2248	2088
Room AC	1600	800

In addition, Efficiency Vermont provides rebates for HVAC controls and distribution systems as custom measures.

3.5.2.2 Connecticut Light & Power

Connecticut Light & Power (CL&P) encourages the installation of high efficiency DX cooling systems for the commercial and industrial sectors. The Connecticut Light & Power program applies the same savings methodologies as currently cited by the NJ protocols. CL&P program uses a single value for CF, set at 0.82. This value is greater than the NJ clean energy program value of 0.67.

Table 3-18 below shows the baseline efficiencies for A/C systems under CL&P, and the minimum efficiencies required to receive a rebate. The baseline efficiencies are exactly the same as New Jersey.

Table 3-18
Baseline & Compliance Efficiency for Unitary and Split Systems

Btu/h	Tons	Baseline	Minimum Compliance
< 65,000	< 5.4	12 SEER	13 SEER
65,000 to < 135,000	5.4 to < 11.3	10.1 EER	11 EER
135,000 to < 240,000	11.3 to < 20	9.5 EER	10.8 EER
240,000 to < 375,000	20 to < 31.3	9.3 EER	10 EER
375,000 to < 760,000	31.3 to < 63.3	9.3 EER	9.4 EER
≥ 760000	≥ 63.3	9 EER	9.1 EER

CL&P also varies full load cooling hours by building type. These values are below in Table 3-19.

Table 3-19
Full Load Cooling Hours by Facility Type

Facility Type	Full Load Cooling Hours	Facility Type	Full Load Cooling Hours
Auto Related	837	Medical Offices	797
Bakery	681	Motion Picture Theaters	564
Banks, Financial centers	797	Multi-Family (Common Areas)	1306
Church	564	Museum	797
College-Cafeteria	1139	Nursing Homes	1069
College-Classes/Administrative	646	Office (General Office Types)	797
College-Dormitory	709	Office/Retail	797
Commercial Condos	837	Parking Garages & Lots	878
Convenience Stores	1139	Penitentiary	1022
Convention Centers	564	Performing Arts Theaters	646
Dining-Bar Lounge/Leisure	854	Police/Fire Stations (24 Hrs)	1306
Dining-Cafeteria/Fast Food	1149	Post Office	797
Dining-Family	854	Pump Stations	563
Entertainment	564	Refrigerated Warehouse	648
Exercise Center	1069	Religious Buildings	564
Fast Food Restaurants	1139	Residential (Except Nursing Homes)	709
Fire Station	564	Restaurants	854
Food Stores	837	Retail	837
Gymnasium	646	Schools/University	594
Hospitals	1308	Schools (Jr/Sr. High)	594
Hospital/Health Care	1307	Schools (Preschools/elementary)	594
Industrial- 1 Shift	681	Schools (Technical/Vocational)	594
Industrial-2 Shift	925	Small Services	798
Industrial- 3 Shift	1172	Sports Arena	564
Laundromats	837	Town Hall	797
Library	797	Transportation	1149
Light Manufacturers	681	Warehouse (Not Refrigerated)	648
Lodging (Hotels/Motels)	708	Waste Water Treatment Plant	1172
Mall Concourse	938	Warehouse	798
Manufacturing Facility	681		

3.5.2.3 Arkansas

The Arkansas Quickstart program provides financial rebates for installation of unitary A/C and heat pumps. The demand and energy savings algorithms for the Arkansas Quickstart program are given below.

kW Savings

$$kW_{sav} = Capacity*Conversion\ factor*(1/EER_{pre} - 1/\ EER_{post})$$ **Equation 3.5-8**

kWh Savings: A/C

$$A/C\ kWh_{sav} = Capacity*Conversion\ factor*(1/IPLV_{pre} - 1/\ IPLV_{post})*EFLH_c$$ **Equation 3.5-9**

kWh Savings: Heat Pumps

$$kWh_{sav} = Capacity * CF * \left\{ \left(\frac{EFLH_c}{SEER_{pre}} - \frac{EFLH_h}{HSPF_{pre}} \right) - \left(\frac{EFLH_c}{SEER_{post}} - \frac{EFLH_h}{HSPF_{post}} \right) \right\}$$ **Equation 3.5-10**

$EFLH_h = A*(HDD+B)$ **Equation 3.5-11**

where:

Capacity = Rated equipment cooling capacity (Btu/hr)
Conversion Factor = 3412 [Btu/hr]/kW
EER_{pre} = Energy efficiency ratio of baseline cooling equipment
EER_{post} = Energy efficiency ratio of energy efficient cooling equipment
$IPLV_{pre}$ = Integrated part load value of baseline cooling equipment
$IPLV_{post}$ = Integrated part load value of energy efficient cooling equipment
CDD = Cooling degree days
HDD = Heating degree days
$EFLH_c$ = Equivalent Full Load Cooling Hours listed in Table 3-20
$EFLH_h$ = Equivalent Full Load Heating Hours
$HSPF_{post}$ = Heating seasonal performance factor of the new heat pump
$HSPF_{pre}$ = Heating seasonal performance factor of the baseline heat pump
A & B = Coefficients listed in Table 3-21

The Arkansas savings algorithm differs from the NJ saving protocols in following ways:

- Coincidence factor is not used in the kW savings algorithm

- The equivalent full load hour (EFLH) value is not a constant, but varies based on several factors. For cooling, $EFLH_c$ values are listed in Table 3-20. For heating, $EFLH_h$ is calculated using the formula shown above. The values are based on degree days and operating hours. For cooling, staging of the unitary equipment has also been considered.
- Baseline efficiency values come from the Consortium for Energy Efficiency (CEE)
- The energy savings are calculated based on the integrated part load values (IPLV) where energy savings in New Jersey's algorithms is calculated based full load values. As HVAC units are in most situations oversized, they do not operate at their rated load even at peak conditions. Using IPLV values instead of SEER or EER minimizes the effect of over sizing.

Table 3-20

Calculated $EFLH_c$ Values

City	Staging	Cooling EFLH Values					
		M-Fr, 7am- 5pm	M-Fr, 7am-7pm	M-Fr, 9am-10pm; Sun 11am-6pm	All week 6am-10pm	All week 6am-12am	All week 24/7
Fort Smith	Single	1207	1444	2033	2520	2739	3230
	Dual	854	1020	1443	1750	1881	2155
Little Rock	Single	1177	1383	1948	2419	2627	3137
	Dual	801	938	1303	1611	1730	1997

Table 3-21

Coefficients for calculating $EFLH_h$

Operating Hours	A	B
M-Fr, 8am-5pm	0.085	-30.1
M-Fr, 7am-6pm	0.114	-38.1
All Week, 24/7	0.416	-126.5

3.5.2.4 Xcel Energy - Texas

Xcel Energy offers incentive payments based on demand and energy savings for cooling equipment based on the following algorithms. For simplicity, we have changed the names of some of Xcel's variables to match the names that New Jersey uses.

$$kW_{savings} = Tons*(\eta_{baseline} - \eta_{post\ installation}) * CF$$ Equation 3.5-12

$$kWh_{savings} = Tons*(\eta_{baseline} - \eta_{post\ installation}) * EFLH$$ Equation 3.5-13

where:

$kW_{savings}$ = Calculated demand savings

$kWh_{savings}$ = Calculated energy savings

$\eta_{baseline}$ = Efficiency of baseline equipment

$\eta_{post\ installation}$ = Efficiency of energy efficient equipment

Tons = the rated equipment cooling capacity at ARI standard conditions

CF = Coincidence Factor

EFLH = Equivalent Full Load Cooling Hours

Table 3-22

Xcel Energy Coefficients

Building Type	CF for DX Air Cooled	EFLH for DX Air Cooled
College	0.92	1721
Convenience	0.92	3452
Fast food	0.92	2632
Grocery	0.92	2252
Hospital	0.92	-
Hotel	0.92	1791
Motel	0.92	1887
Nursing Home	0.92	1873
Large Office	0.92	2062
Small Office	0.92	1705
Public Assembly	0.92	1979
Restaurant	0.92	1928
Religious Worship	0.9	1585
Retail	0.92	1838
School	0.92	1462
Service	0.92	1848
Warehouse	0.92	1639

The Xcel savings algorithm differs from the NJ saving protocols in following ways:

- As shown above, Xcel’s savings calculations vary based on building type whereas New Jersey’s do not.
- Xcel Energy uses higher coincidence factor (CF) values and equivalent full load cooling hours (EFLH) as compared to New Jersey. This is primarily due to the differences in climate.
- Xcel uses AHSRAE 90.1-2004 efficiency standards as a baseline.

3.5.2.5 DEER Analysis

The Database for Energy Efficiency Resources (DEER) provides energy estimates and peak demand savings values for variety of measures. The data provided by DEER is extensive and varies by building type and vintage, measure type, and climate zone. It uses Title 24 (California Energy Code) as a minimum compliance standard.

Because DEER data is reported for many climate zones, it may be possible to find zones in California that are similar to those in New Jersey. Equivalent full load hours (EFLH) are related to cooling and heating degree days for a particular geographical area. To calculate cooling degree days (CDD), KEMA analyzed Typical Metrological Year Version 3 (TMY3) data for specific climate stations.

Recognizing the variation in New Jersey weather from shore areas to the highlands and from north to south, we obtained hourly TMY3 climate data from the National Solar Radiation Database[28] for the four New Jersey climate zones based on representative cities. Table 3-23 provides the list of counties matched with the weather station from which data was collected.[29]

Table 3-23
Weather Stations Used for New Jersey Counties

Weather Station (USAFN Number)	County
Atlantic City (724070)	Atlantic, Cape May, Monmouth, Ocean
Newark (725020)	Bergen, Essex, Hudson, Middlesex, Passaic, Union
Philadelphia, PA (724080)	Burlington, Camden, Cumberland, Gloucester, Salem
Monticello, NY (725145)	Hunterdon, Mercer, Morris, Somerset, Sussex, Warren

Cooling degree days for specific climate stations in the state of California (CA) are comparable to climate stations in the state of New Jersey. The weather stations and CDD for both states are shown below in Table 3-24.

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[28] http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

[29] We matched counties and weather stations based on an overview of New Jersey's climate from the Office of the New Jersey State Climatologist (http://climate.rutgers.edu/stateclim/?section=uscp&target=NJCoverview) and proximity with available weather stations.

Table 3-24
Weather Stations CDD for CA and NJ

CA weather stations		NJ weather stations	
San Diego	741	Monticello	424
Long Beach	994	Philadelphia	1184
Bakersfield	2214	Newark	1236
Fresno	2102	Atlantic City	885
Santa Barbara	103		
Stockton	1295		
San Francisco	97		
Redding	1687		

From the above table it can be seen that, for example, Stockton (CA) and Newark (NJ) have comparable cooling degree days. Based on this simple comparison, it may appear that EFLH values for Stockton would accurately predict those for Newark. However, this is not necessarily the case. Cooling load is determined not only by cooling degree days, but also by humidity, solar radiation, and other factors.

Given that these other climate differences are not addressed in the simple CDD comparison, we do not recommend that the program use this type of comparison to determine EFLH for New Jersey climate zones. Rather, we recommend that the current value be used until a more accurate value is determined by a more sophisticated conversion of DEER data or by computer modeling.

3.5.3 Recommended A/C savings protocols

We do not recommend any changes to the existing savings protocol algorithms themselves. However, we do recommend changes to the values of the equation variables.

The algorithms are shown below.

kW Savings = (BtuH/1000) * (1/EER$_b$ – 1/ EER$_q$) * CF **Equation 3.5-14**

kWh Savings = (BtuH/1000) * (1/EER$_b$ – 1/ EER$_q$) * EFLH **Equation 3.5-15**

In addition, for Heat Pumps:

Heating kWh Savings = (BtuH$_h$/1000) * (1/EER$_b$ – 1/ EER$_q$) * EFLH$_h$ Equation 3.5-16

where:

$BtuH_h$ = Heating capacity in Btu/Hour
$BtuH_c$ = Cooling capacity in Btu/Hour
EER_b = Efficiency rating of baseline unit
EER_q = Efficiency rating of energy efficient unit
CF = Coincidence factor
$EFLH_h$ = Equivalent Full Load Heating Hours
$EFLH_c$ = Equivalent Full Load Cooling Hours

3.5.3.1 Recommended Changes to Variables

EFLH is in the appropriate range compared to values from Connecticut and Vermont. The CF value of 0.67 is also appears reasonable, as it is similar to values reported in utility work papers in California, which define CF in the range of 0.70 to 0.74. Because we do not have a reliable way to convert these values for the New Jersey climate zones, we have not done that for this report. We recommend that the values for EFLH and CF remain as reported in the current protocol, pending further investigation. Such investigation is outside the scope of this report.

We recommend adjusting the baseline energy efficiency values to fit those provided by the Consortium of Energy Efficiency (CEE) Tier 1 as shown below in Table 3-25, which are provided in both full-load (EER) and partial load (IPLV and SEER) formats. These are derived from an analysis of standard efficiency equipment currently on the market. Tier 2 and Tier 3 values are also listed, as some programs choose to use these values as minimum efficiency levels for providing incentives.

Table 3-25
CEE-Recommended Efficiency Levels

Equipment type		CEE Efficiency Level		
Size	**Equipment**	**Tier 1**	**Tier 2**	**Tier 3**
<65,000	Split	13 SEER	14 SSEER	15 SEER
		11.6 EER	12.0 EER	12.5 EER
	Single Package	13 SEER	14 SSEER	15 SEER
		11.3 EER	11.6 EER	12.0 EER
≥65,000 to 135,000	Split	11 EER	11.5 EER	12.0 EER
	Single Package	11.4 IPLV	11.9 IPLV	12.4 IPLV
≥135,000 to 240,000	Split	10.8 EER	11.5 EER	12.0 EER
	Single Package	11.2 IPLV	11.9 IPLV	12.4 IPLV
≥240,000 to 760,00	Spilt & Single Package	10.0 EER	10.5 EER	10.8 EER
		10.4 IPLV	10.9 IPLV	12.0 IPLV
>760,000	Spilt & Single Package	9.7 EER	9.7 EER	10.2 EER
		10.1 IPLV	11.0 IPLV	11.0 IPLV

3.5.3.2 Future Research

According to the current NJ protocol, JCP&L metered data was used to calculate EFLH, and CF was based on an engineering estimate. Since neither of these sources were available to us, we could not evaluate the method of calculating these variables.

As stated earlier, calculating energy savings based on full load efficiency neglects the over sizing of these units. Most equipment is oversized and so a factor might be included to account for this.

In addition, it would be advantageous to vary the CF and EFLH values based on building type and vintage, and climate zone, rather than using constant values.

Sufficient data is not currently available for New Jersey to produce confident estimates for CF and EFLH values by building type and vintage, and climate zone. However, further research is warranted to determine these values. We recommend the following options:

- Study the conversion of DEER data for use in New Jersey based on adjustment for climate differences.
- Carry out a rigorous DOE 2 (computer-based) energy simulation. The benefit of this method is that it takes into account the solar data, weather data, and the sensible heat data for different regions in the state.

3.6 Electric Chillers

SmartStart currently offers prescriptive rebates on the purchase of a new electric chiller.

3.6.1 Overview of Existing Protocol

This section contains a review of the electric chillers protocol and an analysis of its assumptions, goals, and procedures.

3.6.1.1 Overview of Protocol

Currently SmartStart offers prescriptive incentives based on chiller type and size. The protocols differentiate between two types: air-cooled and water-cooled. Air-cooled chillers have only one size category. Water-cooled chillers have three: <150 tons, 150 to <300 tons, and ≥300 tons. Ton is the measure of cooling capacity used for chillers.

Chiller energy efficiency is measured in kW/ton (kilowatts per ton), which is generally found on the manufacturer's cut sheet. For smaller chillers, EER (energy efficiency ratio) is sometimes used but can be easily converted to kW/ton.

Algorithms

$$kW\ Savings = Tons\ x \left(\frac{kW}{ton_b} - \frac{kW}{ton_q} \right) x\ CF \qquad \text{Equation 3.6-1}$$

$$kWh\ Savings = Tons\ x \left(\frac{kW}{ton_b} - \frac{kW}{ton_q} \right) x\ EFLH \qquad \text{Equation 3.6-2}$$

where:

kW/ton_b = the baseline efficiency, as referenced in ASHRAE 90.1-2004

kW/ton_q = the efficiency of the equipment installed, found on the manufacturer's cut sheet.

Tons = chiller capacity

CF = Coincidence Factor

EFLH = Equivalent Full Load Hours

Table 3-26

Electric Chiller Algorithm Inputs

Component	Type	Situation	Value	Source
Tons	V	All	From App.	
kW/ton_b	F	Water Cooled (=<150 tons) Water Cooled (151 to <300 tons) Water Cooled (≥300 tons) Air Cooled (<150 tons)	0.703 0.634 0.577 1.256	ASHRAE 90.1 2004
kW/ton_q	V	All	ARI Std. 550/590	Application
CF	F	All	67%	Engineering estimate
EFLH	F	All	1,360	JCP&L metered data, 1995-1999
Notes: V=Variable; F=Fixed				

3.6.1.2 Review of Protocol

We requested copies of the sources cited in the protocol but the program was not able to provide them.

One item of note is that the protocol restricts air-cooled chillers to <150 tons where the application allows chillers over 150 tons. This appears to be a typographical error in the protocol.

The algorithm and inputs provide a simple means for calculating kWh and kW savings based on full load efficiency. However, this method is not very accurate because it does not take into account partial load efficiency.

Chillers are sized for maximum load conditions, which rarely occur. They mostly run at partial load. The efficiencies of chillers at partial load vary dramatically across brands and product lines because of features like variable frequency drives and water temperature regulation. For this reason, all manufacturers print IPLV (Integrated Part Load Value) in their literature and SmartStart even provide rebates for a high IPLV. Despite this, the algorithm does not include IPLV but rather makes an assumption of partial load efficiency in the calculation of EFLH (equivalent full-load hours). The protocols do not state the method used to calculate EFLH, but a single EFLH presumes a single IPLV across all products. Since this algorithm does not account for variations in partial loading, it is not accurate for measuring chiller energy savings.

The protocol baseline kW/ton values come from ASHRAE 90.1-2004, which is appropriate because it is a newly adopted code and most manufacturers will only meet the code value with their low-end equipment. Table 3-27 shows a comparison between the ASHRAE 90.1-2004 standards and the baseline values from the New Jersey Protocols.

Table 3-27
Comparison between Code and Protocol Baseline

Description	Size (Tons)	Code (90.1 - 2004) (kW/Ton)	New Jersey (kW/Ton)	Percent Difference
Air Cooled w/ Condenser	All	1.256	1.256	0%
Air Cooled w/o Condenser	All	1.135	1.256	10%
Water Cooled Positive Displacement (Reciprocating)	<150	0.875	0.703	-24%
	150-300	0.875	0.634	-38%
	>=300	0.875	0.577	-52%
Water Cooled Positive Displacement (Rotary Screw or Scroll)	<150	0.790	0.703	-12%
	150-300	0.718	0.634	-13%
	>=300	0.639	0.577	-11%
Water Cooled Centrifugal	<150	0.703	0.703	0%
	150-300	0.634	0.634	0%
	>=300	0.577	0.577	0%

Table 3-27 reveals several interesting issues. As shown, the New Jersey Requirements for air-cooled chillers follow the code value for chillers with condensers. This leaves condenserless chillers with a baseline that is less efficient than code. We recommend that the program either require a condenser (as New York does) or provide a separate category for chillers without condensers. For water-cooled chillers, the protocols follow the code value for centrifugal chillers. This is appropriate for the ≥300 size, but inappropriate in the smaller sizes, where centrifugal chillers are rare. For small reciprocating chillers, we see that the baseline is 24% more efficient than code, which is not realistic. We recommend either creating separate categories for the different types of chillers (as shown in Table 3-27) or using the reciprocating chiller efficiency for <150 tons and the screw/scroll efficiency for 150 to <300 tons.

Table 3-28 shows a comparison between the baseline efficiency listed in the protocols and the minimum efficiency eligible for a rebate, as seen on the 2008 Electric Chillers Application.

Table 3-28
Comparison between Code, Protocols, and Application

Description	Size (tons)	Code (90.1 - 2004)		From Protocol		From App.	
		F.L.	IPLV	F.L.	IPLV	F.L.	IPLV
Air Cooled w/ Condenser	All	1.256	1.153	1.256	na	1.200	na
Air Cooled w/o Condenser	All	1.135	1.019	1.256	na	1.200	na
Water Cooled Positive Displacement (Reciprocating)*	<150	0.875	0.696	0.703	na	0.750	na
	150-300	0.875	0.696	0.634	na	0.560	0.500
	>=300	0.875	0.696	0.577	na	0.470	0.460
Water Cooled Positive Displacement (Rotary Screw or Scroll)	<150	0.790	0.676	0.703	na	0.750	na
	150-300	0.718	0.628	0.634	na	0.560	0.500
	>=300	0.639	0.572	0.577	na	0.470	0.460
Water Cooled Centrifugal	<150	0.703	0.670	0.703	na	0.750	na
	150-300	0.634	0.596	0.634	na	0.560	0.500
	>=300	0.577	0.550	0.577	na	0.470	0.460
Notes: All units in kw/Ton. | F.L. = Full Load | IPLV = Integrated Part Load Value							

Table 3-28 reveals some contradictions between the baseline efficiency and the efficiencies listed on the application.

The air-cooled chiller application is consistent with the protocols. The rebated values for air-cooled chillers with condensers are in the right range. For those without condensers, if a new protocol value is developed (see discussion above), then a new rebated value should be developed as well.

For water-cooled chillers there are more significant issues.

For small water-cooled chillers, the application rebated value is not efficient enough. The application should always require a higher efficiency (lower number) than is listed in the protocol or in code. The protocol number is the baseline, and rebated chillers should by definition be more efficient than the baseline. In other words, if the protocol value is 0.703, then the rebated value should be less than 0.703. This is not true with water-cooled chillers <150 tons, with a rebated value of 0.750. The rebated value is less efficient than the protocol value.

For larger water-cooled chillers there is the opposite problem. The application rebated values are dramatically more efficient than either code or the protocols. As we will see below, some major manufacturers don’t even make products which meet the requirements.

3.6.2 Review of Industry Practice

This section contains a discussion of sources we found in the course of our research. We discuss some technical data related to chillers, industry product offerings, and data from other state programs.

3.6.2.1 University of Oviedo, Spain, Department of Physics Website

The University of Oviedo, Spain, Department of Physics Website outlines the different types of chillers in detail and their general uses. According to the website,[30] reciprocating chillers are generally used for small applications, are inefficient, and require a lot of maintenance. Scroll chillers are also small, generally below 80 tons, but are very efficient and require almost no maintenance. Screw chillers are mid-range in size, are reliable and fairly efficient. Centrifugal chillers are primarily used at large sizes and low pressures, but can be staged to produce higher pressures. They have high partial-load efficiency and so can be run at a small percentage of capacity without a great efficiency drop. This is due to the use of a fan rather than a positive-displacement machine which allows VFDs to take advantage of the cube law.

3.6.2.2 *Choosing a High-Efficiency Chiller System*, Natural Resources Department of Canada, 2002

Table 3-29 shows some of the differences between the various electric chiller types as described in this whitepaper. The prices listed are for these chillers in their typical size range. A small centrifugal chiller will be more expensive per ton.

Table 3-29
Comparisons of Chiller Types

	Centrifugal	Rotary	Reciprocating
Description	Variable-volume compression using centrifugal force	Positive displacement compres-sion using two machined rotors	Piston-type compression, suitable for small and variable loads
Initial cost (per Ton of cooling)	\$500–\$700	\$500–\$800	\$450–\$600
Maintenance cost	Medium	Lower	Higher
Other Issues	Small, high-pitched noise, no vibration	Small, quiet, no vibration	Large, high noise and vibration

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[30] www.nanomagnetics.org

3.6.2.3 Industry Product Offerings

Table 3-30 shows the product offerings of two large chiller manufacturers. This data shows what was described previously: scroll and reciprocating chillers are mostly small; screw chillers are small to mid-range; and centrifugal chillers are mid-range to large. Efficiency ranges from Carrier are more difficult to locate, and so are not included.

Table 3-30
Product offerings by Carrier and Trane

Category	Type	Carrier	Trane	
		Size (Tons)	Size (Tons)	kW / Ton (F.L.)
Air-Cooled	Scroll	9 to 390	20-60	1.22 - 1.23
	Screw	80 to 500	70-500	1.14 - 1.25
Air-Cooled Condenserless	Reciprocating	15 to 60	na	na
	Screw	70 to 265	na	na
Water-Cooled	Reciprocating	15 to 60	na	na
	Scroll	na	20-60	0.77 - 0.79
	Screw	70 to 550	70-450	0.57 - 0.79
	Centrifugal	200 to 1,500	170-3950	0.448 (best)

Table 3-31 shows Trane's efficiency data lined up against code and SmartStart requirements. Trane has a reputation as a high-end HVAC manufacturer, and so its products should be on the efficient end of the spectrum.

Table 3-31
Efficiency Comparison

Description	Size (tons)	Code (90.1 - 2004)	From Protocol	From App.	Trane
		F.L.	F.L.	F.L.	F.L.
Air Cooled w/ Condenser	All	1.256	1.256	1.200	1.14 - 1.25
Air Cooled w/o Condenser	All	1.135	1.256	1.200	na
Water Cooled Positive Displacement (Reciprocating)*	<150	0.875	0.703	0.750	na
	150-300	0.875	0.634	0.560	
	>=300	0.875	0.577	0.470	
Water Cooled Positive Displacement (Rotary Screw or Scroll)	<150	0.790	0.703	0.750	0.55 - 0.79
	150-300	0.718	0.634	0.560	
	>=300	0.639	0.577	0.470	
Water Cooled Centrifugal	<150	0.703	0.703	0.750	0.448 (best)
	150-300	0.634	0.634	0.560	
	>=300	0.577	0.577	0.470	
Notes: All units in kw/Ton. | F.L. = Full Load | IPLV = Integrated Part Load Value					

Based on this table, the rebate requirements for chillers >150 tons are too high. Most strikingly, the most efficient Trane centrifugal chiller ≥300 tons is just barely eligible for a rebate. Since efficiency generally goes up as size goes up, this 0.448 kW/ton chiller is probably very large. In addition, only the most efficient screw chiller 150 to <300 tons can earn a rebate.

3.6.2.4 Nearby Utilities

Table 3-32 shows a comparison between code requirements and rebate eligibility requirements from states around New Jersey. Pennsylvania, Maryland, Virginia, Connecticut, and Delaware do not provide chiller rebates and so are not listed.

Table 3-32

Comparison of Rebate Eligibility Requirements between Utilities

Description	Size (Tons)	Code (90.1 - 2004)		New Jersey		New York		Mass		RI & NH	
		Full kW/Ton	IPLV kW/Ton	Full kW/Ton	IPLV kW/Ton	Full kW/Ton	IPLV kW/Ton	Full kW/Ton	IPLV kW/Ton	Full kW/Ton	IPLV kW/Ton
Air Cooled w/ Condenser	All	1.256	1.153	1.200	na	1.220	0.902	1.170	na	1.170	na
Air Cooled w/o Condenser	All	1.135	1.019	1.200	na	na	na	1.170	na	1.170	na
Water Cooled Positive Displacement (Reciprocating)	<150	0.875	0.696	0.750	na	na	na	na	na	0.740	na
	150-300	0.875	0.696	0.560	0.500	na	na	na	na	0.640	0.530
	>=300	0.875	0.696	0.470	0.460	na	na	na	na	0.580	0.530
Water Cooled Positive Displacement (Rotary Screw or Scroll)	<150	0.790	0.676	0.750	na	0.720	0.590	0.740	na	0.740	na
	150-300	0.718	0.628	0.560	0.500	0.640	0.490	0.610	0.510	0.640	0.530
	>=300	0.639	0.572	0.470	0.460	custom	custom	0.560	0.510	0.580	0.530
Water Cooled Centrifugal	<150	0.703	0.670	0.750	na	0.640	0.530	0.650	na	0.740	na
	150-300	0.634	0.596	0.560	0.500	0.590	0.520	0.610	0.510	0.640	0.530
	>=300	0.577	0.550	0.470	0.460	custom	custom	0.560	0.510	0.580	0.530

New York is notable in that it excludes both air-cooled chillers without condensers and water-cooled reciprocating chillers, and requires large chillers (≥300 tons) to file a custom rebate application. Massachusetts also excludes water-cooled reciprocating chillers. New York and Massachusetts both differentiate between rotary screw / scroll and centrifugal chillers, providing separate requirements for each.

For small (<150 ton) water-cooled chillers, all states are similar, with New York the most strict. For New York and Massachusetts, the small centrifugal chiller requirement is different but this is unimportant because small centrifugal chillers are rarely sold. For larger chillers, New Jersey's rebate eligibility requirements are much stricter than all the other states, particularly for the largest chillers (≥300 tons) where New Jersey is 16-19% stricter than the other states.

3.6.2.5 Deemed Savings, Installation & Efficiency Standards – Arkansas Statewide Quickstart Programs, 2007

This source uses different terms to describe the same quantities, and so we have translated their terminology to match New Jersey's.

Arkansas uses the following algorithms in their energy savings protocols.

$$kW\ Savings = Tons\ x\ (IPLV_b - IPLV_q)$$ Equation 3.6-3

$$kWh\ Savings = Tons\ x\ EFLH\ x\ (IPLV_b - IPLV_q)$$ Equation 3.6-4

where:

Tons = Rated equipment cooling capacity
EFLH = Equivalent full load hours, developed from DEER savings data.
$IPLV_b$ = Integrated Part Load Value of the baseline chiller
$IPLV_q$ = Integrated Part Load Value of the qualifying chiller

These protocols use IPLV rather than full load efficiency. The kW Savings algorithm is probably not completely accurate because IPLV is not climate-specific, and should be adjusted with a Coincidence Factor to suit the climate for which the technology is being applied. In addition, Arkansas does not specify in their protocols over what period their peak kW savings is measured.

The kWh Savings number is appropriate because EFLH is a climate-specific value which accounts for the number of cooling hours, in this case for Arkansas.

If these algorithms were used in New Jersey, the factors would need to be adjusted for New Jersey's climate and hours of peak kW measurement. EFLH would have to be adjusted, and a Coincidence Factor (CF) added to the kW Savings algorithm.

3.6.2.6 Technical Reference User Manual – Efficiency Vermont, 2004

Vermont uses the following algorithms to calculate energy savings. Names of values have been changed to match those used by New Jersey when equivalent.

$$kWh\ Savings = Tons \times (IPLV_b\ \text{-}\ IPLV_q) \times FLH$$ Equation 3.6-5

$$kW\ Savings = Tons \times \left(\frac{kW}{Ton_b} - \frac{kW}{Ton_q} \right)$$ Equation 3.6-6

where:

Tons = Rated equipment cooling capacity
$IPLV_b$ = Integrated part load value efficiency of the baseline chiller (kW/ton)
$IPLV_b$ = Integrated part load value efficiency of the qualifying chiller (kW/ton)
kW/Ton_b = Full load efficiency of the baseline chiller (kW/ton)
kW/Ton_q = Full load efficiency of the qualifying chiller (kW/ton)
FLH = cooling full load hours per year (based on engineering estimate)

These algorithms are similar to the method that New Jersey uses except for three differences.

- Vermont uses IPLV in its kWh algorithm. This provides a better estimate of actual performance, because it reflects the operation at partial load, which is how the system operates most of the time.
- Vermont uses Full Load Hours for its kWh calculation. This is either a calculation error or a typographical error. Since equipment rarely operates at full load, full load operation should never be multiplied by IPLV (EFLH, as discussed elsewhere, is a different case).
- Vermont calculates kW savings at the moment of peak usage, rather than averaged over a time period. This eliminates the need for a coincidence factor and recommends the use of peak (full load) efficiency rather than IPLV.

Table 3-33 shows a comparison between New Jersey's protocol values and Vermont's protocol values.

Table 3-33
Comparison with Vermont Protocols

Description	**Size**	**New Jersey Protocols**		**Vermont Protocols**	
		Peak Load (kW/Ton)	IPLV (kW/Ton)	Peak Load (kW/Ton)	IPLV (kW/Ton)
Air-Cooled Chiller, with Condenser	All Capacities	1.256	na	1.256	1.256
Air-Cooled Chiller, without Condenser	All Capacities	1.256	na	1.135	1.135
Water Cooled Positive Displacement (Reciprocating)	< 150 Tons	0.703	na	0.837	0.748
	150 to < 300 Tons	0.634	na	0.837	0.748
	≥ 300 Tons	0.577	na	0.837	0.748
Displacement (Rotary Screw and Scroll)	< 150 Tons	0.703	na	0.782	0.782
	150 to < 300 Tons	0.634	na	0.718	0.703
	≥ 300 Tons	0.577	na	0.639	0.628
Water Cooled (Centrifugal)	< 150 Tons	0.703	na	0.703	0.703
	150 to < 300 Tons	0.634	na	0.628	0.628
	≥ 300 Tons	0.577	na	0.577	0.577

The two protocol values are similar in their values, but here are three differences.

- Vermont includes IPLV.
- Vermont recognizes air-cooled chillers without condensers as a separate category with a separate baseline.
- Vermont separates out the various water-cooled chiller types, giving each its own baseline.
- Vermont recognizes only one baseline efficiency for all reciprocating chillers.

3.6.2.7 CL&P and UI Program Savings Documentation for 2008 Program Year – Connecticut Clean Energy Fund, 2007

Connecticut calculates all chiller rebates on a custom basis.

3.6.3 Recommendations

3.6.3.1 Algorithms

We recommend using IPLV (Integrated Part Load Value) for efficiency rather than full load efficiency. IPLV is a value established by the ARI (Air Conditioning and Refrigeration Institute) which is specifically designed to approximate actual product loading. Since chillers rarely run at full load, and since IPLV can vary so much between manufacturers, the efficiency value used should take into account partial loading. Based on the use of IPLV rather than full load efficiency, we recommend using the term Peak Duty Cycle (PDC) instead of Coincidence Factor (CF). PDC is the accurate term for what the value represents. Therefore, we recommend the following algorithm be used.

$$\textbf{kWh Savings} = \text{Tons} \times \text{EFLH} \times (IPLV_b - IPLV_q) \qquad \text{Equation 3.6-7}$$

$$\textbf{kW Savings} = \text{Tons PDC} \times (IPLV_b - IPLV_q) \qquad \text{Equation 3.6-8}$$

where:

Tons = Rated equipment cooling capacity
EFLH = Equivalent full load hours
PDC = Peak Duty Cycle
$IPLV_b$ = IPLV of baseline equipment
$IPLV_q$ = IPLV of qualifying equipment

3.6.3.2 Values

As discussed above, there are issues with both protocols and with the rebated values on the application.

The protocols are based on code values (ASHRAE 90.1-2004), which is appropriate, but the values which are used are not specific to the technologies they represent. For instance, there is only one value for air-cooled chillers, even though there are two types. There is also only one set of size-specific values for water-cooled chillers, even though there are three different types.

For the baseline IPLV values, we have four recommendations:

- For air-cooled chillers, we recommend creating another value for air-cooled chillers without condensers.
- For water-cooled chillers, we recommend keeping the values together (differentiated by size), but using the values shown below. These values are derived from the code requirements for the most common chiller types in the various sizes.
- For very large chillers, we recommend a custom approach because large systems present much greater potential for energy savings. Large chillers present an opportunity to building simulation and to coordinate the different parts of the system for maximum savings. For this reason we recommend that chillers over 1000 tons be treated as custom measures.

Table 3-34
Recommended Protocol Values

Component	Type	Situation	Protocols	Source
IPLV_b (kW/ton)	F	Air Cooled with Condenser (all)	1.153	ASHRAE 90.1-2004
		Air Cooled w/o Condenser (all)	1.019	
		Water Cooled (≤150 tons)	0.676	ASHRAE 90.1-2004 (screw / scroll chillers)
		Water Cooled (151 to <300 tons)	0.628	
		Water Cooled (≥300 to <1000 tons)	0.560	ASHRAE 90.1-2004 (between screw / scroll and centrifugal chillers)
	V	Water Cooled (≥1000 tons)	Custom	Custom
Tons	V	All	Varies	From Application
IPLV_q (kW/ton)	V	All	Varies	From Application (per ARI Std. 550/590)
PDC	F	All	67%	Engineering Estimate
EFLH	F	All	1,360	Based on California DEER Database
Notes: V=Variable; F=Fixed				

For the application rebated values, we recommend a simple rule that chillers must be 5% more efficient than the protocols to receive a rebate. We also recommend that the program use IPLV to define rebate eligibility for all chillers, for the reasons discussed above. Therefore, we recommend the following changes to application rebated values:

Table 3-35
Recommendations for Application Rebate Values

Description	Size (tons)	IPLV
Air Cooled w/ Condenser	All	1.095
Air Cooled w/o Condenser	All	0.968
Water Cooled	<150	0.643
	150-300	0.597
	301-1000	0.532
	>1000	Custom

Finally, market research into the installed baseline of chillers in New Jersey, including installed size, age, efficiency, and operational hours, would be very useful to determine the future importance of this measure and appropriate benchmarks.

We did not attempt to provide a more accurate value for EFLH or CF during this round of review. These values are highly climate dependent, so they must be determined for New Jersey climate zones, rather than adapting values from other states. We recommend that they remain as provided in the current Protocols, pending further study or modeling.

3.7 Variable Frequency Drives

This prescriptive measure applies to Variable Frequency Drives (VFDs)[31] installed to control motors for HVAC fans in variable air volume (VAV) systems and on chilled water pumps only. Both must operate a minimum of 2,000 hours per year to be eligible. VFD applications for other types of motors, such as process installations, are handled on a custom basis. For this measure, the baseline assumes no VFD.

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[31] Also known as Variable Speed Drives (VSDs) and Adjustable Speed Drives (ASDs)

3.7.1 Variable Frequency Drive Energy (kWh) and Peak Demand (kW) Savings Algorithm

Algorithms

$$kW\ Savings = 0.746 * HP * \frac{RLF}{\eta_{motor}} * DSF \qquad \text{Equation 3.7-1}$$

$$kWh\ Savings = 0.746 * HP * \frac{RLF}{\eta_{motor}} * ESF * FLH_{base} \qquad \text{Equation 3.7-2}$$

$$DSF = 1 - \left(\frac{kW_{asd}}{kW_{base}} \right)_{peak} \qquad \text{Equation 3.7-3}$$

$$ESF = 1 - \left(\frac{FLH_{asd}}{FLH_{base}} \right) \qquad \text{Equation 3.7-4}$$

where:

HP = Nameplate motor horsepower

RLF = Rated load factor. This is the ratio of the peak running load to the nameplate rating of the motor.

h_{motor} = Motor Efficiency at peak load. Motor efficiency varies with load. At low loads relative to the rated HP (usually below 50%), efficiency often drops dramatically.

DSF = Demand Savings Factor. The demand savings factor is calculated by determining the ratio of the power requirement for baseline and VFD control at peak conditions.

ESF = Energy Savings Factor. This can also be computed according to fan and pump laws assuming an average flow reduction and a cubic relationship between flow rate reduction and power draw savings.

FLH_{asd} = Full Load Hours of the fan/pump with the VFD.

FLH_{base} = Full Load Hours of the fan/pump with baseline drive.

kW_{asd} = peak demand of the motor under the variable control conditions.

kW_{base} = peak demand of the motor under the base operating conditions.

Table 3-36.
Variable Frequency Drives Algorithm Inputs

Component	Type	Value	Source
Motor HP	Variable	Nameplate	Application
kWh/motor HP	Fixed	1,653 for VAV air handler systems. 1,360 for chilled water pumps.	JCP&L metered data for VFDs and chillers
RLF	Variable	Dependent on HP and peak running load	
h_{motor}	Variable	Nameplate or manufacturer specs	Application
ESF	Variable	Dependent on full load of base and VFD	
FLH_{asd}	Variable	Nameplate	Application
FLH_{base}	Fixed		Application
DSF	Variable	Dependent on base and variable peak demand	
kW_{asd}	Variable	Nameplate	Application
kW_{base}	Fixed		Manufacturer

3.7.2 Discussion of Key Protocol Algorithm and Inputs

The current protocol is comprised almost entirely of the recommendations provided in the Market Assessment conducted by Summit Blue[32]. There are, however, some artifacts from the "New Jersey Clean Energy Program Protocols" of September 2004 that are no longer used. As the following variables are no longer used, they should be removed from the current protocol as follows:

> *Motor kWh/motor HP*: While this variable is listed in Table 3-36 as coming from the application, we find no mention of this metric on the 2008 Variable Frequency Drives Application for New Jersey's Clean Energy Program™. Furthermore, this variable is not used in any of the equations in the current protocol.
>
> *Drive Efficiency:* This variable is asked for on the application but is not used in the protocols. Hence, this variable can be eliminated from the application.

A discussion follows regarding some of the variables used in the algorithm of the current protocol:

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[32] Energy Efficiency Market Assessment of New Jersey Clean Energy Programs, Book III—Commercial and Industrial Programs (Summit Blue Consulting, LLC, July 2006).

Rated Load Factor: This term appears to be confused with either “Service Factor,” which is printed on motor nameplates and represents how much the motor can safely be overloaded or “Load Factor,” which is the percentage of full load the motor operates at under typical conditions. “Load Factor” is a site-specific value, and is commonly used to determine energy usage. We assume that this is what the program intended the value for. We recommend that the program eliminate this variable and combine it with ESF and DSF.

Energy Savings Factor (ESF): This variable claims to be based on full load hours, but these values are not collected on the application. We recommend collecting metered data on motor usage with and without VFDs to develop values for this variable.

Full Load Hours (baseline and VFD): These variables are not asked for on the current application. Nor would applicants be likely to be able to provide accurate numbers without having observed the operation with the VFD for at least one year. In addition, full load hours is not a meaningful measure for VFDs, as most energy savings occurs at partial load. We recommend that the program eliminate this variable and replace it with operating hours.

Demand Savings Factor (DSF): This variable claims to be based on peak demand kW, but these values are not collected on the application. We recommend collecting metered data on motor usage with and without VFDs to develop values for this variable.

Peak Demand kW (baseline and VFD): These variables are not asked for on the current application. Nor would applicants be likely to be able to provide accurate numbers without having observed the operation with the VFD. We recommend that the program eliminate this variable.

3.7.3 Review of Industry Practice

The practices of a number of other programs were reviewed and used to develop the recommended VFD protocol provided in 3.7.4.

For consistency throughout the discussion regarding this measure, we standardized and made uniform variables across all program citations. The terms Demand Savings Factor (DSF) and Energy Savings Factor (ESF) are unit-less under SmartStart, but other programs use kW/HP and/or kWh/HP. Please take this into account when comparing values.

3.7.3.1 Efficiency Vermont

The most noteworthy elements of this program are that 1) in most cases, VFDs are a custom measure, and 2) the program considers the interactive effects of another measure, commissioning services. Said commissioning interaction factor is applied to both prescriptive and custom VFD applications. The following standardized algorithm is only intended for VFDs applied to motors *less than 10 HP* that are installed at HVAC fan or pump applications:

kW Savings = HP * DSF * CXS *Equation 3.7-5*

kWh Savings = HP * ESF * CXS *Equation 3.7-6*

where:

kW = gross customer kW savings for the measure at the greater of either the summer peak or the winter peak

kWh = gross customer annual kWh savings for the measure

HP = horsepower of motor controlled by VFD, per application or

DSF = demand savings factor, see Table 3-37 below, kW/HP

ESF = energy savings factor, see Table 3-37 below, kWh/HP

CXS = commissioning factor for standard approach applications:

= 1.1 with commissioning services;

= 1.0 without commissioning services.

Table 3-37.
VFD Energy and Demand Savings Factors[33] (DSF and ESF)

Application	DSF (kW/HP)	ESF (kWh/HP)
Supply Fans	0.173	1,001
Return Fans	0.263	1,524
Exhaust Fans	0.12	755
Chilled Water Pumps	0.188	1,746
Boiler Feedwater Pumps	0.098	745

The following Table 3-38 provides the load shapes that were said to have been used as the basis for the Demand and Energy Savings Factors shown above. The table includes the percentages of time that each equipment end use can be expected to be operating during four seasons.

Table 3-38
Loadshapes for VFD Measures

End Use of VFD (Motors <10 hp, only)	Winter On, kWh	Winter Off, kWh	Summer On, kWh	Summer Off, kWh	Winter kW	Summer kW	Fall/ Spring kW
Supply Fans	23.50%	6.00%	47.50%	23.00%	100.00%	41.00%	71.00%
Return Fans	23.50%	6.00%	47.50%	23.00%	100.00%	66.00%	83.00%
Exhaust Fans	22.00%	11.00%	32.00%	35.00%	100.00%	37.00%	69.00%
Chilled Water Pumps	0.20%	0.10%	52.00%	48.00%	0.00%	100.00%	50.00%
Boiler Feedwater Pumps	44.00%	38.00%	7.00%	11.00%	100.00%	67.00%	83.00%

In Efficiency Vermont's VFD program, a different algorithm is used for VFDs that control motors that are installed at non-HVAC installations and motors of 10 HP or more that are installed at HVAC fan or pump applications. Though not shown due to its custom nature, this algorithm relies nearly exclusively on metered data. Savings are based upon the baseline conditions including no control, inlet guide vanes, outlet guide vanes (or discharge dampers), and throttling valves.

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[33] National Grid 2001 values averaged from previous evaluations of VFD installations. Values are those used for existing constructions, except for chilled water pumps, which are those used for new construction. National Grid existing construction baseline is similar to Vermont baseline for new and existing applications. The DSF factors represent coincident savings for the winter peak, except for the chilled water pumps value which represent coincident savings for the summer peak.

3.7.3.2 Connecticut Light & Power/The United Illuminating Co.

The Program Savings Documentation for 2008 Program Year indicates that CL&P calculates the savings for VFD measures in a manner rather different from both the New Jersey Clean Energy Program and Efficiency Vermont Program.

Algorithm:

$$kW\ Savings = HP * \frac{DSF}{\eta_{motor}} \qquad \text{Equation 3.7-7}$$

$$kWh\ Savings = HP * HRS * \frac{ESF}{\eta_{motor}} \qquad \text{Equation 3.7-8}$$

where:

HP = horsepower of motor controlled by VFD, per application or
DSF = demand savings factor, see Table 3-39 below, kW/HP
ESF = energy savings factor, see Table 3-39 below, kW/HP
h_{motor} = motor efficiency at full load, per application/nameplate
HRS = annual hours of operation per application or default hours in Table 3-41 below.

The Demand and Energy Savings Factors provided in Table 3-39 are said to have been calculated based upon, in part, the peak coincident values shown in Table 3-40 and using a bin analysis of the typical heating, cooling and fan load profiles at various temperatures. No further explanation is provided, however.

Table 3-39
HVAC Fan VFD Savings Factors

Baseline	DSF, Summer (kW/HP)	DSF, Winter (kW/HP)	ESF (kW/HP)
Fans:			
Airfoil/Backward-Inclined w/Discharge Dampers	0.260	0.408	0.354
Airfoil/Backward-Inclined w/Inlet Guide Vanes	0.130	0.291	0.227
Forward Curved w/Discharge Dampers	0.136	0.187	0.179
Forward Curved w/Inlet Guide Vanes	0.029	0.137	0.092
Pumps:			
Chilled Water	0.299	0.000	0.433
Hot Water	0.000	0.208	0.482

Table 3-40
Default C&I Peak Coincidence Factors

Season	Variable Frequency Drives		
	Pumps, Avg. of Cooling & Other	AHU Fans	All
Summer	0.55	0.28	0.44
Winter	0.43	0.44	0.36

Where the applicant cannot provide hours of operation, the default values shown in Table 3-41 are to be used.

Table 3-41. Commercial & Industrial Hours of Use

Facility Type	Fan Motor Hours	Chilled Water Pumps	Heating Pumps
Auto Related	4,056	1,878	6,000
Bakery	2,854	1,445	6,000
Banks, Financial Centers	3,748	1,767	6,000
Church	1,955	1,121	6,000
College - Cafeteria	6,376	2,713	6,000
College - Classes/Administrative	2,586	1,348	6,000
College - Dormitory	3,066	1,521	6,000
Commercial Condos	4,055	1,877	6,000
Convenience Stores	6,376	2,713	6,000
Convention Center	1,954	1,121	6,000
Court House	3,748	1,767	6,000
Dining: Bar Lounge/Leisure	4,182	1,923	6,000
Dining: Cafeteria / Fast Food	6,456	2,742	6,000
Dining: Family	4,182	1,923	6,000
Entertainment	1,952	1,120	6,000
Exercise Center	5,836	2,518	6,000
Fast Food Restaurants	6,376	2,713	6,000
Fire Station (Unmanned)	1,953	1,121	6,000
Food Stores	4,055	1,877	6,000
Gymnasium	2,586	1,348	6,000
Hospitals	7,674	3,180	6,000
Hospitals / Health Care	7,666	3,177	6,000
Industrial - 1 Shift	2,857	1,446	6,000
Industrial - 2 Shift	4,730	2,120	6,000
Industrial - 3 Shift	6,631	2,805	6,000
Laundromats	4,056	1,878	6,000
Library	3,748	1,767	6,000
Light Manufacturers	2,857	1,446	6,000
Lodging (Hotels/Motels)	3,064	1,521	6,000
Mall Concourse	4,833	2,157	6,000
Manufacturing Facility	2,857	1,446	6,000
Medical Offices	3,748	1,767	6,000
Motion Picture Theatre	1,954	1,121	6,000
Multi-Family (Common Areas)	7,665	3,177	6,000
Museum	3,748	1,767	6,000
Nursing Homes	5,840	2,520	6,000
Office (General Office Types)	3,748	1,767	6,000
Office/Retail	3,748	1,767	6,000
Parking Garages & Lots	4,368	1,990	6,000
Penitentiary	5,477	2,389	6,000
Performing Arts Theatre	2,586	1,348	6,000
Police / Fire Stations (24 Hr)	7,665	3,177	6,000
Post Office	3,748	1,767	6,000
Pump Stations	1,949	1,119	6,000
Refrigerated Warehouse	2,602	1,354	6,000
Religious Building	1,955	1,121	6,000
Residential (Except Nursing Homes)	3,066	1,521	6,000
Restaurants	4,182	1,923	6,000
Retail	4,057	1,878	6,000
School / University	2,187	1,205	6,000
Schools (Jr./Sr. High)	2,187	1,205	6,000
Schools (Preschool/Elementary)	2,187	1,205	6,000
Schools (Technical/Vocational)	2,187	1,205	6,000
Small Services	3,750	1,768	6,000
Sports Arena	1,954	1,121	6,000
Town Hall	3,748	1,767	6,000
Transportation	6,456	2,742	6,000
Warehouse (Not Refrigerated)	2,602	1,354	6,000
Waste Water Treatment Plant	6,631	2,805	6,000
Workshop	3,750	1,768	6,000

3.7.3.3 Silicon Valley Power

Although the protocol or work paper for this program could not be found, the measure application indicates that the following algorithm is used:

kW Savings = 0

kWh Savings = HP * ESF *Equation 3.7-9*

where:

ESF = Energy Savings Factor, 984 kWh/hp.

3.7.3.4 Hawaiian Electric Company 2005-2006

The HECO program applies to VFD installations for HVAC fans and pumps that are between 3 and 100 HP. The algorithm for calculating the savings are as follows:

kW Savings = HP * DSF *Equation 3.7-10*

kWh Savings = HP * ESF *Equation 3.7-11*

where:

HP = motor horsepower per application/nameplate

DSF = Demand Savings Factor, kW/HP

= 0.10 kW/hp for HVAC fans

= 0.12 kW/hp for HVAC pumps

ESF = Energy Savings Factor, kWh/HP

= 750 kWh/hp for HVAC fans

= 1,300 kWh/hp for HVAC pumps

The above savings factors were based on studies that used linear regression methodology with the metering data from 22 VFD fans and 26 VFD pumps.

3.7.3.5 New Jersey Clean Energy 2004

As a point of reference, we provide a discussion regarding the previous New Jersey protocols.

kW Savings = 0

kWh Savings = HP * ESF *Equation 3.7-12*

where:

HP = motor horsepower per application/nameplate

ESF = Energy Savings Factor, 1,653 for VAV air handler systems or 1,360 for chilled water pumps, kWh/HP

3.7.4 Recommended VFD Protocol Algorithm and Inputs

We recommend that the program simplify the algorithms, removing the terms for Rated Load Factor and adjusting the remaining terms as shown below.

Algorithms:

$$kW\ Savings = 0.746 * HP * \frac{DSF}{\eta_{motor}}$$ *Equation 3.7-13*

$$kWh\ Savings = 0.746 * HP * HRS * \frac{ESF}{\eta_{motor}}$$ *Equation 3.7-14*

where:

HP = motor horsepower per application/nameplate

η_{motor} = motor efficiency at full load

HRS = annual operating hours per application

DSF = Demand Savings Factor, see Table 3-42.

ESF = Energy Savings Factor, see Table 3-42.

We recommend that the program undertake a metering study to determine accurate values for DSF and ESF. Since HVAC motors are highly dependent upon weather, it will be important to use data that are collected within New Jersey.

For the time being, we recommend that the program use values based on Connecticut Light and Power as shown below in Table 3-42. The values in Table 3-42 have been adjusted to be unit-less (Connecticut's values have units of kW/HP) to match New Jersey's algorithm. We did not attempt to adjust these values for New Jersey climate zones. The protocol is not limited to VFDs installed on motors used for space conditioning. It applies to industrial motors as well, the energy use of which will not vary greatly by climate. So, we do not have an accurate method for adjusting for climate without doing a metering study, which is beyond the scope of this report.

Table 3-42
VFD Savings Factors

Component	Energy Savings Factor, ESF	Demand Savings Factor, DSF
Airfoil/Backward Inclined Fans	0.475	0.448
Forward Curved Fans	0.240	0.216
Chilled Water Pumps	0.580	0.201

Note that this method requires that the program know the type of fan or pump application on which the VFD is installed. This will require the program to update the application to collect this information from the customer.

3.8 Air Compressors with Variable Frequency Drives

This measure provides an incentive for customers purchasing an air compressor with a variable frequency drive (VFD). First we will review the protocol and make recommendations about how it should be restructured. Then we will look into sources from other programs and from industry. Finally we will make recommendations for changes to the values used to calculate energy savings.

3.8.1 Review of Existing Protocol

We begin by describing how energy savings is calculated under the existing protocol, and then follow with a review of and recommendations for the structure of the protocol.

3.8.1.1 Overview of Protocol

Currently the program offers prescriptive rebates for the purchase of an air compressor with a VFD. An existing air compressor being retrofit with a new VFD is handled under a custom measure. Only one VFD per air compressor system is eligible for a rebate, and the customer must demonstrate that the air compressor runs at least 2000 hours per year.

The algorithms for calculating energy and demand savings are as follows:

$$\text{kWh Savings} = \text{Yearly kWh/HP Savings} * \text{HP} \qquad \text{Equation 3.8-1}$$

$$\text{kW Savings} = \text{Peak kW/HP Savings} * \text{HP} \qquad \text{Equation 3.8-2}$$

where:

HP = horsepower
Yearly kWh/HP Savings = kilowatt hours saved per year per horsepower
Peak kW/HP Savings = kilowatts saved per horsepower during peak demand period

Table 3-43 shows the values currently used in this formula and their sources. Table 3-43 lists a term called Maximum kW/HP Savings, which is the demand savings (kW/HP) achieved while the compressor is running.

Table 3-43
Existing Protocol Values

Component	Type	Value	Source
Motor HP	Variable	Nameplate	Application
Yearly kWh/HP Savings	Fixed	774	Aspen*
Maximum kW/HP Savings	Fixed	0.129	Aspen*
Peak kW/HP Savings	Fixed	0.106	Aspen*
Aspen Systems Corporation, Prescriptive Variable Speed Drive Incentive Development Support for Industrial Air Compressors, Executive Summary, June 20, 2005			

3.8.1.2 Review of Protocol

We requested copies of the sources cited in the protocol but the program was not able to provide them. We were also unable to get a copy of the Aspen study.

The algorithm used is clearly intended for greatest simplicity, using only a single multiplier, and it is an effective method for calculating energy savings. The only problem with the protocol is the lack of information on how it was developed. Using kW/HP and kWh/HP is a useful calculation approach, but it is not intuitive and is difficult to evaluate. This will become apparent in a moment as we examine the assumptions inherent in the algorithm. Our final recommendations will not involve fundamental structural changes to the algorithm, but will simply suggest including more information.

3.8.1.2.1 Reverse-Engineering

The factors given in Table 3-43 are listed but the method for calculating them is not. They are likely based on Coincidence Factor, Percentage Energy Savings, and Yearly Operating hours, which we will now calculate.

Coincidence Factor

Coincidence Factor (CF) can be derived from Maximum kW/HP Savings and Peak kW/HP Savings using the following formula.

$$CF = \frac{0.106\ \text{kW/HP Peak Savings}}{0.129\ \text{kW/HP Maximum Savings}}$$

Equation 3.8-3

This gives us a CF of 0.865. In other words, air compressors are assumed to be on 86.5% of the time during peak hours. This is an intuitively fair assumption given the nature of the industries compressed air is used in.

Percentage Energy Savings

Percentage Energy Savings can be derived from Maximum kW/HP Savings. Assuming a baseline efficiency of 75% (a reasonable assumption at average load without a VFD), using the conversion factor 0.746 kW/HP, and using the following formula we can find the percentage energy savings.

$$\text{Savings Percentage} = 0.129\ \text{kW/HP Maximum Savings} * \frac{0.75\ \text{Baseline Efficiency}}{0.746\ \text{kW/HP}}$$

Equation 3.8-4

Therefore, according to the program’s algorithm, a compressor with a VFD uses 13.0% less kW at average load. This also means that the same compressor will use 13% less kWh per year and will see a reduction in peak kW of 13%. This is a low estimate.

Yearly Operating Hours

Yearly operating hours can be derived from Maximum kW/HP Savings and Yearly kWh/HP Savings using the following formula:

$$\text{Yearly Operating Hours} = \frac{774 \text{ Yearly kW/HP Savings}}{0.129 \text{ Maximum kW/HP Savings}} \qquad \text{Equation 3.8-5}$$

This gives us 6000 yearly hours of operation. This is equivalent to 19.2 hours per day, 6 days per week, and 52 weeks per year; While this may be accurate for some industries, it unrealistically high as an average.

3.8.2 Review of Industry Practice

This section contains a discussion of sources we found in the course of our research. We were unable to find another program with a prescriptive approach to VFD compressors, so these are all technical sources.

3.8.2.1 Improving Compressed Air System Performance, a Sourcebook for Industry - DOE Compressed Air Challenge

This source provides a wealth of information about the various components of a compressed air system and the opportunities for savings with each of them. It strongly recommends a “systems approach” to compressed air energy savings – looking carefully at all components and how they interact before determining which improvements are most cost-effective. This is equivalent to the custom *Compressed Air System Optimization* measure discussed elsewhere.

3.8.2.2 A Critical Look at Variable-Speed-Drive Air Compressors – plantservices.com

According to this source, some manufacturers have oversold the use of VFDs on air compressors, and promised dramatic energy savings where none actually occurred. If a customer runs their compressor above 80% of capacity most of the time, adding a VFD will cause them to use more energy rather than less. This is a common problem when VFDs are added to complex compressed air systems with multiple compressors.

3.8.2.3 Energy Savings in Compressed Air, by Air Power USA, Inc.

This source includes a discussion of the situations in which the installation of a VFD onto a compressed air system makes sense. According to this source, within a window of 30%-70% loading, VFDs can provide significant savings, but for compressors which typically operate outside that window savings will be minimal or negative.

3.8.2.4 New Air Compressor Designs Explode Myth of VFD Savings - PR News Now

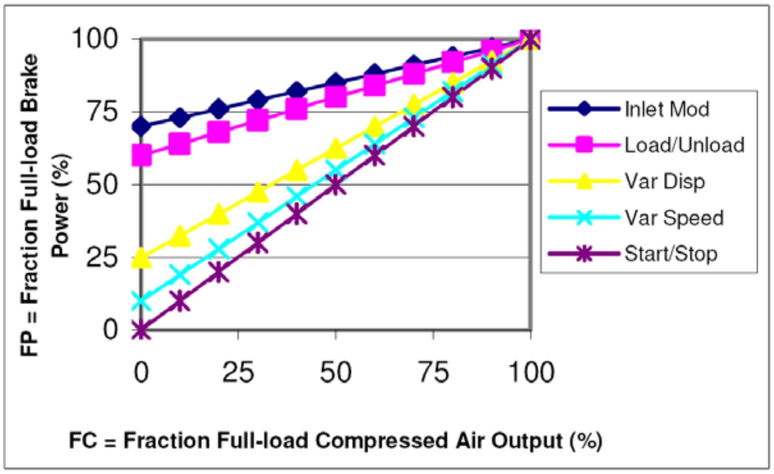
This source agrees with the previous source in suggesting a range of 30%-70% as the window in which VFDs provide significant energy savings.

3.8.2.5 Modeling and Simulation of Air Compressor Energy Use – ACEEE Summer Study on Energy in Industry, 2005

The most useful piece of information in this source is the following Figure 3-1. This figure gives us a intuitive understanding of the percentage energy saved by a VFD at the various load conditions. Assuming the simplest case of a single compressor system, the baseline is probably Inlet Modulation. Adding a VFD corresponds to the Variable Speed line in the figure. This figure is extremely helpful and approximately correct, but is inaccurate in the following two ways:

- The variable speed line does not include the 5% energy waste from the power conversion of the VFD. At full load with a VFD uses more power than one without.
- Running a compressor below about 30% load with a VFD is damaging to the compressor. In this situation, the VFD should either unload the compressor or shut it off. Below 30% load the Variable Speed line should either rise up to the Load/Unload line out or drop to zero.

Figure 3-1
Power Input vs. Power Output



Comparing the Inlet Modulating line and the Variable Speed line are shown in Table 3-44. Here we see that the number derived from the existing protocol, 13% energy savings, is approximately equivalent to a compressor running at 70% load, which is overly conservative as an industry average. Engineers at KEMA recommend a percent savings of 25-40% based on field experience, which is equivalent to a compressor running at 30-50% of full load.

In addition, Baseline Equipment Efficiency is calculated using the following formula with Inlet Modulation used as the baseline:

$$\text{Baseline Equipment Efficiency} = \frac{\text{Baseline Equipment Output}}{\text{Baseline Equipment Input}} \qquad \text{Equation 3.8-6}$$

Table 3-44
Power Input vs. Power Output

% of Full Load Output	% of Full Load Input			% Energy Savings	Baseline Equipment Efficiency
	Inlet Mod	Var Speed			
		In Figure	Plus VFD Waste		
0%	72%	11%	16%	56%	0%
10%	74%	18%	23%	51%	14%
20%	76%	25%	30%	46%	26%
30%	78%	34%	39%	39%	38%
40%	81%	45%	50%	30%	50%
50%	83%	56%	61%	22%	60%
60%	86%	64%	69%	17%	70%
70%	89%	73%	78%	12%	78%
80%	93%	82%	87%	6%	86%
90%	96%	91%	96%	1%	93%
100%	100%	100%	105%	-5%	100%

Taking a compromise position between KEMA's field experience and the protocol-derived value gives us a compressor loading of 50%, which corresponds to a Percent Energy Savings of 22% and a Baseline Equipment Efficiency of 60%.

3.8.3 Assessment of the Market for Compressed Air Efficiency Systems – DOE Office of Industrial Technologies, 2001 (prepared by Xenergy)

This source provides market research data about the use of industrial air compressors in California as shown in Table 3-45. Since air compressor operation is not climate-dependent, there is no reason to believe that the hours of usage between California and New Jersey are significantly different. Averaging the data together gives us an average of 95 hours per week or

4957 hours per year. This is equivalent to 16 hours per day, 5 days per week, and 52 weeks per year. It is also much less than the 6000 hours per year that the protocol assumed.

Table 3-45
Hours of Compressed Air Operation

Hours of Operation/Week	CA Market Assessment (n = 218)	PG&E Survey (n= 268)
40 hours or less	12%	19%
41 - 80 hours	25%	36%
81 -120 hours	21%	22%
121 - 167 hours	18%	6%
168 hours/week (7 days x 24 hours per day)	24%	17%

3.8.4 Recommendations

We recommend that the program proceed conservatively with the promotion of VFDs on air compressors unless there is confidence that the compressor regularly operates in the 30%-70% window. Within a window of 30%-70% loading, VFDs can provide significant savings, but for compressors which typically operate outside that window savings will be minimal or negative.

We recommend that SmartStart specifically limit this prescriptive measure to facilities with a single operating compressor, who are either replacing their existing compressor with a new single compressor of the same size, or installing a retrofit VFD on the existing compressor. The customer should be asked whether they often they run their current compressor below 80% load. If they run above 80% of capacity most of the time, adding a VFD will cause them to use *more* energy.

We suggest this because, for multiple-compressor systems, it is much more difficult to determine whether a VFD would save energy. In addition, with multiple-compressor systems there are often many additional ways to save energy. Some of these other options might save more energy for less cost less than a VFD. An on-site audit would bring to light many of these opportunities, including receiver tanks, leak reductions, pressure reductions, staged or trim compressors, dryer improvements, maintenance schedules, and more. All of these additional opportunities depend on the facility and its usage trends and should be addressed in a custom incentive under *Compressed Air System Optimization*.

In the interest of providing additional information to future evaluators and to make the measure energy savings more intuitive, we recommend including the following information in the protocol in addition to the existing formulas. We recommend replacing the term Coincidence Factor (CF) with the term Peak Duty Cycle (PDC) which more accurately describes what the value represents.

$$\text{Yearly kWh/HP Savings} = \text{HRS} * \text{Maximum kW/HP Savings}$$

Equation 3.8-7

$$\text{Peak kW/HP Savings} = \text{PDC} * \text{Maximum kW/HP Savings}$$

Equation 3.8-8

$$\text{Maximum kW/HP Savings} = \text{Percent Energy Savings} * \frac{0.746\ \text{kW/HP Conversion Factor}}{\text{EFF}_b}$$

Equation 3.8-9

where:

HRS = Hours the compressor runs in an average year.
PDC = Fraction of time the compressor runs during peak hours.
Conversion Factor = Factor for converting kW to Horsepower
EFF_b = Efficiency of the industry standard compressor at average load

In addition, we recommend changing and expanding the values in the protocol as shown in Table 3-46. The Yearly Operating Hours are updated to reflect the Xenergy market study done for DOE discussed above. The Average Compressor Loading and Baseline Compressor Efficiency are based on a compromise between the existing protocol and KEMA engineers' field experience as discussed above in section 3.8.2.5. These suggested changes together would result in significantly higher energy savings than under the previous protocol.

We did not adjust any of these values for the New Jersey climate. Based on our experience in many regions, as we do not expect energy savings for VFDs on compressors to vary significantly by region.

Table 3-46

Recommendations for Updated Protocol Values

Component	Type	Value	Source
Motor HP	Variable	Nameplate	Application
Yearly kWh/HP Savings	Fixed	1356	Calculated
Peak kW/HP Savings	Fixed	0.237	Calculated
Maximum kW/HP Savings	Fixed	0.274	Calculated
PDC	Fixed	0.865	Aspen
HRS	Fixed	4957	Xenergy
Percent Energy Savings	Fixed	22%	ACEE, Engineering Estimate
EFF_b	Fixed	0.60	ACEEE
Average Compressor Loading	Fixed	50%	ACEEE
Modeling and Simulation of Air Compressor Energy Use – ACEEE Summer Study on Energy in Industry, 2005			
Assessment of the Market for Compressed Air Efficiency Systems – DOE Office of Industrial Technologies, 2001 (prepared by Xenergy)			
Aspen Systems Corporation, Prescriptive Variable Speed Drive Incentive Development Support for Industrial Air Compressors, Executive Summary, June 20, 2005 (Legacy source - no longer available)			

It must be noted that the suggested changes to values are *only* appropriate if the rebate is limited to facilities who are either replacing their existing compressor with a new single compressor of the same size, or installing a retrofit VFD on the existing compressor. Without these limitations, savings cannot be accurately predicted and these values are not appropriate.

We do not recommend any studies specifically into VFDs for compressors, but would encourage further market research into compressed air systems as a whole.

3.9 Gas Chillers (Absorption Chillers)

This measure is not properly named, and should be called “Gas Absorption Chillers.” The term “Gas Chiller” implies a gas-driven engine chiller, which is not addressed by this measure.

The energy savings protocol for gas absorption chillers and chiller/heaters is reviewed in this section. This measure encourages the installation of gas absorption chiller units to replace electric chillers.

3.9.1 Overview of Existing Protocol

Energy savings protocols for the gas absorption chiller measure are reviewed in this section.

3.9.1.1 Overview of Protocol

Measurement of energy savings for gas absorption chillers is based on following algorithms:

Winter gas savings = $(VBE_q – BE_b)/ VBE_q*IR*EFLH$ **Equation 3.9-1**

kW Savings = $Tons*(kW/Ton_b - kW/Ton_{gc})*CF$ **Equation 3.9-2**

kWh Savings = $Tons*(kW/Ton_b - kW/Ton_{gc)})*EFLH$ **Equation 3.9-3**

Summer gas usage (MMBtu) = MMBtu Output capacity/COP * EFLH **Equation 3.9-4**

Net energy savings = Electric energy savings + Winter gas savings – Summer gas usage **Equation 3.9-5**

where:

VBE_q = Vacuum boiler efficiency
BE_b = Efficiency of a baseline gas boiler
IR = Input Ratings = Therms/Hour
Tons = The capacity of a chiller (in tones) at the site design conditions
kW/Ton_b = The baseline efficiency for electric chiller
kW/Ton_{gc} = Parasitic electrical usage for gas chiller
COP = Coefficient of Performance for new gas chiller (efficiency measurement)
MMBtu Output capacity = Cooling capacity of gas chiller in MMBtu
CF = Coincidence Factor
EFLH = Equivalent Full Load Hours

Table 3-47
Variables Used in Protocol with Sources

Component	Type	Value	Source
VBE_q	Variable		Rebate application or manufacturer data
BE_b	Fixed	75%	ASHRAE 90.1
IR	Variable		Rebate application or manufacturer data
Tons	Variable		Rebate application
MMBTU	Variable		Rebate application
kW/Ton_b	Fixed	0.703 kW/ton (< 150 tons) 0.634 kW/Ton (150 to <300 tons) 0.577 kW/ton (300 tons or more)	Collaborative agreement and C&I baseline study. Assumes baseline using air cooled unit for chillers < 100 tons / water cooled unit for chillers > 100 tons
kW/Ton_{gc}	Variable		Manufacturer data
COP	Variable		Manufacturer data
CF	Fixed	67%	Engineering estimate
EFLH	Fixed	1360	JCP&L measured data

3.9.1.2 Review of Protocol

The program was not able to provide us with the JCP&L metered data used to determine EFLH, or the source for the engineering estimate used to determine CF.

The savings are calculated based on the boiler and the chiller capacities and efficiencies, and it is essentially a reasonable calculation method. However the protocol does not account for the fact that most equipment is oversized and operating at partial load. In addition, CF and EFLH would be much more accurate if they were broken out by building type and climate zone.

The protocols state that the cooling capacity of chiller in MMBtu is collected from the rebate application, but in the rebate application does not show a field box to populate this variable.

3.9.2 Review of Industry Practice

The current program rebates the replacement of an electric chiller with a gas absorption chiller, using the gas absorption chiller in summer in pace of an electric chiller and using the gas chiller/heater in winter in place of a regular gas boiler.

We did extensive research for similar studies in various jurisdictions to determine expected energy savings from this type of measure, but were not able to find any other program which either rebates or has even looked into rebating this type of chiller as a prescriptive measure.

3.9.3 Recommendations

We suggest the following recommendations for evaluating the energy savings for gas chillers.

First, we suggest doing a custom calculation.

Gas absorption chiller energy use is extremely site-specific. The reason for installing a gas absorption chiller is most commonly either a large amount of waste heat or a lot of extra boiler capacity. If the waste heat used to run the absorption chiller already exists on-site, then the absorption chiller energy use drops almost to zero. But if the waste heat isn't available (e.g. the boiler isn't running), then the absorption chiller is extremely inefficient.

We suggest using a custom temperature bin calculation method both for the baseline chiller and for the new proposed chiller.

The custom calculation should be site-specific, based on actual equipment replaced, sources of waste heat used, and the site-specific operating hours and load profile. A custom temperature bin calculation would be a good method. At minimum, the load profile must be based on operating hours during peak times and operating hours during off-peak times. Better resolution can be achieved by collecting the operating hours for occupied and non-occupied conditions. Information about the time variability of the availability of waste heat would also help to increase accuracy.

Second, we suggest creating a complete building simulation using energy modeling software. The various simulation tools like DOE-2, HAP, Trace and e-Quest have in built performance simulation modules for gas absorption chillers, gas chillers and for electric chillers also. Gas absorption chillers are a complex technology with many interactive effects with other building and industrial systems. Therefore, we suggest the option of using a computer simulation model to evaluate the energy savings for gas chillers.

3.10 Gas Fired Desiccants

This measure provides an incentive for installing a gas fired desiccant. Currently there is no Protocol developed for this measure.

The measure is included on the gas cooling application, and the incentive is based on cubic feet per minute (CFM) of process airflow. The application states that gas fired desiccants are eligible for an incentive when matched with core gas or electric cooling equipment.

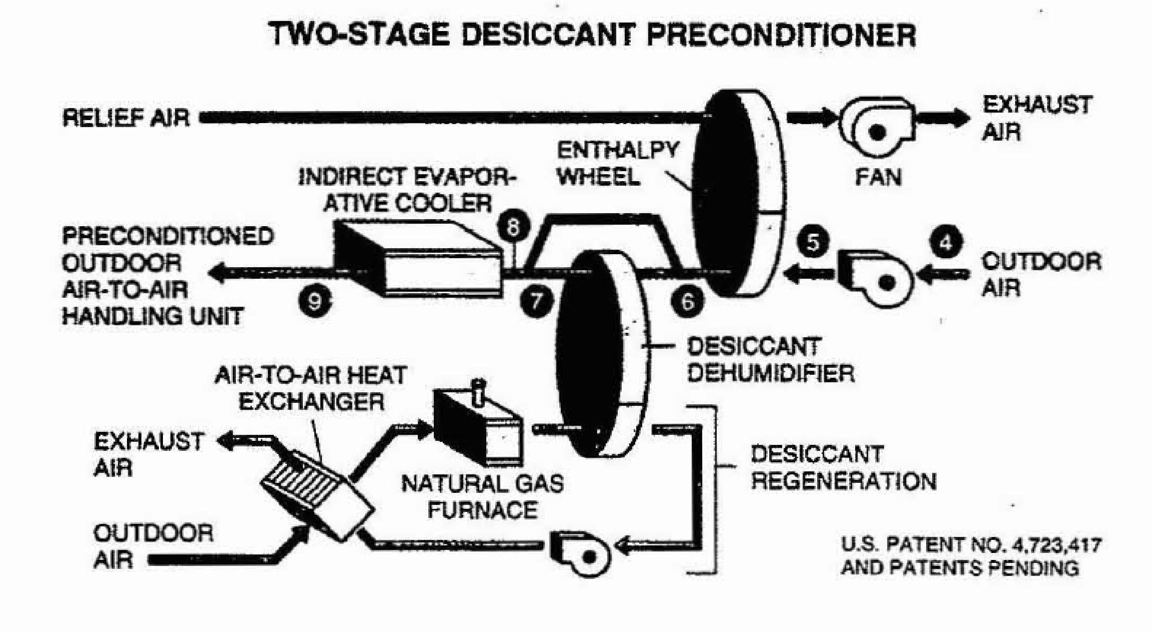
3.10.1 Discussion of Technology

Maintaining humidity levels is important to indoor air quality. As ventilation air is brought into a conditioned system, both sensible and latent heat loads are treated. Latent heat is associated with the phase change of water (dehumidification) and sensible heat is associated with changing the temperature of air.

There are two basic types of dehumidification, refrigerative and desiccant. Refrigerative dehumidification can be in the form of a stand-alone dehumidifier or in cooling equipment (chillers, direct expansion air conditioning, etc). Moisture is removed by cooling air to the dew point temperature and removing moisture in the form of condensation.

Desiccant systems move air across a desiccant material that absorbs moisture. The desiccant material is placed in a warm air stream to reverse the process, expelling moisture from the system and regenerating (drying) the desiccant. A typical two-stage desiccant system is shown in Figure 3-2 below.[34]

Figure 3-2
Typical Two-stage Desiccant System



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[34] Figure from “A Review of Desiccant Dehumidification Technology, NREL, Pesaran, October 1994.

Gas fired desiccant units dehumidify incoming ventilation air before it enters cooling equipment or conditioned space.

Determining the savings associated with installing a gas fired desiccant is challenging, because the baseline system efficiency will be highly variable. The baseline system is usually a cooling system that meets both latent and sensible cooling loads. The efficiency with which the baseline system treats these loads will be based on the individual system design and configuration and individual component efficiencies within the system. For example, the base case could be one or more package units (DX systems), a heat pump, or a chiller. The cooling equipment could be centralized or distributed. Each of these cooling equipment categories contains multiple variations. Thus, the baseline dehumidification equipment is difficult to quantify in a prescriptive measure.

In addition, some secondary savings are difficult to determine, including savings resulting from being able to install a lower capacity cooling system if a gas fired desiccant is used to remove part of the latent heat load.

3.10.2 Review of Resources

While it is clear that the latent load in ventilation air is significant and desiccant systems often offer a more efficient alternative to refrigerative systems, there has been little research done to determine how effectively the technology can be applied across the commercial sector. Until recently, gas fired desiccants were only used for specific applications that had tight climate control needs. Grocery stores and other specialty applications started using the technology as an energy efficiency measure. However, the technology has not been widely used as an efficiency measure in other standard commercial buildings.

We reviewed numerous secondary sources, and the more useful of these are summarized below.

3.10.2.1 Dehumidification and Cooling Loads from Ventilation Air, ASHRAE Journal, November 1997.

While internal loads for most buildings are sensible, ventilation loads are primarily latent (depending on location). This article[35] calculates latent and sensible loads for ventilation air based on annual weather conditions for many locations.

The author proposes a “ventilation load index” (VLI) which indicates latent and sensible heat loads per CFM. The VLI is in units of ton-hrs per SCFM-yr and is based on TMY-2 data from major cities. Harriman indicates that the VLI values for latent and sensible loads for Atlantic City are 4.1 and 0.6 respectively, while the respective values in Newark are 3.1 and 0.6. This supports the assertion in the paper that (except for desert climates) most latent loads in the United States are at least three times greater than sensible loads.

3.10.2.2 Improving Humidity Control with Energy Recovery Ventilation, ASHRAE Journal, August 2008.

This ASHRAE Journal article[36] discusses the evolution of ASHRAE Standards 90 and 62 which define maximum sensible cooling loads. According to this article, most cooling equipment is designed to be more efficient with sensible heat than with latent loads. The ability of cooling equipment to dehumidify is characterized by the sensible heat ratio, (SHR), the ratio of sensible cooling capacity to total capacity.

It is commonly accepted that efficiency improvements reflected in energy efficiency ratio (EER) have been at the expense of decreased latent capacity and increased SHR. Additionally, this article goes on to explain that building codes have stimulated a reduction in sensible loads through “energy-efficiency improvement measures such as better wall and roof insulation, reduction in window U-values, increase in solar shading, and more energy-efficient lighting,” while there has been almost no change in latent load demands.

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[35] “Dehumidification and Cooling Loads From Ventilation Air”, ASHRAE Journal, November 1997, Harriman III, Plager, Kosar.

[36] “Improving Humidity Control with Energy Recovery Ventilation”, ASHRAE Journal, August 2008, John Dieckmann.

3.10.2.3 Active Humidity Control through Gas-Fired Desiccant Humidity Pump, Novosel and Griffiths, 1988

Novosel and Griffths focus on re-introducing the HVAC market to desiccant dehumidifiers (also called humidity pumps) as a measure of energy and cost efficiency. The paper mentions that desiccant dehumidifiers were once integrated with air cooling systems for comfort, but they fell out of favor with the market due to cheap electricity and mass production.

With building simulation, the authors illustrate various benefits that can be realized with a desiccant dehumidifier. They maintain that when combined with a gas chiller the cooling capacity of a given unit can be increased 50% and the COP increased by 10%.

3.10.2.4 Federal Technology Alert: Two Wheel Desiccant Dehumidification System[37]

This paper provides a detailed discussion about how desiccant dehumidifiers work and why they are an energy efficiency improvement over conventional cooling methods to remove latent heat. It addresses some of the variables affecting desiccant performance, including process air moisture, process air temperature, process air velocity, reactivation air temperature, reactivation air velocity, amount of desiccant available to the air stream, and desiccant absorption characteristics.

The benefits of desiccant dehumidifiers are shown to be highest when there is available heat, electricity cost is high, and latent load fraction is greater than 25%.

According to this report:

> “Site-specific conditions and differing application requirements must be understood before use of desiccant-based hybrid systems in a building can be justified on economic grounds. A detailed analysis is generally required to compare the cost-effectiveness of a hybrid system with a conventional cooling system. While it is difficult to generalize the cost-effectiveness of the hybrid systems, there are a few applications where cost-effectiveness is so well established that detailed analysis is not necessary.”

This paper additionally states:

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[37] “Federal Technology Alert: Two wheel Desiccant Dehumidification System”, Produced for the U.S. Department of Energy by the Pacific Northwest Nation Lab, April 2007.

> "Estimation of energy savings from use of TWDS (two wheel desiccant systems) is an intricate task, because of the complexity involved in modeling the annual performance. A spread-sheet analysis using the ASHRAE bin method works well for the conventional system, but can not be used for desiccant systems."

This paper also provides a list of desiccant dehumidifier manufacturers.

3.10.2.5 A Review of Desiccant Dehumidification technology, NREL, Pesaran, October 1994

This document discusses the process of desiccant dehumidification and the various types of desiccant units. Additionally, it looks a case study savings results and ongoing research.

3.10.2.6 Munters Engineering Catalogue

The Munters design catalogue features a large range of options and examples of desiccant system configurations. It features a number of simple engineering calculations which provide some insight into what range might be acceptable for values such as desiccant wheel efficiency, heater efficiency, comfort temperatures, and humidity levels.

3.10.3 Recommendations

In order to provide a prescriptive protocol for energy savings, we would need to characterize both the baseline and new case for dehumidification. As discussed above, there is limited information available toward this goal. Secondary sources explicitly state that energy savings from using gas fired desiccants is highly site and system dependent. We were unable to find another program that provides gas desiccant incentives as a prescriptive measure.

For these reasons, we recommend that gas desiccants be treated as a custom measure.

Some of the factors that will affect energy saving of this custom measure will be:

- Baseline
    Equipment type
    Equipment Efficiency
    System Efficiency
    Individual component efficiencies
- Desiccant equipment
    Equipment efficiency (burner efficiency, wheel efficiency)
    Equipment type (enthalpy wheel or heat exchanger)

  - Source of regenerative air (indoor or outdoor)
  - Whether waste heat is available to heat regeneration air
- Building characteristics
  - Internal latent heat load[38]
  - Building operating hours
  - Building ventilation needs
  - Humidity control needs
  - Air infiltration rate and building shell

One possible approach to determine savings for gas fired desiccants is to use existing modeling software. There are several models that are currently available, including TRACE, DOE2.1E, and DesiCalc.

Another option is to conduct further research into the benefits of switching to a gas fired desiccant. This could be done by conducting measurement and verification of SmartStart customers who are installing the technology. Also, vendor surveys may offer insight into common practices in the market.

3.11 Gas Booster Water Heaters

This measure pertains to replacing an electric booster water heater with a gas booster water heater. This results in electrical peak demand savings (kW), electrical energy savings (kWh), and an increase in gas consumption.

3.11.1 Overview Gas Booster Water Heater Protocol

Booster water heaters are typically used in commercial kitchens in conjunction with a commercial dishwasher. The booster heaters heat water from the building water heater to a higher temperature for dish sanitation. There are other applications for booster water heaters, including laundries and dairies, but we believe the vast majority will be kitchen installations. The following discussion pertains to kitchen installations only.

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[38] Certain buildings will inherently have higher internal latent loads, driving up the moisture content of the exhaust air (air that is drying desiccant). Among these will be buildings with pools, high air infiltration, or high occupancy density, and supermarkets and ice arenas.

3.11.1.1 Overview of Current Protocol

The protocol calculates the electrical peak kW, electrical kWh savings, and the gas consumption increase incurred by replacing an electric booster heater with a gas booster heater.

The current algorithms are:

kW Savings = IR x EFF/3412 x CF *Equation 3.11-1*

kWh Savings = IR x EFF/3412 x EFLH *Equation 3.11-2*

Gas use increase = IR x EFLH *Equation 3.11-3*

where:

IR = Input rating of replacement gas booster heater (Btu/hr), from application or manufacturer data
EFF = Efficiency of the gas booster heater, from application or manufacturer data
CF = Coincidence Factor
EFLH = Equivalent Full Load Hours

3.11.1.1.1 Review of Protocol

Background: There are four basic kinds of commercial dishwashers: under-counter, door type, conveyor, and flight.[39] Some analyses break conveyor type down into single-tank and multi-tank. Each of these dishwashers uses a different amount of water, and each of these can be either low-temperature or high-temperature. The high temperature units require a booster heater to heat water from the building water heater to a temperature of at least 180°F for sanitation. Low-temperature units do not need a booster heater and so are not considered in this analysis. Under counter-type units are small and have their own internal electric booster heater, so they too are not considered here.

EFLH: EFLH is fixed at 1000 and PSE&G is given as the source. We do not know if this value was metered or have any information as to how it was determined.

Operating hours of the booster heater will vary widely with dishwasher type and among different types of restaurants or institutions. Even if operating hours can be estimated, EFLH is very difficult to accurately estimate, because these booster heaters vary energy input based on water

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[39] Flight type dishwashers are a high-capacity, “rackless” conveyor type model.

flow rate and inlet water temperature. So the percent of full load at which the booster heater operates will vary greatly even for dishwashers with the same booster heater and operating hours.

CF: CF is given as 0.27–0.32, based on the Summit Blue Market Assessment.[40] We do not know whether the program is using 0.27, 0.32, or some value in between.

We believe this value to be high based on the value of 1000 EFLH. If CF is the fraction of time equipment is operating during the peak period, CF values of 0.27–0.32 yield 2.16—2.56 hours per day during the peak hours. Dividing 1000 EFLH by an assumed 360 operating days per year yields only 2.78 hours per day total. This means that CF values of 0.27—0.32 predict that 78—91% of dishwashing occurs during the peak period, which is unrealistic.

EFF: This refers to the efficiency of the qualifying gas booster heater. The protocol states that EFF is from the application or manufacturer data. The rebate application for this measure asks for either Energy Factor (EF) or Annual Fuel Utilization Efficiency (AFUE). Our review of manufacturer specification sheets for gas booster heaters indicates that they do not always provide efficiency, so the customer may not be able to report it.

Efficiency of electric booster heaters is a separate matter. The algorithms for electrical peak demand and energy savings do not include efficiency, and thereby assume that electric boosters are 100% efficient. While they are highly efficient, 100% is unrealistic.

3.11.2 Review of Industry Practice

We reviewed secondary sources to find methods of calculating energy use of booster water heaters. The Energy Star calculator for dishwasher replacement,[41] booster heater manufacturer savings calculators, and other manufacturer data proved valuable in this effort.

We searched for and did not find protocols from any other programs for prescriptive gas booster water heater replacement, though Wisconsin's Focus on Energy program does provide booster heater calculations in its commercial dishwasher replacement protocol. Their calculation is based on the Energy Star calculator.

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[40] Energy Efficiency Market Assessment of New Jersey Clean Energy Programs. Book III – Commercial and Industrial Programs. July 20, 2006.

[41] http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/CalculatorCommercialDishwasherBulk.xls

3.11.2.1 Sensible Heat Equation for Energy Use

All of the sources we found use the sensible heat equation, rather than capacity and EFLH, to calculate the energy use of a booster water heater.

The sensible heat equation is:

$$\textbf{Output Energy} = m * c_p * \Delta T \qquad \text{Equation 3.11-4}$$

or

$$\textbf{Input energy} = \text{volume of water per year} * \text{density} * c_p * \Delta T / EFF \qquad \text{Equation 3.11-5}$$

Where:

density = density of water, 8.3 lb/gal
c_p = specific heat of water, 1 Btu/lb-°F
ΔT = temperature rise provided by the booster heater, in °F
EFF = efficiency of the booster heater (gas or electric)

Note that the sensible heat equation eliminates the need to estimate EFLH.

The manufacturers' calculators require inputs of water flow rate, hours of use, and input and exit water temperatures. The most accurate way to calculate energy savings for a given installation would be to require these values on the application. However, that would effectively require that rebates be custom rather than prescriptive.

To provide a prescriptive protocol for energy savings using this equation, we must determine reasonable values for each variable, including the amount of water heated, temperature rise required, and efficiency.

3.11.2.1.1 Amount of Water Heated

The amount of water heated by a given booster heater will vary greatly based on the type of restaurant/institution and number of meals served. It will also vary based on the dishwasher type.

The Energy Star calculator is the only source we found that provides estimates of the amount of water heated. It estimates this value based on the number of racks of dishes that the dishwasher processes per day. An analysis based on racks per day excludes flight type dishwashers, which are rackless. We pursue this analysis because flight type dishwashers make up a small percentage of the market.[42]

The calculator provides values for racks/day, gallons/rack, and minutes/rack for each dishwasher type from the Food Service Technology Center (FSTC) and Lawrence Berkeley National Labs (LBNL). These values are used to calculate gallons per year, assuming 360 operating days per year, and are presented in Table 3-48.

Table 3-48
Energy Star Calculator Dishwasher Data

Dishwasher Type	Racks/Day	Gal/Rack	Gal/year
Door Type	280	1.44	145,152
Single-tank Conveyor	400	1.13	162,720
Multi-tank Conveyor	600	1.10	237,600

Racks per Day: FSTC is listed as the source for racks per day for door type dishwashers. According to the FSTC, this value is based on informal interviews. For single and multi-tank conveyors, the source listed for the racks/day values is "assumption." It is not clear what this assumption is based on. When the racks/day values of 400 and 600 are multiplied by the minutes per rack data provided (0.3 and 0.2 minutes/rack, respectively), both values yield exactly 2 hours of operation per day. This suggests that the actual assumption may have been the hours/day figure.

Based on the unreliability of assumed usage, we recommend that the program ask for racks/day on the application. We believe that the reliability of the self-reported racks per day value will be greater than that of the assumptions in Table 3-48.

Gallons per Rack: LBNL is the cited source of the gallons/rack data. LBNL obtained this data from NSF 3 standards, using an average value across non-Energy Star models.

Energy Star strives to represent the top 25% of product models available when it sets its specifications (In the case of door type dishwashers, 14 of 61, or 23%, meet the standard). 43

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[42] In 2001, flight-type dishwashers made up only 5% of the installed base and only 1% of sales, according to data presented by the EPA in "Energy Star for Commercial Dishwashers: Sizing up the Savings Opportunity".

[43] http://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/Spec_Req_NRA_Presentation_5_22_06.pdf

We therefore recommend that gallons per rack be calculated as a weighted average of 75% of the average reported by LBNL and 25% of the Energy Star standard, as shown below.

Table 3-49
Weighted Average Gallons per Rack

Dishwasher Type	Non-Energy Star (gal/rack)	Energy Star (gal/rack)	Weighted average (gal/rack)
Door Type	1.44	0.95	1.32
Single-tank conveyor	1.13	0.70	1.02
Multi-tank conveyor	1.10	0.54	0.96

Note that gallons per rack ranges from 0.96 to 1.32. For greatest accuracy, we recommend that the program ask for the type of dishwasher on the application, and reference Table 3-49 for gallons per rack.[44] However, if the program would like to limit the information required on the application, we recommend that the conservative value of 0.96 gal/rack be used.

3.11.2.1.2 Temperature Rise

The outlet temperature of 180°F is the minimum required for sanitation. The actual outlet temperature may be slightly greater than 180°F. Using a value of 180°F will produce a conservative energy savings estimate. The Energy Star calculator assumes 180°F, so we recommend that 180°F be used for outlet temperature.

The Energy Star calculator assumes 140°F inlet temperature. This value is often cited as the outlet temperature of a typical restaurant water heater. However, according to FSTC, many institutions and schools will have an inlet temperature not of 140°F, but of 110°F instead. The FSTC tests booster heaters at both of these inlet temperatures for this reason.[45]

An assumption of 140°F inlet temperature may not be accurate for all program participants, though it would be accurate for many restaurants. In the absence of customer data or further study, we recommend using 140°F. Note that this may underestimates energy savings for customers using 110°F inlet water. Asking for inlet temperature on the application would produce more accurate results.

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[44] Wisconsin Focus on Energy also uses a lookup table based on dishwasher type for dishwasher incentives.

[45] http://www.fishnick.com/publications/appliancereports/warewashers/Precision_Temp_PT-56_Booster_Heater.pdf

3.11.2.1.3 Efficiency

Gas Booster Efficiency: The program currently asks for booster heater efficiency (EF or AFUE) on the rebate application.[46] Of the three reviewed manufacturers of gas booster heaters, only Vanguard provides efficiency on their product specification sheets (listed at 88% across all models). Hatco and PrecisionTemp provide heat input and water flow values that suggest a thermal efficiency of 80%.

An FSTC test of the PrecisionTemp PT-56 indicates that it is greater than 85% efficient at both full and half load, which is higher than our 80% calculation. FSTC's test of the Vanguard Powermax indicates that it performs at the listed efficiency of 88%.[47] We do not have test data for any Hatco models.

The energy savings calculators from both Energy Star and Hatco assume 80% efficiency. Based on the above tests, this may be low. Wisconsin Focus on Energy uses the Energy Star model but assumes 85% efficiency.[48] If the program chooses to fix efficiency at a single value, we recommend 85%.

Since there are few manufacturers of gas booster heaters, further research could produce a lookup table with the efficiencies of each. This would also eliminate the need to ask for efficiency on the application.

Electric Booster Efficiency: The current protocol effectively assumes that electric booster heaters are 100% efficient, which produces a conservative estimate of energy savings. The Energy Star calculator assumes 95% efficiency, and the Hatco calculator and Wisconsin Focus on Energy 98%.

We recommend that SmartStart use an electric booster heater efficiency of 98%.

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[46] This may be because the booster heater incentive shares an application with the self-contained water heater application.

[47] http://www.fishnick.com/publications/appliancereports/warewashers/Vanguard_Booster_Heater.pdf

[48] The Wisconsin Focus calculation is for savings due to replacing a standard commercial dishwasher with an energy star model that uses less water. Therefore, assuming a higher efficiency for the booster heater reduces the estimate of gas use in each case, and is conservative for savings.

3.11.2.2 Peak Electric Demand Savings

We have found no studies regarding booster heaters usage patterns, and so we cannot accurately predict what percentage of the total energy use occurs during peak hours. Without data, this analysis amounts to quantifying a qualitative argument, and is necessarily imprecise.

As discussed in the protocol review section, we believe the current value of CF is high, based on a comparison with the existing EFLH value. However, as discussed above, we recommend eliminating these variables by switching to the racks per day method using the sensible heat equation.

Demand savings in kW is defined as the average kWh saved during the peak period divided by the hours in that period. So, in order to use the sensible heat equation to estimate demand savings, we must estimate the percent of dishwashing that occurs during the peak period.

In the absence of accurate data, we offer the following:

On any given day, perhaps 2/3 of dishwashing in the average restaurant occurs during peak hours (12-8 pm), with 1/3 occurring off-peak. We suggest that approximately 70% (5/7) of dishwashing will occur on weekdays.[49] Multiplying these values yields a fraction of 0.5.[50] For the time being, we recommend that 0.5 be used as an estimate of the fraction of dishwashing done during the peak period.

We recommend that the program study the use profile of booster heaters with respect to time.

3.11.3 Recommendations

The above analysis is not ideal, in that it excludes installations other than those on dishwashers. It also excludes those on rackless, flight-type dishwashers. Since we have no data regarding the operation of booster heaters in these installations, we recommend that they be considered for a custom measure if requested.

Energy use variability is extremely high between different booster heater installations and is difficult to predict, even amongst dishwasher applications. This may be the reason that other programs do not offer prescriptive rebates for this technology. For this reason, the program

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[49] Indeed, 5/7 may be a bit high, since Monday and Tuesday are usually the days with fewer meals served.

[50] Given the obvious imprecision of this analysis, we hold the value to one decimal place.

might consider removing the prescriptive measure, leaving gas booster water heaters as a custom measure.

3.11.3.1 Algorithm Recommendations

For the current prescriptive measure we make the following recommendations, which we believe will provide accurate energy savings estimates for the highest possible percentage of installations:

- Use the sensible heat equation to calculate electrical energy savings and gas use increase based on racks per day.
- Ask for racks per day and dishwasher type on the application, and use dishwasher type to look up gallons per rack in Table 3-49.[51]
- Use a 40°F temperature rise.
- Fix the efficiency of gas booster heaters at 85%, and electric booster heaters at 98%.
- Convert gas consumption to therms to be consistent with other measures

The energy algorithms are then as follows:

$$\text{kWh Savings} = RPD \times GPR \times OD \times D \times c_p \times \Delta T / EFF_e / 3412 \qquad \text{Equation 3.11-6}$$

$$\text{kW Savings} = 0.5 * RPD * GPR * D * c_p * \Delta T / (EFF_e * 3412) / 8\ hr \qquad \text{Equation 3.11-7}$$

$$\text{Gas Energy Increase} = RPD \times GPR \times OD \times D \times c_p \times \Delta T / EFF_g / 100{,}000 \qquad \text{Equation 3.11-8}$$

where:

RPD = racks per day, from the application
GPR = gallons per rack, weighted average, from Table 3-49 based on dishwasher type
OD = operating days per year, 360 days, assumed
D = density, 8.3 lb/gal
c_p = specific heat of water, 1 Btu/lb-F
ΔT = 40°F temperature gain
EFF_g = efficiency of electric booster heater, 0.98
EFF_e = efficiency of gas booster water heater, 0.85

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[51] Recommended changes to the application could make it necessary to separate the gas booster heater application from the general water heating application, or at least provide a different section with different inputs.

3412 = conversion factor from Btu to kWh
100,000 = conversion factor, Btu/therm
0.5 = assumed fraction of racks washed during peak period

We have not adjusted any of the above factors for the New Jersey climate. We do not expect energy savings incurred by using gas booster heaters to vary significantly by region.

3.11.3.2 Additional Recommendations

We recommend that SmartStart perform further research into dishwasher use with respect to time, and typical booster water heater input temperatures (conventional water heater output temperatures).

We recommend that SmartStart carry out a market research study on booster heater installations other than dishwashers.

3.12 Gas Water Heaters

This measure pertains to replacing a less efficient gas water heater with a more efficient model. The incentives apply to smaller units (50 gallons or less) with energy factors of at least 0.62 and larger units with AFUE values of at least 84% or 85%, depending on MBH capacity.

3.12.1 Overview of Existing Gas Water Heater Protocol

The protocol states that this measure is limited to smaller-scale domestic water heaters of 50 gallons or fewer. However, according to the application the program now allows for water heaters greater than 50 gallons. This section of the protocol review concerns water heaters of 50 gallons or fewer. A discussion of larger water heaters follows in Section 3.12.3.

3.12.1.1 Overview of Protocol

The current algorithm for gas savings is:

$$\textbf{Gas Savings} = ((EF_q - EF_b)/EF_q) \times \textbf{Baseline Usage} \qquad \textit{Equation 3.12-1}$$

Where:

EF_q = Energy factor of the qualifying water heater, from application or manufacturer data.
EF_b = Energy factor of the baseline water heater.

Baseline Usage = Annual gas usage of baseline water heater, fixed at 254 therms.

Baseline energy factor is calculated by:

$EF_b = 0.67 - 0.0019 \times \text{Fluid Capacity (gal)}$ **Equation 3.12-2**

Where:

Fluid Capacity = 40 gallons

Substituting 40 gallons into the equation yields a fixed value for EF_b of 0.594.[52]

3.12.1.2 Review of Protocol

The algorithm is a standard engineering equation for gas savings due to changes in efficiency, and is consistent with equations used by Minnesota and Arkansas programs.

Baseline Energy Factor, EF_b: The energy factor currently used is based on a 40 gallon model. Forty gallon models are by far the most common, and most other small water heaters will be 30 or 50 gallons. Using Equation 3.12-2, we calculate 0.613 for a 30 gallon, 0.594 for 40 gallon, and 0.575 for a 50 gallon. Using the actual gallons of the water heater entered on the application instead of assuming 40 gallons would be more accurate.

Baseline Usage: Baseline gas usage is fixed at 254 therms, a value taken from the DOE-reported average for residential water heaters.[53] That value is based on hot water consumption of 64 gallons per day, 365 days/yr, heating from 58°F to 135°F.

These temperature values are widely cited and used by many programs, producing a temperature rise of 77°F. However, actual hot water consumption, and therefore baseline use, will vary greatly by building type. Commercial hot water use is not accurately predicted by average residential hot water use.

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[52] Note that based on a 40 gallon unit, the calculated EF is 0.594, not 0.544 as reported in the current protocol.

[53] http://www1.eere.energy.gov/femp/procurement/eep_gas_waterheaters.html

3.12.2 Review of Industry Practice

The bulk of our analysis of this protocol focuses on establishing a baseline for gas usage in a commercial building water heater. We found two secondary sources, both of which provide water heating energy use per square foot (energy use density) for various building types. We reviewed one study prepared by Lawrence Berkeley National Laboratory (LBNL) in 1995, and one from the Energy Information Administration's (EIA) Commercial Building Energy Consumption Survey (CBEC).[54] We also compared programs in Minnesota and Arkansas which use energy density to estimate energy savings by building type.

3.12.2.1 Water Heating Energy Use Density in Commercial Buildings

The LBNL report uses data from the Electric Power Research Institute and ASHRAE for gallons of hot water per unit (units include person, meal/day, room, employee, patient, etc.) per day. It uses units per 1000 ft^2 from a previous LNBL study and assumes operating days per year for each building type. These values are multiplied to determine annual gallons of hot water per 1000 ft^2.

The sensible heat equation is used to calculate energy demand, based on a temperature gain of 85 °F for all building types besides health, for which they assume 125°F. These values are presented in Table 3-50 below.

Table 3-50
Hot Water Energy Density (LBNL)

Building Type	Hot Water Demand (gal/day/1000 sf)	Hot Water Energy Demand (kBtu/1000 sf)
office	568	402
fast food restaurant	200,469	141,942
sit down restaurant	297,840	210,886
retail	730	517
grocery	777	550
warehouse	240	170
elementary school	1,143	809
jr. high/high school	3,429	2,428
health	125,286	130,454
motel	36,274	25,684
hotel	11,242	7,960
other	175	124

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[54] http://www.CBEC.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set19/2003html/e07.html

The CBEC 2003 survey also provides estimates for water heating energy use density by end use, shown in Table 3-51. This data is gathered from utility metering data for overall facility consumption. Individual end uses, like water heating, are allocated from that metered data based on a model. Information about the assumptions for the model is not yet publicly available.

Table 3-51
Hot Water Energy Density (CBEC)

Building Type	Hot Water Energy Demand (kBtu/1000 sf)
Education	5.2
Food Sales	3.2
Food Service	40.0
Health Care	28.9
- Inpatient	39.4
- Outpatient	3.5
Lodging	29.2
Retail (Other Than Mall)	1.0
Office	1.6
Public Assembly	0.9
Public Order and Safety	15.1
Religious Worship	0.9
Service	0.9
Warehouse and Storage	0.7
Other	1.7

3.12.2.2 Commercial Building Size

We recommend that the program ask for the square feet served by the water heater on the application. Mean[55] and median[56] building square footage data are available from the 2003 CBEC Survey Report, but this data is not site-specific and does not account for buildings and businesses that have more than one water heater. If the mean or median were used to calculate energy use, the results would be inaccurate for projects in buildings with multiple water heaters. Hot water energy use for the average entire building may be much greater than that of the average water heater being replaced. Therefore we recommend asking for and using the actual square-footage served by the water heater.

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[55] http://www.CBEC.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set1/2003html/b1.html

[56] http://www.CBEC.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set1/2003html/b2.html

3.12.2.3 Comparison of LBNL and CBEC Energy Density Estimates

Both the LBNL and CBEC values predict significant variability by building type. Table 3-52 compares the values for those building types where the categories match up between the two data sets. Since a temperature gain of 77 °F is more widely used, we have prorated the LBNL values to be based on that temperature gain and converted the result from kBtu/1000ft2 to kBtu/ft2.

Table 3-52
Comparison of CBEC and LBNL Hot Water Energy Densities

Building Type	CBEC Hot Water Energy Density (kBtu/sf)	LBNL Hot Water Energy Density (kBtu/sf)
Food Sales/Grocery	3.2	0.5
Health Care	28.9	80.4
Retail/Mercantile	1.0	0.5
Office	1.6	0.4
Warehouse/Storage	0.7	0.2

Note that even among the categories with consistent building type descriptions, the data from the two sources differ significantly.

Programs in Minnesota and Arkansas use the LBNL values for hot water energy use density and square feet served from the application to determine energy use and savings. However, we believe that the LBNL data underestimates hot water energy use for many building types.

The CBEC reports the median office size in the United States is 4000 ft^2. Multiplying that square footage by the CBEC value of 1.6 kBtu/ft2 and converting to therms yields 63 therms/yr. The same treatment using the LBNL value of 0.4 kBtu/ft2 yields 16 therms/yr. This analysis for grocery/food sales yields 90 therms/yr using the CBEC value and 14 therms for LBNL.

According to this example, the CBEC data yields more reasonable results. The median 4000 ft^2 office uses about ¼ of the energy used in a residential home, which is reasonable. The CBEC data are extracted from whole-building gas metering data. While we would like to know the basis of the allocation from total building gas use to water heating gas use, based on the calculated values for annual energy use we believe that the CBEC data is more accurate.

3.12.3 Large (>50 Gallon) Water Heaters

The current protocol and application were written for water heaters of 50 gallons or fewer. Larger water heaters are now covered by the same protocol and application. For water heaters greater than 50 gallons, the incentive and qualifying requirements depend on the heating capacity of the unit. Water heaters of less than 1500 MBtuH must be at least 85% efficient (AFUE), and those between 1500 and 4000 MBtuH must be at least 84% (AFUE).

The addition of larger water heaters to this measure presents several new challenges with regard to the protocol and application, as discussed below.

3.12.3.1 Applicability of Current Algorithm

The current algorithm is written in terms of energy factor (EF). The qualifying requirements for larger water heaters are in terms of Annual Fuel Utilization Efficiency (AFUE), not EF. Fortunately, the form of the current algorithm holds true when using AFUE, as long as AFUE is used for both the qualifying and baseline cases. The algorithm based on AFUE would be:

$$\text{Gas Savings} = ((AFUE_q - AFUE_b)/AFUE_q) \times \text{Baseline Usage} \qquad \text{Equation 3.12-3}$$

Where:

$AFUE_q$ = Annual Fuel Utilization Efficiency of the qualifying water heater, from application or manufacturer data.

$AFUE_b$ = Annual Fuel Utilization Efficiency of baseline water heater.

However, water heater manufacturers’ specifications are typically in terms of thermal efficiency (TE), not AFUE. We do not know whether the SmartStart program is currently using these terms interchangeably. Using AFUE instead of TE may be confusing to the customer, and the customer is likely reporting thermal efficiency on the application, since that is the data available to them. The SmartStart program should clarify which of these terms are being used both on the application and in the protocol, and consider using thermal efficiency rather than AFUE.

3.12.3.2 Current Code and Division between Small and Large Water Heaters

It should also be noted that current New Jersey code requirement for water heaters, based on ASHRAE 90.1-2004, separates water heaters into size categories based on gas input capacity (Btu/h) not by water storage capacity (gallons). For storage water heaters less than 75,000 Btu/h, the code is defined by Equation 3.12-2 which uses energy factor (EF). For those greater than 75,000 Btu/h, the code is based on a value of standby loss (SL), which is calculated based on thermal efficiency. Because of this, the code cannot be used as a source for baseline thermal efficiency.

The Federal EPACT standard upon which Equation 3.12-2 is based applies to water heaters between 20 and 50 gallons with a maximum energy input of 75,000 Btu/h. For this reason, the SmartStart program may want to consider including water heaters below 75,000 Btu/h in its small water heater measure.

3.12.3.3 Other Programs' Large Water Heater Methods

Minnesota's Centerpoint Energy uses an algorithm of the same form as SmartStart. The algorithm uses efficiency in terms of EF for small water heaters and in terms of thermal efficiency for large water heaters. For smaller water heaters (<75,000 Btu/h), the EF is calculated by Equation 3.12-2. For larger storage water heaters, the baseline efficiency value is a thermal efficiency (TE) equal to 0.78. The division between small and large water heaters is based on Minnesota's 1999 code, which is based on the National Appliance Energy Conservation Act.

New York's NYSERTA program also uses thermal efficiency for its baseline for storage water heaters greater than 75,000 Btu/h. They use a thermal efficiency of 0.80 as their baseline.

Note that both of these programs use 75,000 Btu/h as the division between small and large water heaters, and that is consistent with New Jersey energy code.

3.12.4 Recommendations

We recommend that the energy savings algorithm be based on energy use density by building type, using a lookup table based on CBEC data. We recommend that the program ask for the square footage served by the water heater on the application.

We also recommend that the algorithm be generalized such that efficiency may be expressed in EF for small water heaters and thermal efficiency (TE) for larger water heaters. The efficiency term used for the baseline water heater must also be used for the qualifying water heater. The generalized algorithm is as follows:

Gas Savings = $((EFF_q - EFF_b)/EFF_q)$ x Energy Use Density x Area / 100 *Equation 3.12-4*

Where:

EFF_q is the efficiency of the qualifying water heater from the application, EF or TE
EFF_b is the efficiency of the baseline water heater, EF or TE
Energy Use Density (kBtu/ft^2/yr) is taken from Table 3-53
Area = square feet served by the water heater, from the application
100 = conversion factor from kBtu to therms

Table 3-53
Energy Use Density Lookup Table

Building Type	Energy Use Density (kBtu/1000 sf/yr)
Education	5.2
Food Sales	3.2
Food Service	40.0
Health Care	28.9
- Inpatient	39.4
- Outpatient	3.5
Lodging	29.2
Retail (Other Than Mall)	1.0
Office	1.6
Public Assembly	0.9
Public Order and Safety	15.1
Religious Worship	0.9
Service	0.9
Warehouse and Storage	0.7
Other	1.7

These values have not been adjusted for the New Jersey climate. Water heating energy use density is dependent both on hot water consumption and on temperature rise. We do not expect hot water consumption to vary significantly by region. Temperature rise will depend on average water supply temperature, which is somewhat dependent on climate. However, we did not find studies of seasonal water supply temperature for New Jersey or other regions, and conducting such a study is beyond the scope of this report.

For water heaters of 50 or fewer gallons, efficiency (EFF) in Equation 3.12-4 should be in terms of EF. We recommend that the actual gallons of the water heater be used in Equation 3.12-2 to calculate EF_b, as follows:

EF_q = Energy Factor of qualifying water heater, from application

EF_b = Energy Factor of baseline water heater, where:

$EF_b = 0.67 – 0.0019 \times \text{Fluid Capacity (gal)}$

For water heaters greater than 50 gallons, efficiency (EFF) in Equation 3.12-4 should be in terms of thermal efficiency (TE). We found programs that use 0.78 – 0.80 for baseline thermal efficiency. We recommend using the more conservative value of 0.80.

TE_q = thermal efficiency of qualifying water heater, from the application

TE_b = thermal efficiency of the baseline water heater, fixed at 0.80.

Values for use in the algorithms are shown below in Table 3-54.

Table 3-54

Protocol Variables

Variable	Type	Size	Value	Source
EFF_q	Variable	<50 gal. or ≤75,000 Btu/h	EF	Applicaton
		>50 gal or >75,000 Btu/h	TE	
EFF_b	Fixed	<50 gal. or ≤75,000 Btu/h	EF	Calculated
		>50 gal or >75,000 Btu/h	0.80 TE	NYSERTA
Energy Use Density	Variable	All	kBtu/1000 sf/yr (From Table)	CBEC 2003 Study
Fluid Capacity	Variable	All	Gallons	Application

3.13 Furnaces and Boilers

This measure pertains to replacing a gas boiler (4000 MBH or less) or furnace (no size limit) with a more efficient furnace or boiler. The boiler or furnace must be used for heating – industrial furnaces and boilers are not eligible for this measure.

3.13.1 Overview of Existing Protocol

A review of the furnace and boiler protocol follows, with an analysis of the protocol, its variables, and its assumptions.

3.13.1.1 Overview of Furnace and Boiler Protocol

The current algorithm is as follows:

Gas Savings = ((AFUE$_q$ – AFUE$_b$)/AFUE$_q$) x CAPY x EFLH Equation 3.13-1

where:

AFUE$_q$ = Annual Fuel Utilization Efficiency of the qualifying furnace or boiler, from application or manufacturer data

AFUE$_b$ = Annual Fuel Utilization Efficiency of the baseline furnace or boiler, EPACT standards of 78% for furnaces and 80% for boilers

CAPY = Capacity of furnace or boiler in therms/hr

EFLH = Equivalent full load heating hours, fixed at 900

3.13.1.2 Review of Protocol

The algorithm is the basic engineering equation for energy savings due to improved efficiency. It is consistent with that provided by the DOE best practices for steam boilers:[57]

Annual Savings = Fuel Consumption x (E1/E2) Equation 3.13-2

Fuel consumption then must be calculated based on the capacity of the boiler or furnace. The program currently calculates fuel consumption using EFLH and input capacity of the boiler or furnace. SmartStart uses an EFLH of 900, while Summit Blue calculated an EFLH of 1500 from climate bin data.

EFLH is difficult to estimate for an average boiler or furnace across the commercial sector and will vary based on building type and operating hours. The current method does not account for differences in heating energy load by building type.

The baseline AFUE values agree with EPACT standards which are commonly used as the base case in this type of calculation.

3.13.2 Review of Industry Practice

We found programs and secondary sources that use two basic methods of calculating heating load. Wisconsin Focus on Energy uses heating degree days, design temperatures, and an

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[57] http://www1.eere.energy.gov/industry/bestpractices/pdfs/steam4_boiler_efficiency.pdf. The DOE algorithm is for savings in dollars, and we have removed the fuel cost portion of the algorithm.

oversize factor to calculate heating load. Other programs, including Efficiency Vermont, Energy Star, and California's Database for Energy Efficient Resources (DEER) use heating load density estimates. Some of these programs provide for variations in heating load by building type, while others do not.

3.13.2.1 Wisconsin Focus on Energy

Wisconsin's Focus on Energy (Focus) uses heating degree days (HDD) to calculate gas energy savings. They use the following equation to calculate energy savings for furnace replacement:

$$Gas\ Energy\ Savings = \left[\frac{(0.8\ x\ CAPY_{out}\ x\ HDD\ x\ 24)}{\Delta T} \right] x \left(\frac{1}{AFUE_b} - \frac{1}{AFUE_q} \right) \qquad \text{Equation 3.13-3}$$

where:

0.8 = oversize factor, the fraction of furnace capacity that represents heat load
$CAPY_{out}$ = output capacity of base boiler
HDD = heating degree days, a fixed, population-weighted state average
24 = conversion from days to hours
ΔT = the difference between the 65°F balance point and a fixed outdoor design temperature

The oversize factor accounts for the fact that engineers typically oversize systems to account for expansion and to avoid customer complaints about cold buildings. This program assumes an oversize factor of 25%, or 1/1.25. The oversize factor depends on the design engineer, but some degree of oversize is common practice. We have seen 25% and 30% used, which yield oversize factors of 0.77-0.8.

Replacing output capacity with input capacity times $AFUE_b$ yields:

$$Gas\ Energy\ Savings = \left[\frac{(0.8\ x\ CAPY_{in}\ x\ HDD\ x\ 24)}{\Delta T} \right] x \left(1 - \frac{AFUE_b}{AFUE_q} \right) \qquad \text{Equation 3.13-4}$$

This equation is consistent with the current algorithm used by the SmartStart program and the DOE. The differences are that Focus on Energy uses an oversize factor and makes their assumptions more explicit in their algorithm. Hidden in the SmartStart protocol's EFLH value is a calculation based on HDD, even if it is not apparent from the algorithm.

3.13.2.2 New Jersey Climate Data and Heating Degree Days

Reviewing the SmartStart protocol requires an estimate of HDD and heating design temperatures, which we pursue here using New Jersey climate data.

Recognizing the variation in New Jersey weather from shore areas to the highlands and from north to south, we obtained hourly Typical Meteorological Year Version 3 (TMY3) climate data from the National Solar Radiation Database[58] for the four New Jersey climate zones based on representative cities. Table 3-55 provides the list of counties matched with the weather station from which data was collected.[59]

Table 3-55
Weather Stations Used for New Jersey Counties

Weather Station (USAFN Number)	County
Atlantic City (724070)	Atlantic, Cape May, Monmouth, Ocean
Newark (725020)	Bergen, Essex, Hudson, Middlesex, Passaic, Union
Philadelphia, PA (724080)	Burlington, Camden, Cumberland, Gloucester, Salem
Monticello, NY (725145)	Hunterdon, Mercer, Morris, Somerset, Sussex, Warren

Next we obtained the heating design temperatures for Atlantic City, Newark, and Philadelphia from the 1997 ASHRAE Fundamentals Handbook.[60] Design temperature was not available for Monticello, so we used the relationship between design temperatures for the other cities and their TMY3 data to predict design temperature for Monticello.[61]

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[58] http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

[59] We matched counties and weather stations based on an overview of New Jersey's climate from the Office of the New Jersey State Climatologist (http://climate.rutgers.edu/stateclim/?section=uscp&target=NJCoverview) and proximity with available weather stations.

[60] Using the 99% HDD value.

[61] We estimated a design temperature based on the number of TMY3 temperature readings for Atlantic City and Newark that are below their design temperatures. The average of these is 76 hours of the year below design temperature. Applying that standard to the Monticello TMY3 data yields a design temperature of 8°F.

Table 3-56
Heading Degree Days and Outdoor Design Temperatures by Zone

Weather Station	HDD	Outdoor Design Temperature (F)
Atlantic City	5073	13
Newark	5057	14
Philadelphia, PA	4824	15
Monticello, NY	7060	8

These values for HDD and outdoor design temperature can then be used in the above equation to generate an algorithm for each climate zone. One weakness in the analysis, however, is that it contains no mechanism for adjusting savings by building type.

3.13.2.3 Heating Energy Density Method

Another method of calculating the heating load on a building is to obtain a value for heating load per square foot. Efficiency Vermont and Energy Star both use a version of this method. California's Database for Energy Efficient Resources (DEER) and the Energy Information Administration (EIA) provide energy density data for use with this method.

3.13.2.3.1 Efficiency Vermont

The Efficiency Vermont algorithm for gas heating replacement[62] is:

$$Energy\ Savings = Heating\ Energy\ Density\ x\ SF\ x\ EFF_b \left(\frac{1}{EFF_b} - \frac{1}{EFF_q} \right) \qquad \text{Equation 3.13-5}$$

where:

Heating Energy Density = 72 kBtu/ft^2 (average of office and retail estimates for Upstate New York, as reported by NYSERDA[63])
SF = Square Feet
EEF_b = Efficiency of the baseline equipment
EFF_q = Efficiency of the qualifying equipment

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[62] Efficiency Vermont Technical Reference Manual No. 2005-37

[63] Gas DSM and Fuel-Switching Opportunities and Experiences, NYSERDA, 1994, NYPP estimate for upstate NY, average of office and retail.

This model does not provide a mechanism to vary heating load by building type or climate zone, and the heating energy density value used is an estimate for a more harsh winter than that of New Jersey.

3.13.2.3.2 Energy Star

The Energy Star calculator for home furnace replacement uses a similar method, but allows heating energy to vary based on climate zone.[64] This calculator is based on replacing a 78% efficient furnace with one that is 90% efficient and calculates heating load based on climate zone and building age. While this method does allow variation by climate, it is for the residential sector rather than the commercial, and therefore does not allow for variation based on building type.

3.13.2.3.3 DEER

Data for heating load per square foot is available from California's Database for Energy Efficient Resources.[65] We obtained the 2005 DEER savings density data for commercial furnaces, based on replacing a 78% efficient furnace with one that is 94% efficient. The latter value is greater than is required under this program, but it may serve as a maximum savings value. We obtained HDD for a representative city of each climate zone as defined by Pacific Gas and Electric.[66]

These values may be used to predict the relationship between HDD and energy savings density. A plot of energy savings density for all building types and vintages versus HDD and a linear regression of that plot yields this equation with a correlation factor (accuracy) of $r^2 = 0.2$:

$$\mathit{Energy\ Savings\ Density}\left(\frac{kBtu}{1000\ sf}\right) = \left(0.8413\ x\ HDD\right) - 573.78 \qquad \text{Equation 3.13-6}$$

A similar analysis by building type shows that heating load in California does vary considerably by building type. The linear regressions by building type have a greater degree of correlation,

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[64] http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Furnaces.xls

[65] http://www.deeresources.com/index.php?option=com_content&view=category&layout=blog&id=36&Itemid=53

[66] http://www.pge.com/includes/docs/pdfs/about/edusafety/training/pec/toolbox/arch/climate/california_climate_zone_12.pdf

with r2 values ranging between 0.49 and 0.79. Substituting the HDD for each New Jersey climate zone into the regression equation for each building type yields the values for energy density savings by zone presented in Table 3-57.

Table 3-57
Energy Savings Density Based DEER Regression

Building Type	Energy Savings Density By Climate Zone, kBtu/sf				Correlation Factor
	Atlantic City	Newark	Philadelphia	Monticello	
Restaurant	8.7	8.7	7.4	12.7	0.79
Office	1.0	1.0	0.9	1.6	0.53
Education	2.7	2.7	2.3	3.9	0.49
Hotel	0.3	0.3	0.3	0.5	0.73
Retail	2.1	2.1	1.7	3.1	0.60
Health Care	6.2	6.1	5.2	9.0	0.71
Assembly	12.5	12.5	1.8	17.8	0.83
Grocery	5.3	5.2	4.6	7.4	0.79
Storage	1.6	1.6	1.3	2.3	0.76

Note the extreme variability in savings by building type within a singe zone. For example, this analysis predicts that a hotel in Newark will save 0.3/12.5, or 2.4% of the savings of an assembly building of the same size. Even removing the high and low values in case they are anomalous yields extreme variability. This model predicts that an office will save only 11% of what a restaurant of the same size would save.

These equations generated using California data may not be applicable to New Jersey, even using New Jersey HDD values. California Title 24 requires that buildings not be fully heated during unoccupied times. Since much of the variation between building types may have to do with differences in occupied hours, buildings in other states may not exhibit as great a variation based on building type. Another discrepancy exists in that most of California's climate zones are warmer in winter than New Jersey's. Because of these differences, the data does not correlate effectively to New Jersey.

3.13.2.3.4 Energy Information Administration CBEC

Another source of heating energy density values is the EIA Commercial Building Energy Consumption Survey (CBEC).[67] These are nationwide values. The values in Table 3-58 are from that report, and are based on metered gas use by building type. The individual end uses, including heating, are allocated based on a model rather than on metering. Information about the assumptions of the model is not yet available.

Table 3-58
CBEC Heating Energy Density by Building Type

Building Type	Heating Energy Use Density (kBtu/sf)
Education	29.5
Food Sales	35.6
Food Service	39.0
Health Care	53.6
Inpatient	56.8
Outpatient	45.6
Lodging	15.0
Retail (Other Than Mall)	29.3
Office	28.1
Public Assembly	33.8
Public Order and Safety	24.1
Religious Worship	29.1
Service	47.8
Warehouse/Storage	20.2
Other	57.9

Note that the CBEC model predicts significant variability by building type, but much less variability than is predicted by the DEER analysis.

The CBEC values are national averages rather than climate-specific and therefore should not be used to determine baseline energy use. They also include all furnace and boilers in the survey, including qualifying models which should be excluded when determining a baseline. However, these values do help to show load variation by building type.

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[67] http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set19/2003html/e07.html. Note that these values represent heating energy density, not heating energy *savings* density, as in the case of the DEER values.

3.13.2.4 Heating Degree Days Method with Building Type Variation

Neither the DEER nor the CBEC data are directly applicable to the New Jersey program. The DEER data is for a climate range and regulatory environment different from New Jersey, and the CBEC data are nationwide averages based on an unknown allocation model for all furnace efficiency ranges.

However, both of these data sources suggest significant variation by building type, and the Focus on Energy method does not accommodate that variation. It assumes that all buildings are heated to the same temperature twenty-four hours a day for the entire heating season. In reality, any reduction in operating hours would reduce that heating load. The Focus on Energy method in effect calculates the maximum heating load that could be expected.

One method of making the Focus algorithm specific to building type would be to use the Focus method above and adjust it for building type based on the DEER or CBEC building type data. The DEER analysis predicts such extreme variation by building type that we do not believe it to be directly applicable, so we pursue such an analysis based on the EIA data.

An inherent assumption in this analysis is that while the CBEC heating energy density values will not apply to New Jersey directly, the variation by building type will. Here we use the CBEC data to develop a degree day adjustment factor based on the ratio between the heating energy density for each building type and the maximum. These values are presented below using health care as the maximum, with the "other" category removed.[68] We calculate the adjusted HDD for each climate zone by multiplying the HDD values in Table 3-56 by the adjustment factor.

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[68] "Other" is the maximum in the EIA data. Since "other" is a catch-all category, we did not believe that it should be used as the maximum heating energy case.

Table 3-59
Adjusted Heating Degree Days by Building Type

Building Type	Heating Energy Density (kBtu/sf)	Degree Day Adjustment Factor	Atlantic City (HDD)	Newark (HDD)	Philadelphia (HDD)	Monticello (HDD)
Education	29.5	0.55	2792	2783	2655	3886
Food Sales	35.6	0.66	3369	3359	3204	4689
Food Service	39.0	0.73	3691	3680	3510	5137
Health Care	53.6	1.00	5073	5057	4824	7060
Lodging	15.0	0.28	1420	1415	1350	1976
Retail	29.3	0.55	2773	2764	2637	3859
Office	28.1	0.52	2660	2651	2529	3701
Public Assembly	33.8	0.63	3199	3189	3042	4452
Public Order/Safety	24.1	0.45	2281	2274	2169	3174
Religious Worship	29.1	0.54	2754	2745	2619	3833
Service	47.8	0.89	4524	4510	4302	6296
Warehouse/Storage	20.2	0.38	1912	1906	1818	2661

This provides a climate-specific method that is modified to reflect variability of heating load by building type.

3.13.3 Recommendations

3.13.3.1 Energy Savings

We recommend that the program calculate energy savings based on HDD for four zones and twelve building types, as shown in Table 3-59. The HDD values are based on those calculated for each New Jersey climate zone using TMY3 data.

The algorithm then becomes:

$$Gas\ Energy\ Savings = \left(\frac{(0.8\ x\ CAPY_{in}\ x\ HDD_{mod}\ x\ 24)}{\Delta T\ \ x\ 100{,}000}\right) x \left(1 - \frac{AFUE_b}{AFUE_q}\right) \qquad \text{Equation 3.13-7}$$

Where:

0.8 = oversize factor of standard boiler or furnace, equivalent to 25% of capacity
$CAPY_{in}$ = input capacity of the boiler or furnace in BtuH
HDD_{mod} = HDD by zone and building type, from Table 3-59
24 = conversion from days to hours
ΔT = design temperature difference, with balance temperature = 65°F and outdoor temperature from Table 3-56

$AFUE_b$ = Annual Fuel Utilization Efficiency of the baseline furnace or boiler, EPACT standards of 78% for furnaces and 80% for boilers
$AFUE_q$ = Annual Fuel Utilization Efficiency of the qualifying furnace or boiler, from application or manufacturer data
100,000 = conversion factor, Btu/therm

3.14 Compressed Air System Optimization

This measure provides an incentive for customers making upgrades to their compressed air system. This is a custom measure, and there is a related prescriptive measure, *Air Compressors with Variable Frequency Drives*.

First we will review the protocol and make recommendations about how it should be restructured. Then we will look into sources from other programs and from industry. Finally we will make recommendations for how to implement the protocol.

3.14.1 Overview of Existing Protocol

We begin by describing how the protocol is structured and how energy savings is likely calculated under the existing protocol, then follow with a review of and recommendations for the structure of the protocol.

3.14.1.1 Overview of Protocol

The current protocol consists of two options: Compressed Air System Analysis and the Pay for Performance Program.

Compressed Air System Analysis

Under this option, a custom rebate is developed prior to project implementation. Measures are based on a site-specific engineering analysis completed for each participating site. The engineering analysis determines what increase in efficiency would be realized through program participation. This analysis is compared to the current baseline condition to estimate energy savings.

Pay for Performance Program

Under this option, the program pays the customer for the energy saved by the project, measured on-site after project completion. Savings calculations are developed during project planning and a measurement and verification (M&V) plan is agreed upon and approved. The M&V plan must follow the International Performance Measurement and Verification Protocol (IPMVP). Reported energy savings are calculated by comparing pre-installation estimates with post-installation measured savings.

3.14.1.2 Review of Protocol

The program did not cite or provide any sources as the basis for these measures.

The description of the two options above are not explained in detail, so some speculation is required to understand what they are intended to do. The two options appear similar to each other in that they are custom measures meant to account for complicated compressed air system improvements. However, assuming that SmartStart approaches these measures like other programs do, they are very different in the roles that the program and the customer take during the project.

In a typical Compressed Air System Analysis, the program takes the initiative through much of the project. The program, or a contractor on behalf of the program, provides the on-site audit, performs the engineering analysis, identifies savings opportunities, determines the energy savings, and determines the size of the rebate. The program also reduces the customer's risk by providing analysis and research to give confidence to the project's goals, and by guaranteeing funding regardless of whether the savings materialize. All the customer has to do is agree to install the recommended measures and claim the promised rebate once the project is complete.

Under a typical Pay for Performance project, however, the customer takes the initiative. The customer presents the savings opportunities to the program based on their own analysis, and together they develop a Measurement and Verification (M&V) plan. The customer takes on all of the risk, because if the savings don't materialize they do not receive a rebate. After the installation the customer and the program together carry out the M&V plan. The program provides a rebate based on the measured energy savings. The program then compares the initial savings estimates to the M&V results to determine energy savings. This type of measure is typically taken on by a customer with a lot of confidence in the project's energy savings potential, who thinks they will receive more savings than is calculated in the often-conservative pre-installation estimates.

These are both appropriate methods for providing incentives to customers making improvements to compressed air systems.

One potential pitfall of the Pay for Performance measure is that it is tempting to offer it to a customer who has already begun installing an energy efficiency improvement. However, this customer is by definition a free rider who would have installed the improvement without the program, and so the energy savings cannot be attributed to SmartStart.

3.14.2 Review of Industry Practice

This section contains a discussion of sources we found in the course of our research.

3.14.2.1 Improving Compressed Air System Performance, a Sourcebook for Industry - DOE Compressed Air Challenge

This source provides a wealth of information about the various components of a compressed air system and the opportunities for savings with each of them. It strongly recommends a “systems approach” to compressed air energy savings – looking carefully at all components and how they interact before determining which improvements are most cost-effective. This is essentially the approach suggested in the protocol.

This source is published by *Compressed Air Challenge*, an organization funded by the DOE whose goal is to improve energy efficiency in compressed air systems nationwide. They provide education, software tools, and literature on how to understand, audit, and improve system efficiency at all levels. They would be a great resource to coordinate with on program implementation.

3.14.2.2 Assessment of the Market for Compressed Air Efficiency Systems – DOE Office of Industrial Technologies, 2001 (prepared by Xenergy)

This report provides market research data for the usage of compressed air systems in California. The goal was to determine the market potential for compressed air system audits and energy savings improvements.

The report came to the strong conclusion that most facilities do not adequately maintain their compressed air systems and waste large amounts of energy from air leaks and other inefficiencies. Facilities appear mostly unwilling to pay for system audits, claiming that they maintain the systems themselves, but because of time and budget constraints, owner-maintained systems are mostly in poor states of repair. However, owners appear open to audits as long as they are free. Most are open to making capital improvements to compressed air systems for energy efficiency reasons, and claim to take seriously the recommendations of government entities or non-profit groups who are not attempting to sell services.

3.14.2.3 International Performance Measurement and Verification Protocol (IPMVP) - Efficiency Valuation Organization, April 2007

This set of protocols provides two tracks for measurement and verification:

- Option A consists of separating out a specific piece of equipment and attempting to measure all energy inputs and all energy outputs to determine energy use. This involves measuring all mass flows and energy flows in and out of the equipment, and accounting for any waste heat. Under this method, interactive effects must be accounted for, as in where reducing energy use in one area requires more energy input in another area. It is effective for equipment that can be easily isolated from the larger system and tested separately.
- Option B consists of measuring a system as a whole. This involves a process of baselining, creating a model for normal energy use prior to system improvement. It then measures differences between pre-installation and post-installation energy use by monitoring the primary energy input into the system. Interactive effects are accounted for because all components are included. It is most effective for testing equipment that cannot be easily isolated from the larger system, or for upgrades to multiple parts of a system.

The protocol states that measurement and verification (M&V) under the Pay for Performance method must conform to the IPVMP standards, but it does not state which option must be used. Under the *Compressed Air Challenge* approach, Option B is highly preferable, because compressed air systems are highly interactive with many inter-related components. Upgrading one component necessarily requires a reevaluation of the other components. This option treats the system as a whole and encourages understanding and maintenance of the entire system.

3.14.2.4 Industrial Compressed Air Supply System Efficiency – California Energy Commission PIER Program, May 2004

This source attempts to provide a standard benchmark for measuring air compressor energy efficiency. Their benchmark, Compressed Air Supply Efficiency (CASE) Index, has the units of Standard Cubic Feet (SCF) per kWh. It has a potential range of 0 to 325. Higher indices represent better efficiencies.

This is a method that can be used with a simple measurement of output air flow and input wattage to determine energy efficiency. It is only for use with head-end equipment upgrades. It is not useful for determining overall system efficiency because it does not account for end-uses or leaks.

3.14.3 Recommendations

We recommend that SmartStart take advantage of the DOE Compressed Air Challenge (CAC), which provides training and other services regarding compressed air systems. SmartStart could sponsor CAC training classes which compressed air vendors and factory maintenance managers could attend. Following CAC guidelines will help to provide a more thorough and standardized approach to compressed air systems and give more confidence and authority to the SmartStart's energy savings recommendations. Coordinating with the DOE will also help to avoid duplication of effort.

We recommend that SmartStart maintain both options for rebates under Compressed Air System Optimization. Below we discuss recommendations for these measures separately.

3.14.3.1 Compressed Air System Analysis Recommendations

The CAC methodology involves a system-wide approach in which a trained auditor takes a broad view to determine where in the system the most cost-effective energy saving measures might be applied. The reason for this approach is that most facility management and maintenance personnel do not have a good understanding of the operation or condition of their compressed air systems, and so are generally not aware of the best ways to proceed in saving energy.

We recommend that the program require any auditor providing this service to attend the CAC two-part training series and not be under the employ of a company which also sells compressed air products. Evaluation studies show that customers often do not trust the findings of auditors with a sales motive.

The process begins with an audit of the existing system. Depending on the size, this may include a process of baselining, in which the existing system operating conditions are measured over a period of time (from a few hours to multiple weeks) using monitoring equipment. This provides a baseline energy use profile to which energy efficiency measures can be applied. Subsequently, the system could be monitored by maintenance personnel and compared to the baseline to help diagnose problems and find additional energy savings. Baselining is essential for large systems both to root out energy waste and to provide early diagnoses of system malfunctions.

Once the audit is complete, the auditor develops a series of measure options at varying levels of cost, so that a customer can select those which fit budget and payback expectations. These options include all parts of the system, including the head-end compressor side, the air delivery system, and the end-uses of compressed air. The following measures can be suggested depending on site-specific conditions:

Table 3-60

Potential Compressed Air System Improvements

Improvement	Description
Compressor Head-End	
Air Compressor VFD	Add a variable frequency drive (VFD) to the compressor or purchase a compressor with a VFD.
Trim Compressors	Use multiple compressors, in which only one is running at partial load and the rest are running at full load. The compressor which runs at partial load should be the smallest of the compressors and may be equipped with a VFD.
Staged Compression	Use multiple compression steps, in which one compressor steps the pressure up to one level and the next compressor steps it up to the final use level. This is especially efficient with centrifugal compressors.
Compressor Replacement / Upgrade	Significant energy savings can result from replacement of an inefficient compressor with a new efficient model. Reciprocating compressors are great candidates for replacement. This often results in less required maintenance, particularly if the replacement compressor is a scroll compressor.
Dryer Replacement / Upgrade	There are a large variety of dryer types and they are very system-specific, and some are much more efficient than others. A thorough analysis can lead a more educated dryer choice. In some situations a dryer can reuse waste compressor heat and therefore require no separate energy source.
Dryer Refrigerant Compressor VFD	Refrigerant type dryers have a compressor which is used to cool the air. This compressor can benefit from a VFD.
Receiver Tank(s)	Receiver tanks can help supply system peak loads over short bursts, which can allow the compressor to be sized down and help prevent the need to operate at partial load. The larger the receiver tank, the greater the benefit.
Pressure Reduction	At high pressure, leaks leak more and compressors operate less efficiently. A leak-repair strategy and an analysis of system load requirements can lead to pressure-reduction opportunities.
Heat Recovery	Approximately 85% of compressor input power is converted to heat. This heat can be transferred to the HVAC system and used to heat air or water. Absorption chillers can use this heat also.
Electronic or Microprocessor Controls	Compressors which modulate based on air flow are more efficient than those that don't. Multiple compressor systems can operate much more efficiently and prevent cycling if their controls are linked. This is easier to do if they are made by the same manufacturer.
Scheduled Maintenance	Much like cars, compressors need oil changes and regular maintenance or performance can drop off dramatically. This should be scheduled.

Air Delivery System	
Leak Repairs	Leaks can account for up to 40% of a compressed air system energy use. On average, leak inspections show 10-20% wasted through leaks. In addition, leak repairs can lead to system pressure reduction.
Repair/Replace Condensate Drains	These drains are the most fragile part of a compressed air system, and can fail over time. Leaking condensate drains can be ignored for years. They should be inspected and replaced on a schedule.
Downstream Receiver Tank(s)	The closer that the air supply is to the end-use, the more efficient the system becomes. Local storage in effect provides an air supply closer to the end-use. This is especially helpful in systems in very large factories.
Scheduled Maintenance, Walk-Throughs	Leaks come back, and can create tremendous waste if not monitored on a regular basis. An ultrasonic leak detector can be very useful for detecting leaks. Also, factory employees can over time adjust end uses to use compressed air less efficiently, and even use compressed air for local cooling and ventilation, which is horribly inefficient. If this is discovered, the ventilation and cooling can be provided using fans and other methods, which are much more efficient than running a compressor.
End Uses	
Conversion to Low Pressure Operation	Though often convenient, a plant compressed air system is almost always the least efficient way to supply power to equipment. A system audit can show that pieces of end-use equipment can operate on lower pressure, which can be supplied locally using fans or small low-pressure compressors. Sometimes this can eliminate whole portions of compressed air system or even eliminate the system entirely.
Step Down Pressure	Sometimes portions of systems can operate on lower pressure than the rest of the system. Stepping down the pressure can save energy.
End Use Feedback to Control System	When system end uses are wired to the compressor control system, indicating when air is required, the compressor(s) can better predict the load and supply it more efficiently. It can also drop pressure off when there is no call for air.

To highlight one item from Table 3-60, any system optimization should take seriously and make recommendations for converting various operations from compressed air–driven to low-pressure motor-driven. A compressed air system typically operates at around 5% wire-to-work efficiency, where a small motor could increase this efficiency to 60%. There are common instances in industrial facilities where a ¼ hp motor could provide the same level of service that 7 hp of compressor power currently provides.

3.14.3.2 Pay for Performance Recommendations

The pay-for-performance option makes sense for highly motivated customers with their own engineering staff. In this case the customer takes on all the risk and is not guaranteed a rebate if savings do not materialize. However, if a lot of savings do materialize the customer can get a large rebate.

One danger with pay for performance options, as discussed above, is the temptation to offer this option to customers who have already begun installation of a product. We recommend that the program resist this temptation, because this type of project would have occurred without the program and program dollars could be better spent elsewhere.

We recommend that SmartStart promote the systems approach to air compressor energy savings for multiple-compressor systems even under pay for performance. We also recommend that the program encourage customers to take CAC training.

For M&V plans, the protocol states that they must follow IPMVP methods. This is a wise choice, and we recommend that the program generally promote Option B, the system-wide M&V approach. Providing recommendations as to using Option A or Option B will also help ensure that the customer at reads the IPMVP at least far enough to find out what the options are. We recommend that the program also consider the CASE method as promoted by California as a simple standardized M&V method.

3.14.3.3 Additional Recommendations

Ultrasonic leak detectors are an essential tool for checking leaks in air lines. It would be beneficial to either rebate ultrasonic leak detectors, or to create a tool library like Wisconsin’s Focus on Energy or Pacific Gas and Electric in California, where customers can check out and borrow ultrasonic leak detectors.

NJCEP can improve the SmartStart program by performing studies to better understand the market potential for compressed air energy savings in New Jersey. In addition, research into existing practice would help to establish a statewide baseline to which program goals might be more effectively set.

3.15 Time Period Allocation Factors

As part of KEMA’s review of the Protocols, KEMA also examined the Time Period Allocation Factors used for each measure. The time periods are defined as follows:

- Electricity (kWh) savings across summer peak, summer off-peak, winter peak, and winter off-peak
- Gas (therm) savings across summer and winter periods

The time periods are chosen by to best fit the seasonal avoided cost patterns for electricity and natural gas. Table 3-61 and Table 3-62 show the relative number of hours in each time period for electricity and natural gas across one year. For any efficiency measure that operates 8760 hours in a year with constant hourly savings (e.g. LED exit signs), then the Time Period Allocation Factor percentages should be the same as shown below.

Table 3-61
Percent of Total Year, Represented by Each Time Period (Electricity)

Season	Period type	Percent of each year
Summer (5 months)	**Peak** (12 hours)	15%
	Off-peak (12 hours, including weekends and holidays)	27%
Winter (7 months)	**Peak** (12 hours)	21%
	Off-peak (12 hours, including weekends and holidays)	37%

Table 3-62
Percent of Total Year, Represented by Each Time Period (Natural Gas)

Season	Percent of each year
Summer (6 months)	50%
Winter (6 months)	50%

In general, the Protocols do not appear to cite specific sources for the Time Period Allocation Factors that are used for each measure.

3.15.1 Electric Efficiency Measures

Given the lack of information on the sources used to determine Time Period Allocation Factors in the Protocols, KEMA surmises that data related to load shapes may have been used to determine when measure savings occur across a single year. This has been the approach used by several other programs, including California investor-owned utilities (IOUs), Efficiency Vermont, and Connecticut Energy Efficiency Fund.

3.15.1.1 Discussion of Applicability of Load Shapes

The relevant shape for calculation of measure avoided costs is the measure shape – that is, what fraction of energy *savings* falls into each time period. Most of the sources available, however, rely on end-use load shapes – the fraction of energy *consumption* for the affected end use that falls in each time period.

For some measures, the measure and end-use shapes are very similar (e.g. high efficiency lighting), but for other measures, the measure savings curve may be very different from the end-use shape (e.g. daylighting controls). Table 3-63 summarizes which program efficiency measures have savings load shapes that are the same as the end use load-shape and which do not.

Table 3-63
Summary of Measure Shapes Likely to be Same as End Use Load Shape

Measure	End Use	Measure Shape similar to End Use shape?
Lighting Equipment	Lighting	Yes
Lighting Controls	Lighting	No
High Efficiency Motors	Motors	Yes
High Efficiency HVAC	HVAC	Yes
High Efficiency Chillers	HVAC	Yes
VFDs	HVAC	No
VFD air compressors	HVAC	No

Those measures which have savings that follow the end-use load shape, the end-use load shape data is considered generally acceptable for calculating the Time Period Allocation Factors. For measures that have different measure savings shapes from the end use shape, alternate approaches to calculating Time Period Allocation Factors may need to be explored.

3.15.1.2 Lighting Equipment

In general, the lighting equipment measure Time Period Allocation Factors used in the Protocols appear to be reasonable. As shown in Table 3-64, load shapes used for commercial lighting in Connecticut and Vermont programs more heavily emphasize lighting use during summer peak and winter peak periods. Since Connecticut has a slightly longer winter period definition and peak hour definition, however, we do not currently recommend any changes for the lighting equipment Time Period Allocation Factors.

Table 3-64
Time Period Allocation Factors for Lighting Equipment

Source	**Time Period**			
	Summer Peak	**Summer Off-Peak**	**Winter Peak**	**Winter Off-Peak**
Percent of total year represented by each Time Period	15%	27%	21%	**37%**
NJCEP Lighting Equipment Protocols	26%	16%	36%	**22%**
Connecticut C&I Load Shape **C&I Lighting end use load shape**[69]	30%	10%	50%	**10%**
Vermont Technical User Manual No. 2005-37 **Commercial Indoor Lighting load shape**[70]	**42%**	**25%**	**28%**	**5%**

3.15.1.3 Lighting Controls

Lighting controls is an efficiency measure for which the energy savings do not generally follow the same shape as the end use consumption factors. The current Protocols use the same Time Period Allocation Factors for lighting controls as used for high efficiency lighting equipment. We recommend additional research and on-site metering to better determine when savings related to lighting controls occur across Time Periods for a typical year.

3.15.1.4 Motors

Again, no reference is cited for the Time Period Allocation Factors used for motors. Given the wide range of motor applications in the field, it is difficult to apply a single set of Time Period Allocation Factors. High efficiency motors are expected to have a measure savings shape similar to the motor end-use load shape. Therefore, using load shapes should be generally acceptable. Table 3-65 shows a comparison of program Time Period Allocation Factors for New Jersey, Connecticut and Vermont.

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[69] Winter = October – May. Summer = June – September. Peak is 6:00 AM – 11:00 PM. Off-peak is 11:00 PM to 6:00 AM, plus weekend and holidays. Source: Connecticut Energy Efficiency Fund. UI and CL&P Program Savings Documentation for 2009 Program Year. Page 222

[70] Time Period definitions unknown. Efficiency Vermont. Technical Reference User Manual (TRC) No. 2005-37. November 29, 2005. Page 10.

Table 3-65
Time Period Allocation Factors for Motors

Source	Time Period			
	Summer Peak	Summer Off-Peak	Winter Peak	Winter Off-Peak
Percent of total year represented by each Time Period	15%	27%	21%	**37%**
NJCEP Motor Protocol	25%	16%	36%	**23%**
Connecticut C&I Load Shape **C&I Motor end use load shape**[71]	30%	10%	50%	**10%**
Vermont Technical User Manual No. 2005-37 **Commercial ventilation motor**[72]	**37%**	**38%**	**17%**	**8%**

Depending on the motor's intended end use, the Time Period Allocation Factor should utilize the end use specific load shape. Since most commercial motor installations are expected to be related to HVAC, we recommend an HVAC-specific load shape.

3.15.1.5 HVAC Systems

HVAC system efficiency measures should generally save energy evenly across the end use load shape. Table 3-66 and Table 3-67 show how the New Jersey Protocols compare to those of Connecticut and Vermont. We believe that the New Jersey Time Period Allocation Factors are generally of the right scale and of the relative magnitude.

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[71] Winter = October – May. Summer = June – September. Peak is 6:00 AM – 11:00 PM. Off-peak is 11:00 PM to 6:00 AM, plus weekend and holidays. Source: Connecticut Energy Efficiency Fund. UI and CL&P Program Savings Documentation for 2009 Program Year. Page 222

[72] Time Period definitions unknown. Efficiency Vermont. Technical Reference User Manual (TRC) No. 2005-37. November 29, 2005. Page 10.

Table 3-66
Time Period Allocation Factors for HVAC Cooling

Source	Time Period			
	Summer Peak	Summer Off-Peak	Winter Peak	Winter Off-Peak
Percent of total year represented by each Time Period	15%	27%	21%	**37%**
NJCEP HVAC Protocol **(Cooling)**	45%	39%	7%	**9%**
Connecticut C&I Load Shape **C&I Cooling**[73]	80%	15%	3%	**2%**
Vermont Technical User Manual No. 2005-37 **Commercial A/C**[74]	**37%**	**38%**	**17%**	**8%**

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[73] Winter = October – May. Summer = June – September. Peak is 6:00 AM – 11:00 PM. Off-peak is 11:00 PM to 6:00 AM, plus weekend and holidays. Source: Connecticut Energy Efficiency Fund. UI and CL&P Program Savings Documentation for 2009 Program Year. Page 222

[74] Time Period definitions unknown. Efficiency Vermont. Technical Reference User Manual (TRC) No. 2005-37. November 29, 2005. Page 10.

Table 3-67
Time Period Allocation Factors for HVAC Heating

Source	Time Period			
	Summer Peak	Summer Off-Peak	Winter Peak	Winter Off-Peak
Percent of total year represented by each Time Period	15%	27%	21%	**37%**
NJCEP HVAC Protocol **(Heating)**	0%	0%	41%	**58%**
Connecticut C&I Load Shape **C&I Heating**[75]	5%	0%	60%	**35%**
Vermont Technical User Manual No. 2005-37 **Commercial Space Heat**[76]	**7%**	**11%**	**44%**	**38%**

3.15.1.6 Electric Chillers

The Protocols use the same Time Period Allocation Factors for electric chillers as for HVAC cooling, which is appropriate.

3.15.1.7 VFDs

Variable frequency drives (VFDs) are not expected to have the same measure savings shape as the HVAC end use load shape. As shown below in Table 3-68, based on the values used by Efficiency Vermont, the specific VFD application is expected to significantly affect the Time Period Allocation Factors. Therefore, we recommend equipment specific Time Period Allocation Factors to be used in the Protocols. Lacking New Jersey specific factors, the Vermont factors are recommended at this time, pending further research. Note that the recommended measurement of energy and demand savings is for HVAC fans and water pumps only. VFD applications for other end uses should follow the custom path.

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[75] Winter = October – May. Summer = June – September. Peak is 6:00 AM – 11:00 PM. Off-peak is 11:00 PM to 6:00 AM, plus weekend and holidays. Source: Connecticut Energy Efficiency Fund. UI and CL&P Program Savings Documentation for 2009 Program Year. Page 222

[76] Time Period definitions unknown. Efficiency Vermont. Technical Reference User Manual (TRC) No. 2005-37. November 29, 2005. Page 10.

Table 3-68
Time Period Allocation Factors VFDs

Source	Time Period			
	Summer Peak	Summer Off-Peak	Winter Peak	Winter Off-Peak
Percent of total year represented by each Time Period	15%	27%	21%	**37%**
NJCEP VFD Protocol	22%	10%	47%	**21%**
Vermont Technical User Manual No. 2005-37				
Commercial VFD Supply Fan[77]	**48%**	**23%**	**24%**	**6%**
Commercial VFD Exhaust Fan	**32%**	**35%**	**22%**	**11%**
Commercial VFD Boiler	**7%**	**11%**	**44%**	**38%**
Commercial VFD CHWP	**52%**	**48%**	**0%**	**0%**

3.15.1.8 VFD air compressors

No comparable sources were found for estimating VFD air compressor Time Period Allocation Factors. Table 3-69 shows the percentages used in the Protocols. A significant portion of energy savings are currently being allocated to off-peak hours, from 8:00 PM to 8:00 AM, and both weekend days. This may be an over-estimation, as the majority of air compressor usage may be occurring during normal business hours for most businesses, such as auto mechanic shops, although some usage in major manufacturing plants may be around the clock.

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[77] Time Period definitions unknown. Efficiency Vermont. Technical Reference User Manual (TRC) No. 2005-37. November 29, 2005. Page 10.

Table 3-69
Time Period Allocation Factors VFD Air Compressors

Source	**Time Period**			
	Summer Peak	**Summer Off-Peak**	**Winter Peak**	**Winter Off-Peak**
Percent of total year represented by each Time Period	15%	27%	21%	**37%**
NJCEP VFD Protocol	**28%**	**39%**	**14%**	**19%**

Additional research into the business types related to most VFD air compressor applications can help yield insights into the appropriate Time Period Allocation Factors. This is an area recommended for further investigation.

3.15.1.9 Summary of Recommendations

Time Period Allocation Factors are an important component of determining the cost-effectiveness of program measures from a utility perspective. For several measures, the Time Period Allocation Factors for electricity are believed to be mostly correct.

For other measures, additional research is recommended. These measures are mostly control measures that save energy at specific times, rather than over the normal course of equipment operations. In these cases, the measure saving shape is expected to be different from the end use load shape. Unfortunately, most load shape research to date has focused on end use load shapes (energy consumption), rather than measure specific load shapes (energy savings).

Table 3-70 below summarizes the recommendations for improving Time Period Allocation Factors for electric measures.

Table 3-70

Summary of Recommendations (Electric Measures)

Measure	Recommendations
Lighting Equipment	No changes currently recommended.
Lighting Controls	Use current Time Period Allocation Factors until additional research and possible on-site metering surveys yield more appropriate data on measure shape of lighting controls.
High Efficiency Motors	Time Period Allocations should utilize the specific end-use load shapes. Since most motor applications are for HVAC systems, the HVAC system Time Period allocation Factors should suffice.
High Efficiency HVAC	No changes currently recommended.
High Efficiency Chillers	No changes currently recommended.
VFDs	Use equipment specific Time Period Allocation Factors, per Efficiency Vermont Technical Reference User Manual (TRC) No. 2005-37.
VFD air compressors	Use current Time Period Allocation Factors until additional analysis of business and application types inform more appropriate hours of operation.

3.15.2 Gas Efficiency Measures

Gas efficiency measures only have Time Period Allocation Factors associated with summer and winter use. The Protocols stipulate that the summer and winter periods are six months each. Therefore, for any efficiency measures that operate at a constant rate year round, the Time Period Allocation Factor is expected to be roughly 50/50 for summer and winter periods, unless the measure is a control measure.

3.15.2.1 Gas Chillers

The Gas Chiller section of the Protocols only outlines Time Period Allocation Factors for electric savings. This measure is unique in that it has both electricity and natural gas saving. No Time Period Allocation Factors are provided for gas savings in the Protocols.

The measure saves electricity in the summer by using the gas chiller for cooling instead of the electric chiller. Normal electric chiller operations are in effect during the winter. The electric Time Period Allocation Factors currently used in the Gas Chiller Protocols is identical to those used for electric chillers and year-round HVAC operations, and do not properly reflect the lack of savings in the winter. Gas chillers are not expected to save any electricity during the winter, because gas chillers have no effect on electric chiller operations during the winter. Therefore, the electric Time Period Allocation Factors should maintain the same ratio of peak and off-peak savings during the summer, but show zero savings in the winter. Table 3-71 summarizes the current Protocols and KEMA’s recommended changes.

Table 3-71
Time Period Allocation Factors for Gas Chiller (Electric Savings)

Source	Time Period			
	Summer Peak	Summer Off-Peak	Winter Peak	Winter Off-Peak
Percent of total year represented by each Time Period	15%	27%	21%	**37%**
NJCEP Gas Chiller Protocol	45%	39%	7%	**9%**
KEMA recommended Allocation Factors	**54%**	**46%**	**0%**	**0%**

The Protocols do not include any estimates for gas Allocation Factors. This measure saves gas in the winter by using the gas chiller heater instead of a regular gas boiler. The gas chiller actually increases gas consumption during the summer, when it operates in place of the electric chiller. Therefore, the Time Period Allocation Factors should show 100% of natural gas savings occurring during the winter, since no savings occur during the summer. Table 3-72 summarizes KEMA's recommendation.

Table 3-72
Time Period Allocation Factors for Gas Chiller

Source	Summer	Winter
Percent of total year represented by each Time Period	50%	**50%**
KEMA recommended Allocation Factors	**0%**	**100%**

3.15.2.2 Gas Fired Desiccants

Gas fired desiccant systems remove moisture from incoming fresh air (make-up air), which reduces the burden on the HVAC cooling units. This measure actually increases the use of natural gas in the system, meaning there are no gas savings related to this measure. The electric savings are expected to roughly follow the load shapes for electric chillers and HVAC systems. Per Table 3-73 below, KEMA recommends using the same Time Period Allocation Factors as used for HVAC systems.

Table 3-73
Time Period Allocation Factors for Gas Fired Desiccants

(Electric Savings)

Source	Time Period			
	Summer Peak	Summer Off-Peak	Winter Peak	Winter Off-Peak
Percent of total year represented by each Time Period	15%	27%	21%	**37%**
KEMA recommended Allocation Factors	**45%**	**39%**	**7%**	**9%**

3.15.2.3 Gas Booster Water Heaters

The program currently allocates 50% of booster heater use to summer and 50% to winter. Although the amount of water heated by individual booster heaters may vary with the season, no data has been found to indicate that it will vary on average across all installations. We recommend that the time allocation factors remain unchanged at 50% summer and 50% winter.

3.15.2.4 Water Heaters

The program currently allocates 50% of water heating energy use to summer and 50% to winter. Time allocation factors will depend on the seasonal variability in water use and delivery temperature.

The water use of individual buildings will vary with the season. However, we have no data that would indicate that hot water use will vary in a predictable way on average across the commercial sector.

Seasonal variation in water delivery temperature should be more predictable. However, we did not find a study reporting seasonal water delivery temperature variability for New Jersey or other climates. We recommend that the program study average water delivery temperature by climate zone and adopt time allocation factors accordingly.

Until that study is complete, we recommend that the time allocation factors remain unchanged at 50% summer and 50% winter.

3.15.2.5 Furnaces and Boilers

This prescriptive measure targets the replacement of furnaces and smaller-scale boilers. Table 3-74 shows the current Time Period Allocation Factors used in the Protocols.

Table 3-74
Time Period Allocation Factors for Boilers and Furnaces

Source	Summer	Winter
Percent of total year represented by each Time Period	50%	**50%**
NJCEP Furnaces and Boilers Protocol	**12%**	**88%**

KEMA has re-calculated the estimated usage based on the typical meteorological year (TMY) used for each climate zone. Table 3-75 shows the recommended Time Period Allocation Factors by zone. The discussion of this calculation and the mapping of these weather stations to New Jersey counties is provided in the Furnace and Boiler Protocol review.

Table 3-75
Recommended Time Period Allocation Factors for Boilers and Furnaces

Weather Station	Winter	Summer
Atlantic City	87%	13%
Newark	89%	11%
Philadelphia, PA	91%	9%
Monticello, NY	85%	15%

3.15.2.6 Summary of Recommendations

Some of the measures in the C&I Gas Protocols result primarily in electric savings, rather than gas savings. Although they are being recommended as custom savings measures, estimated Time Period Allocation Factors for gas chillers and gas fired desiccants have been provided in this analysis. Table 3-76 summarizes the Time Period Allocation Factor recommendations for measures in the Gas Protocols.

Table 3-76
Summary of Recommendations (Gas Protocols)

Measure	Recommendations
Gas Chillers	Revise Time Period Allocation Factors to reflect zero electric savings in the winter, and zero gas savings in the summer.
Gas Fired Desiccants	Use HVAC system Time Period Allocation Factors for electric savings. No gas savings are associated with this measure.
Gas Booster Water Heaters	No changes currently recommended.
Water Heaters	Use current Time Period Allocation Factors until additional research on seasonal variation in water delivery temperature can be completed.
Furnaces and Boilers	Minor changes to the Time Period Allocation Factors are recommended, based on climate zone.

4. Estimating Savings for Custom Projects

4.1 Introduction

Custom measures allow customers to qualify for and receive an incentive for energy efficiency measures that are not on the Prescriptive Equipment incentive list. Custom measures are site and end-use specific, and require a detailed analysis to qualify for incentives. Projects generally fall into the custom measure category for one or more of the following reasons:

- The project is a non-standard or unusual energy efficiency measure.
- The measure is highly site-specific, where energy savings vary dramatically between sites, even at a given product type and size.
- The project is very large, warranting extra effort to provide an accurate energy savings estimate and appropriate incentive amount.
- The customer or contractor who fills out the application is unlikely to know the needed information to determine energy savings for a given measure.
- The customer applying for a certain type of measure would likely have many other “low-hanging-fruit” type energy savings opportunities that a custom measure may identify and encompass.

According to the *2009 Draft Program Budget and Filing*, measures which are eligible for custom incentives include the following:

- Lighting systems
- HVAC systems
- Motor systems
- Larger boiler systems
- Gas-engine driven chillers
- Other non-prescriptive measures proposed by the customer

This section begins with a discussion of some key questions and concerns that SmartStart should consider regarding the Custom Savings program. KEMA then addresses the issues involved in calculating custom energy savings, and provides suggestions for calculation and documentation methods.

4.2 Key Questions and Concerns

There are several issues which come up repeatedly in custom savings calculations. For each of the following questions, we recommend that the program develop a standard answer or a standard approach. We present several options for some of these standards. The chosen option is less critical than consistent application of the selected standard procedure. We do, however, provide recommendations for developing these standards.

4.2.1 Who Calculates or Measures Savings?

Standardization on this issue is important. Experience tells us that two customers installing the same measure at the same time under the same circumstances can receive very different incentives and energy savings estimates depending on who calculates or measures the energy savings.

In a given custom project, any number of groups or individuals may perform energy savings calculations or measurements for any number of reasons. Individuals potentially involved in a project and their likely motivations include:

- Manufacturer (for marketing purposes)
- Vendor or Contractor (to help sell the project)
- Customer or Engineering Consultant (to determine whether the project is feasible or worth pursuing)
- Incentive Program, like SmartStart (to determine incentive level and to include in program-attributable energy savings)

Savings calculations or measurements from any and all of these groups may at times be more or less accurate. However, the motivations and technical expertise of each group should be taken into account when determining which energy savings values will be accepted.

The program currently gathers information from the customer on the *2008 Custom Measure Project Evaluation Input Data Sheet*. This information includes customer or contractor predictions for expected measure life, product and installation costs, energy savings, and the seasonal load profile. The data sheet also asks for copies of utility bills for the previous year. In addition, the custom application form collects information about the specific products proposed.

This information gathered from the customer should provide at least a simple means of double-checking any savings calculations or measurements provided by the sources listed above. At minimum, we recommend that the program carefully review all calculations. For calculations provided by manufacturers, vendors, or contractors, we recommend that the program perform separate calculations using standard methods for comparison.

We recommend that the program develop a standard procedure for checking and verifying energy savings calculations and measurements from various sources.

4.2.2 Early or Natural Replacement?

This issue presents itself with nearly every custom project: Is this project early replacement or natural replacement?

The answer depends on whether the equipment is being replaced for energy efficiency reasons, or whether it is being replaced for other reasons (e.g., upgrade, size increase, end of useful life). If the equipment is still operable and is being replaced for energy efficiency reasons, then it is an early replacement project. If it is being replaced for other reasons, then it is a natural replacement project.

The answer to this question leads to a determination of the baseline which is used in energy efficiency calculations. For early replacement, the baseline is the existing equipment being replaced (for accelerated period of replacement). For natural replacement, the baseline is standard efficiency equipment (defined by market research, program policy, or energy code). The chosen baseline can have a significant effect on the energy savings credited to a measure.

Another factor affecting whether a project is early or natural replacement is how much useful life the existing equipment has left when replaced. If a piece of equipment has only six months left in its useful life and yet is replaced for energy efficiency reasons, it is technically an early replacement. However, natural replacement was eminent. For this reason, some programs call all installations natural replacement. Others specify that if a customer would have replaced the equipment within a specified time period (two years, for example), then the project is natural replacement.

KEMA recommends that the program develop a standard method for determining whether the project is early or natural replacement. Any of the following options could form the basis of a standard:

- Consider all projects natural replacement.
- Ask the owner what their reasons are for replacing the equipment, either in a survey or on the application form.
- Create a standard for each equipment type, based on the nature of the measure.

- Make an educated assumption based on existing equipment age and useful life, and the difference between the existing and new equipment in capacity and functionality.
- Make a standard assumption, with the expectation the energy savings values will be adjusted with evaluation research.

Among these options, the easiest method would be to consider all projects natural replacement. However, this would tend to underestimate savings for projects that were actually early replacement.[78]

We recommend that the program ask why the equipment is being replaced on the application, and determine whether the project is natural or early replacement based on the answer. Some answers will be clear and easy to interpret; others will list multiple reasons, no reason, or will be unclear. If the customer’s answer is not clear or it is otherwise difficult to determine the main reason for the project, we recommend that the program assume natural replacement as a default. This will tend to yield a reasonably conservative estimate of savings.

4.2.3 Consider Interactive Effects?

All energy efficiency measures produce direct savings, which are the energy savings directly associated with the piece of equipment being installed. These are generally what incentives are designed to achieve, and are always considered in calculations.

However, there are also sometimes indirect savings resulting from the interactions between various systems. Some programs include these effects for specific measures and some do not. The California Standard Performance Contract program, for example, does not allow indirect savings to be included.

The SmartStart prescriptive rebate program currently allows lighting measures to claim indirect savings related to reduced A/C use. In this case, the efficient lighting produces less heat, which relieves the A/C system from having to reject this heat from the building.

Other measures produce indirect savings, but they are often very difficult to measure or meaningfully quantify. Calculations must be done thoroughly, taking all factors into account, as interactive effects are often poorly estimated. We recommend that the program decide how it will handle interactive effects on a program-wide basis.

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[78] The baseline case for natural replacement is current standard efficiency, which is often more efficient than the replaced equipment.

We suggest the following options for how to deal with interactive effects:

- Exclude interactive effects from all custom measures.
- Include interactive effects from specific types of custom measures.
- Include interactive effects for projects where interactive effects can be metered or directly measured.
- Include interactive effects only after performing an on-site engineering survey to determine whether interactive effects are realistic.

Our main concern is that the program develops a standard based on one of the options above, rather than which option is chosen. Since interactive effects are difficult to determine and verify, we recommend that the program adopt a default position of excluding interactive effects from custom projects. Exceptions can be made for unusual projects.

4.3 Methods for Determining Savings

4.3.1 Engineering Estimate

4.3.1.1 Method Description

For most equipment types and efficiency measures there are well-established engineering procedures available. The annual electricity and natural gas savings should be calculated using industry accepted engineering algorithms, and these should be used consistently across similar measures. Most commonly, these involve estimating the annual electricity and natural gas usage of both the existing and qualifying equipment based on the current operation of the facility, as shown in the following equation:

Energy savings = (Baseline energy usage) – (Qualifying equipment energy usage)

In this equation, *qualifying equipment energy use* is self-explanatory and can be calculated using standard engineering methods. *Baseline energy usage*, however, is more complicated. For early replacement projects, existing equipment energy use may be used. For natural replacement projects, equipment of code-required efficiency may be used if there is a government-mandated code for the equipment. Alternately, standard market efficiency may be used based on industry practice. These industry practices may be determined from New Jersey baseline studies and/or market research, experience of program staff, utility metering studies, or the experience of other energy incentive programs from comparable jurisdictions.

This method for determining savings can be done using hand calculations, computer spreadsheets, or software programs. Manufacturers, industry groups, and the US Department of Energy (DOE) often make available software programs which calculate energy savings.

4.3.1.2 Documentation

All the calculation steps used to determine energy savings should be documented and saved either electronically or in hard-copy format. These calculations can be used to compare the methods used between related projects. Proper documentation of energy savings calculations is needed for third-party verification of energy savings estimates.

When calculations are done by hand, they should be saved in hard-copy format or scanned as PDFs. When calculations are done in spreadsheets, the spreadsheets should be saved electronically and organized by customer, project, and measure for future use. When computer software is used, a file should be saved which includes the inputs entered into the software.

Hard-copy printouts of spreadsheets or computer software reports are not sufficient unless they include a detailed description of the calculation method used by the spreadsheet or program.

4.3.2 Building or Process Simulation Modeling

For measures that have building-wide impacts or impacts across a number of systems, building or process simulation modeling using generally accepted public domain software may be acceptable to document savings.

4.3.2.1 Method Description

Independent third-party simulation modeling programs are generally preferable to proprietary manufacturer-developed modeling programs. Initial savings estimates that are submitted based on manufacturers’ proprietary performance models may be acceptable for initial estimates of savings. However, additional information should be gathered and calculations performed should be to confirm energy savings.

When using any model, the model should include a version for the baseline and a separate version for the qualifying equipment. All inputs for building or equipment properties should be identical between the two versions, except for the values specific to the equipment being installed.

4.3.2.2 Documentation

The model versions should be annotated to clearly show how the differences between the baseline and qualifying equipment options are being simulated. Electronic copies of the versions used to calculate savings should be saved if possible. Hardcopy printouts are generally not sufficient unless they include a detailed description of the inputs and calculation method used by the program.

4.3.3 Metering

In some situations, it is feasible to directly measure the energy use pre-installation, post-installation, or both. In this case, electric or gas metering data may be used. Sometimes this can be done using existing utility or customer metering, and other times meters may be installed for a time for just this purpose.

Metering may be done both before and after the project. But it also may be done only before the project, to determine a baseline, or only after the project, for measurement and verification purposes.

4.3.3.1 Whole-Building Metering

For some projects, where the savings are a significant fraction (10 percent or more) of the total monthly or annual energy usage, a “bills before – bills after” approach may be used. This approach would assume that operating conditions, such as building occupancy levels or operating hours, are identical before and after the project.

Whole building metering studies should be calibrated based on weather data and other time-varying factors, so that a hot or cold year (for HVAC systems) or a high- or low-production year (for industrial systems) does not skew the data.

4.3.3.2 Equipment or Process Sub-Metering

When measures are installed that affect a large and distinct system (e.g., air compressor, chiller, process blower, or induction molding machine), sub-metering may be the best way to document the savings. This may require the installation of temporary portable monitoring equipment that measures and records the equipment power at short intervals over several days or weeks.

When sub-metering is used, a method should be developed to extrapolate the savings for the measurement period to a full year of operation. Component sub-metering may often include observation of other variables like outside air temperature, operating hours, or production quantities during the measurement period to allow for this extrapolation.

4.3.3.3 Documentation

If a metering study is done, the data should include sufficient documentation describing the differences between the base case and high-efficiency case, so that they can be understood and verified. Adjustments made based on time-varying factors should be outlined in detail. The data should be saved if possible in an electronic file to facilitate bin studies and to account for data anomalies.

4.3.3.4 Measurement and Verification

The program may wish to require metering for measurement and verification (M&V) in order for a project to qualify for an incentive or to gain a greater understanding of energy savings for planning purposes. In these cases, the International Performance Measurement and Verification Protocol[79] (IPMVP) should be followed to develop an M&V plan.

Table 4-1 summarizes the four IPMVP “options” for approaches to M&V for energy conservation measures. The program should develop guidelines for whether the applicant will cover the cost of the M&V activities and to what extent the final incentive will be conditional on M&V activities performed after the project is completed.

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[79] 1.2.3 International Performance Measurement and Verification Protocol (IPMVP) - Efficiency Valuation Organization, April 2007

Table 4-1

Summary of M&V Options from *2007 IPMVP*

IPMVP Option	**A. Retrofit Isolation: Key Parameter Measurement**
Description	Savings are determined by field measurement of the key performance parameter(s) which define the energy use of the affected system(s) and/or the success of the project.
	Parameters not selected for field measurement are estimated. Estimates can based on historical data, manufacturer's specifications, or engineering judgment.
	Documentation of the source or justification of the estimated parameter is required. The plausible savings error arising from estimation rather than measurement is evaluated.
Calculation Method	Engineering calculation of baseline and reporting period energy from: - short-term or continuous measurements of key operating parameter(s) - estimated values.
Typical Application	A lighting retrofit where power draw is the key performance parameter that is measured periodically. Estimate operating hours of the lights based on building schedules and occupant behavior.
IPMVP Option	**B. Retrofit Isolation: All Parameter Measurement**
Description	Savings are determined by field measurement of the energy use of the affected system.
	Measurement frequency ranges from short-term to continuous, depending on the expected variations in the savings and the length of the reporting period.
Calculation Method	Short-term or continuous measurements of baseline- and reporting-period energy use, and/or engineering computations using measurements of proxies of energy use.
	Routine and non-routine adjustments as required.
Typical Application	Application of a variable-speed drive and controls to a motor to adjust pump flow. Measure electric power with a kW meter installed on the electrical supply to the motor, which reads the power every minute. In the baseline period this meter is in place for a week to verify constant loading. The meter is in place throughout the reporting period to track variations in power use.
IPMVP Option	**C. Whole Facility**
Description	Savings are determined by measuring energy use at the whole facility or sub-facility level.
	Continuous measurements of the entire facility's energy use are taken throughout the reporting period.
Calculation Method	Analysis of whole facility baseline and reporting period (utility) meter data.
	Routine adjustments as required, using techniques such as simple comparison or regression analysis.
	Non-routine adjustments as required.
Typical Application	Multifaceted energy management program affecting many systems in a facility. Measure energy use with the gas and electric utility meters for a twelve month baseline period and throughout the reporting period.
IPMVP Option	**D. Calibrated Simulation**
Description	Savings are determined through simulation of the energy use of the whole facility, or of a sub-facility.
	Simulation routines are demonstrated to adequately model actual energy performance measured in the facility.
	This Option usually requires considerable skill in calibrated simulation.
Calculation Method	Energy use simulation, calibrated with hourly or monthly utility billing data. (Energy end use metering may be used to help refine input data.)
Typical Application	Multifaceted energy management program affecting many systems in a facility but where no meter existed in the baseline period.
	Energy use measurements, after installation of gas and electric meters, are used to calibrate a simulation.
	Baseline energy use, determined using the calibrated simulation, is compared to a simulation of reporting period energy use.

4.3.4 Special Case: Increased Capacity

When a customer purchases a larger piece of equipment than they currently have, energy consumption may increase even though the new equipment is more efficient. In this case, the program should use the capacity and operating hours of the qualifying (larger) equipment, and compare the efficiencies of the two pieces of equipment to determine savings.

For example, consider a case in which a customer expands the size of their building and replaces an inefficient small rooftop HVAC unit with a larger and more efficient chiller system. The inefficient small rooftop HVAC unit used the same amount of energy as the chiller system does. However, in this case the customer would have increased HVAC capacity in some way regardless of the program's involvement, either by adding another small HVAC unit, or buying a larger unit.

In general, the energy savings for these measures can be based on post-installation production and calculated as:

$$\text{Energy Savings} = (EFF_b - EFF_q) * \text{Post - Installation Capacity} * \text{Post - Installation Operating Hours}$$

where:

EFF_b = Efficiency of Baseline Equipment
EFF_q = Efficiency of Qualifying Equipment
Post-Installation Capacity = Capacity of qualifying equipment
Post-Installation Operating Hours = Operating hours of qualifying equipment after installation

5. Tracking Data and Hard-Copy Documentation

Consistent and complete program tracking data is a fundamental requirement for a statewide energy efficiency program such as SmartStart. Program tracking data can be used for program operations, program planning, and reporting and verification of accomplishments. KEMA understands that OCE has implemented a statewide tracking database and process for archiving hard-copy project documentation subsequent to the time period covered by this evaluation (2001-2006).

During the period under review (2001-2006), the program relied on policies and procedures to ensure consistency and quality control. The application, technical information, savings and incentive calculations, and supporting documents were reviewed upon receipt to verify eligibility. However the data was not collected and stored in a consistent electronic format across the state. Statewide energy efficiency and renewable programs, such as SmartStart, should have an electronic tracking database to facilitate consistent and accurate measure level energy savings calculations and therefore reporting of overall program impacts. The database should contain the following categories: customer information, contractor/vendor information, measure and project-specific data. The tracking system should also include a hard copy file for each project.

This section includes a discussion of tracking data that should be stored for each customer, project, and measure.

5.1 Customer Information

Customer information includes contact details and other relevant information. A variety of program stakeholders are likely to contact customers, including:

- Program manager and implementers: to ask questions related to any incomplete or unclear aspects of the customer application and/or project.
- Field auditors: to schedule and plan post-installation visits.
- Evaluators: to follow up with questions regarding satisfaction, motivation, verification of installation, and other issues.

Table 5-1 below displays a suggested list of customer information fields for the tracking database, based on information already collected on the Application Form.

Table 5-1

Recommended list of tracking data fields, Customer Data

Tracking Data Field	On the Application Forms?
Application Number	Yes
Unique Customer ID Number	No, should be assigned
Company Name	Yes
Contact Person Name	Yes
Contact Person Title	Yes
Facility Address, City, State and Zip	Yes
Company Address, City, State and Zip	Yes
Contact Telephone	Yes
Contact Fax	Yes
Contact E-mail	No, on the Registration Form only
Federal Tax ID# or SS#	Yes
Electric utility serving customer	Yes
Electric utility account #	Yes
Gas utility serving customer	Yes
Gas utility account #	Yes
Installed by: - Customer - Contractor	Yes
Incentive payment to: - Customer - Contractor	Yes
Installation Date	Yes
Energy-efficiency measure or service	Yes
Measure ID	No, should be assigned

For 2009, TRC proposed to eliminate the pre-approval Registration Form. KEMA does not recommend this change for custom applications. If this occurs, then we recommend that the program update the Application Forms to request an email address, in order to facilitate communications.[80]

5.2 Contractor/Vendor Contact Information

In addition to customer contact information, in many cases the contractor or vendor contact information is also needed by the same program stakeholders, as described above. Table 5-2 lists the recommended fields. The contractor/vendor contact information should be provided with each customer application if the customer receives any assistance from a contractor.

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[80] TRC also recommends accepting equipment purchases (not installations) made up to 12 months prior to submittal of an application. KEMA recommends that the prescriptive program consider a shorter deadline, such as two months after purchase.

Table 5-2

List of tracking data fields, Contractor/Vendor Data

Tracking Data Field	On the Application Forms?
Unique Contractor ID Number	No, should be assigned
Company Name	Yes
Contact Person Name	Yes
Contact Person Title	No, on the Registration Form only
Company Address and CSZ	Yes
Contact Telephone	Yes
Contact Fax	Yes
Contact E-mail	No
Federal Tax ID#	Yes

5.3 Measure and Project Specific Data

The tracking database should also include information about the specific project. This information is also needed by program stakeholders, including:

- Program manager and implementers: to pay out incentives and estimate program impacts.
- Field auditors: to verify measure installation.
- Evaluators: to evaluate program impacts, plan any required measurement & verification activities, and perform other inquiries and tasks.

Table 5-3 provides a brief summary of data fields that are the same across different prescriptive measures.

Table 5-3

List of tracking data fields – Measure Specific Data

Tracking Data Field	On the Application Forms?
Measure:	Yes
- Lighting equipment	
- Lighting controls	
- Motors	
- HVAC systems	
- Chillers	
- VFDs	
- VFD air compressors	
- Gas chillers	
- Gas fired desiccants	
- Gas booster water heaters	
- Water heaters	
- Furnaces	
- Boilers	
- Compressed air system optimization	
Measure ID	No, should be assigned
Custom or Prescriptive Measure	Yes
Reason:	Yes
- New	
- Replaced	
- Stocked	
Type:	Yes
- Varies by measure	
Electric Savings (kW)	No
Electric Demand Savings (kW)	No
Gas Savings (therms)	No

KEMA highly recommends that measure specific energy and demand savings values be entered (custom projects) or officially calculated (non-custom projects) in the electronic database. This will facilitate consistent and accurate measure level energy savings calculations and therefore reporting of overall program impacts.

The database should be as detailed as possible. All measure specific information on the program application should be entered in to the database. The program application for each different type of measure currently collects information specific to that type of measure. For example, for lighting control projects, the following fields are included:

- Fixture type controlled
- Watts controlled per device
- Number of fixtures controlled per device
- Building Type
- Incentive amount

KEMA recommends this type of measure specific information be included in the electronic tracking database. Electronic tracking of this information enables the OCE greater flexibility in monitoring and researching its programs. It will also minimize demands on the program for data requests for program impact evaluations, benefit-cost studies, and other research studies. The accuracy of these studies will also improve with better program tracking data. At a minimum KEMA recommends archiving the hard-copy files containing the measure specific information or electronic PDF of project applications.

5.4 Project Tracking Fields

In addition to the above project and customer information fields, the tracking database should also include fields for program staff to use in project tracking. Table 5-4 below shows examples of project application tracking fields to facilitate management and oversight of application processing.

Table 5-4
List of tracking data fields, Project Tracking Data

Tracking Data Field	Description
Application Number	Number specific to each application
Status	Current Status of Application
	1. Received
	2. Reviewed
	3. Paid
Cancel Date	Date application was cancelled (if applicable).
Incentive Date	Date the check was released.
Program Period	Program year's funds used to pay incentive.

5.5 Hard Copy Documentation

Following data entry into the program tracking database, all project application and supporting documentation should be filed in a dedicated location for the program. Each file should consist of:

- Application form
- Invoices, or other information submitted by the customer or their contractor
- Supporting calculations (e.g. prescriptive lighting worksheet, lighting controls worksheet, etc.)
- Any internal procedural application processing forms (e.g. payment release forms, internal check-in forms, etc.)

In general, these hard copy files may provide more information than can be feasibly entered into the electronic tracking database. For day to day processes, program staff may refer to these files and make copies for evaluators when needed.

6. On-going Protocol Updates

The Protocols to Measure Resource Savings (Protocols) is updated and modified periodically in order to ensure that the savings calculation methodologies are accurate and relevant.

KEMA recommends that OCE update the Protocol document on an annual basis to coincide with the annual program planning process. The Protocol update process should also include the results and recommendations of any independent third party program evaluations of the SmartStart program. Table 6-1 shows a selection of regulations, federal and state policies, and studies which may inform updates to the Protocol.

Table 6-1

Selection of Sources for Protocol Updates

Source	Description
Federal policy	Federal policies such as the EISA 2007 will set new federal efficiency standards for certain motors and lighting
New Jersey building codes	New commercial buildings are required to show compliance to ASHRAE 90.1-2004.
NJCEP Impact Evaluations	Third party evaluations of the SmartStart program can provide important data on the accuracy of key assumptions used in the Protocols.
Regional or New Jersey specific metering studies	Other metering studies may provide improved values for operating hours and equivalent full load hours, across different business types.
Other industry studies	The results and findings of other industry studies may also inform revisions to New Jersey operating hours and savings calculations.

Appendix A: 2008 Standard Performance Contract (SPC), California Investor Owned Utilities

The SPC comprehensive list of standard fixture wattages is provided electronically in PDF format.