Spreadsheet Based Tool for Building Energy Codes: Analysis, Comparison and Compliance

By

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ABSTRACT

Buildings in the United States, account for over 68 percent of electricity consumed, 39 percent of total energy use, and 38 percent of the carbon dioxide emissions. By the year 2035, about 75% of the U.S. building sector will be either new or renovated. The energy efficiency requirements of current building codes would have a significant impact on future energy use, hence, one of the most widely accepted solutions to slowing the growth rate of GHG emissions and then reversing it involves a stringent adoption of building energy codes.

A large number of building energy codes exist and a large number of studies which state the energy savings possible through code compliance. However, most codes are difficult to comprehend and require an extensive understanding of the code, the compliance paths, all mandatory and prescriptive requirements as well as the strategy to convert the same to energy model inputs.

This paper provides a simplified solution for the entire process by providing an easy to use interface for code compliance and energy simulation through a spreadsheet based tool, the **ECCO or the Energy Code COmpliance Tool**. This tool provides a platform for a more detailed analysis of building codes as applicable to each and every individual building in each climate zone. It also facilitates quick building energy simulation to determine energy savings achieved through code compliance.

This process is highly beneficial not only for code compliance, but also for identifying parameters which can be improved for energy efficiency. Code compliance is simplified through a series of parametric runs which generates the minimally compliant baseline building and 30% beyond code building. This tool is seen as an effective solution for architects and engineers for an initial level analysis as well as for jurisdictions as a front-end diagnostic check for code compliance.

DEDICATION

To my mother, Mrs. Anjani Goel, for her love and support.

Thank you ma. I owe everything to you.

ACKNOWLEDMENTS

I would like to offer my sincere gratitude to my thesis chair, Prof. Harvey Bryan, who has supported me not only throughout my thesis but also through my two years at ASU and is largely responsible for where I am today. I appreciate all the advice, help and encouragement he has given me.

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Chapter 1

INTRODUCTION

Buildings: The Problem and the Solution

The Problem: The Major CO2 Culprit

Buildings are responsible for approximately half of all US energy consumption and CO2 emissions annually. Building operations alone, i.e., heating, cooling, lighting, hot water and the plug load, account for 43% of total US CO2 emissions and 76% of total US electricity consumption. Therefore, to have any real impact on climate change, it is essential to address CO2 emissions in the building sector.

The Solution: The 2030 Challenge

Architecture 2030 is one of the solutions offered today for carbon neutrality in all new construction by the year 2030. The initial phase of the Challenge, the 50% reduction target, is designed to bring an immediate halt to the increase of GHG emissions in the Building Sector and subsequent phases aim to systematically reduce carbon emissions in the building sector.

Building energy codes and standards are one of the most significant aspects contributing to achievements of this target. More stringent energy codes along with better defined analysis and compliance tools are provided as the most effective solution to achieving all targets associated with the 2030 challenge for all new and renovated buildings.

Building Energy Codes: Reasons for Development and Adoption

- Energy codes establish a common foundation for evaluating, regulating, and incentivizing building performance, technologies, design, and construction.
- Energy codes provide a common basis upon which to educate the building design and construction community in energy efficiency.
- Energy codes reduce the vast amount of energy that is needlessly consumed each year to heat, cool, light, ventilate, and provide hot water for newly

constructed residential and commercial buildings that lack adequate energy efficiency features.

Energy Standards and Codes

- ASHRAE/IESNA Standard 90.1
- ICC International Energy Conservation Code
- ASHRAE/IESNA/USGBC Standard 189.1
- ICC International Green Construction Code

1.1. OBJECTIVE

- To analyze and compare prevalent building energy codes.
- To develop a spreadsheet based tool to analyze a building for code compliance as well as develop the code compliant baseline building.

1.2. INTENT

The thesis aims at the following-

i. Analysis of Standard 90.1 in comparison to Standard 189.1 to determine energy savings achieved through each of the energy codes, in comparison with each other.

ii. Develop a tool, using eQUEST and the RMI Model Manager, to provide a convenient interface to perform the following simulations-

   - Baseline building generation in compliance with ASHRAE Standards 90.1 2007 Performance Rating Method (Appendix G).
   - Baseline building generation in compliance with ASHRAE Standards 189.1 2009 Performance Rating Method (Appendix D).
   - Calculation of energy savings for each of the runs and an analysis of the results.

1.3. TARGETED AUDIENCE

Intended as a tool to facilitate code compliance and energy savings calculation it is targeted at the following audiences:

Code Officials

- As a comparison between the code vintages, this facilitates code development.

Energy Analysts

- This tool would facilitate in the generation of baseline building and also facilitate parametric runs for energy efficiency and better building performance. A more efficient way for comparison of various EEMs and subsequent energy savings would also facilitate the decision making process.

Jurisdictions

- Intended as a front-end diagnostic to code compliance, this could be used by jurisdictions for an initial analysis.

1.4. SCOPE AND LIMITATIONS

Goals

This tool is intended to be used for buildings that are in the planning, design or construction phases. It is intended to apply to buildings that are within the scope of ASHRAE Standard 90.1-2007. The long-term goal of this thesis is to define modeling procedures for the basic design features that may be incorporated in buildings. However, due to limitations in the development energy simulation algorithms as well as technical expertise, this tool does not incorporate a few aspects of the performance rating method which have been outlined in Section 4.4 below. The goal of the tool is to provide methods that are as flexible and accurate as possible. This goal is best achieved if the tool is continuously developed through regular inputs from professionals as better modeling methods become available.

At present, this tool provides a ‘proof-of-concept’, a strategy which, if developed, can provide an optimal energy modeling guide, providing solutions for code compliance, design solutions for greater energy savings, analysis of design alternatives and system optimization.

Scope

The tool can be developed for all Climate Zones, Building Types and Codes. At present it is has been developed for:

- ASHRAE 90.1 2007 and ASHRAE 189.1
- Climate Zone 2B
- Office Buildings

Limitations

The tool would have the following limitations, and would work on the following assumptions-

- Applicable to Climate Zone 2B.
- Designed for commercial buildings, with a focus on offices.
- Hence the systems- PTAC and PTHP have not been integrated.
- For proposed designs which involve single zone systems in the proposed design and multi-zone systems in the baseline building (or visa-versa), two separate ‘.inp’ files would have to be provided for both single zone and multi-zone assignments.

Simulation Related Limitations-

- Analysis of unmet heating/cooling load hours has not been dealt with.
- Standard 189.1 requires an equal distribution of vertical fenestration on all four orientations, as against 90.1 which requires the fenestration to be distributed in the same proportion as the design building. This requirement has not been met for 189.1.
- Process loads have not been addressed or simulated for either of the standards.
- Energy recovery has not been addressed for any of the standards.

- A supply fan has been modeled, with return assumed to be 1/4th of the supply fan power.
- Minimum outside air flow has been simulated at a system level rather than zone level for ease of understanding.
- Energy recovery systems have not been analyzed and were assumed to be beyond the scope of this thesis.
- Demand control ventilation systems have not been analyzed and were assumed to be beyond the scope of this thesis.

Future Possibilities

At present, user inputs are required at each stage, and through sophisticated programming knowledge, this could be avoided, to automate this process to a greater extent. This tool could then be developed for all energy codes, also incorporate amendments made by local jurisdictions. Like COM*Check* is for the prescriptive requirements, it could act as a front end diagnostic for LEED submittals.

Chapter 2

METHODOLOGY

The methodology of the study involves a *Development Process Flow* which analyzes the codes, defines its requirements and translates them into values which can then be converted to inputs for the spreadsheet tool. The *Application Process Flow* outlines the process for using the tool and applying it for baseline building generation. The *Results* section outlines the concept and strategy applies for the development of the results display as well as the design guides. *ECCO Runs* comprise of two test runs carried out using the tool to analyze it for consistency as well as validate it against the baseline building created by eQUEST. The *Conclusions* section summarizes project in terms of the two standards analyzed as well the applicability and accuracy of the tool.

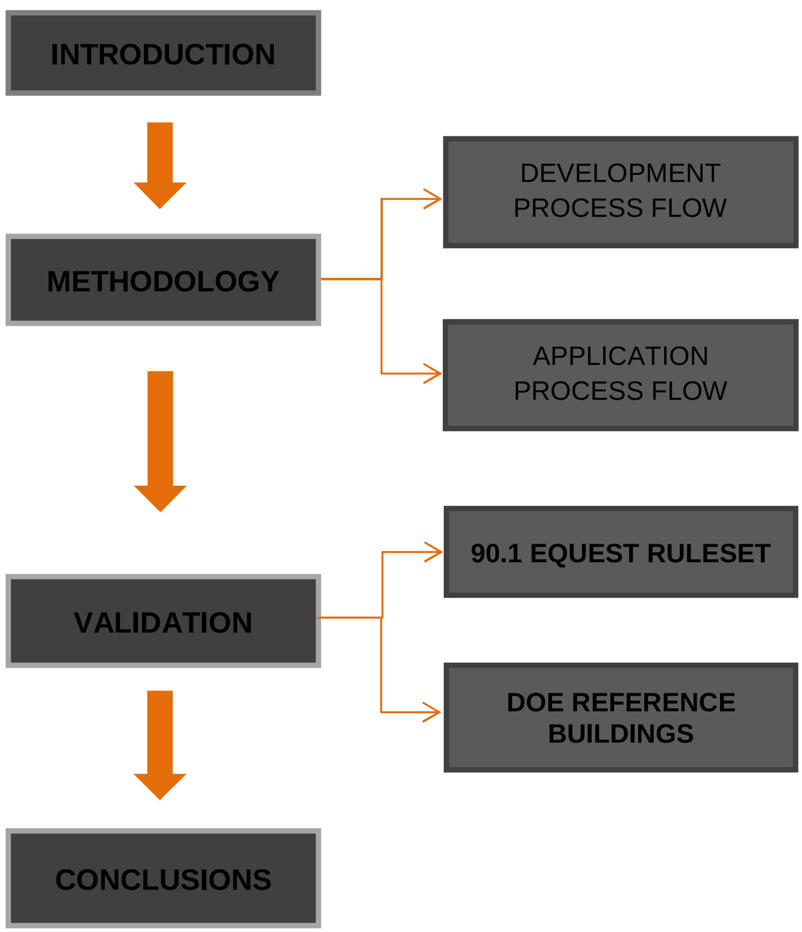

Figure 1: Methodology

2.1. DEVELOPMENT PROCESS FLOW

This section analyzes the energy standards and translates them into parameters for development of the tool. The Development Process Flow broadly comprises of four sections-

1. Overview Of Building Energy Codes
2. Compliance Paths : 90.1 And 189.1
3. Mandatory and Prescriptive Requirements : 90.1 and 189.1
4. Performance Rating Method

    4.1. Interpretation of the Code

    4.2. Translation for ECCO and eQUEST

    4.3. Implementation for eQUEST

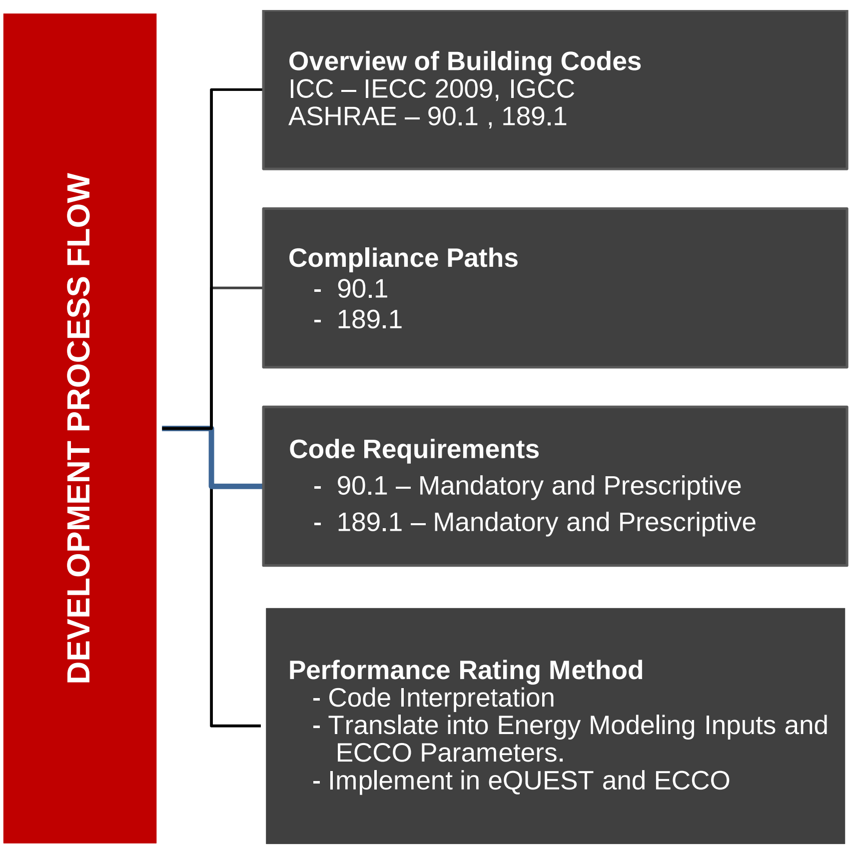

Figure 2: Methodology: Development Process Flow

2.1.1. Overview: Building Energy Codes. The International Codes Council (ICC) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) both contribute greatly to the energy efficiency of the built environment. The ICC's International Energy Conservation Code (IECC) and ASHRAE's Standard 90.1 are the most widely adopted energy codes and standards in the country; adopted solely or by reference in thirty-seven states and numerous municipalities. The IECC applies to both residential and commercial buildings. Updated about every three years, the most current version available is the 2012 IECC, released in April 2011. ASHRAE 90.1 applies to commercial buildings (including multi-family high-rise buildings). Also updated about every three years, the most current version available is ASHRAE 90.1-2010.

Development of Standard 90.1. Standard 90.1-2007 is an incremental improvement to Standard 90.1-2004 and an intermediate step to significant improvement through Standard 90.1-2010. ***Standard 90.1-2007 contains requirements for:***

- Envelope
- Mechanical systems, including HVAC and SWH
- Lighting and power systems
- Standard 90.1-2007 does not contain provisions for plug and process loads

Development of Standard 189.1. Addresses –

- Building thermal envelope
- HVAC and SHW systems and equipment
- Lighting and Plug Loads
- Intended for use to address green and sustainable objectives
- Includes in part Standard 90.1 but increases stringency
- Published January 2010

2.1.2. Compliance Paths.

Standard 90.1 Compliance Path. Mandatory provisions are required to be met for either of the compliance paths. The performance rating method is a modification of the Energy Cost Budget (ECB) Method in Section 11 and is intended for use in rating the energy *efficiency of building designs that exceed the* requirements of the standard.

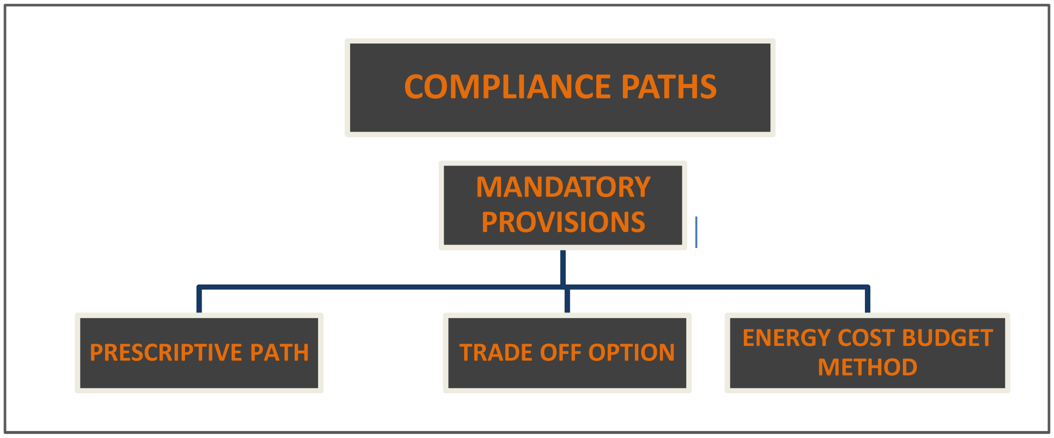

Figure 3: Standard 90.1 - Compliance Paths

Standard 189.1 Compliance Paths. Standard 189.1 clearly delineates two compliance paths- prescriptive and performance. The mandatory requirements are required to be met irrespective of the path. The prescriptive and performance paths also have specific requirements.

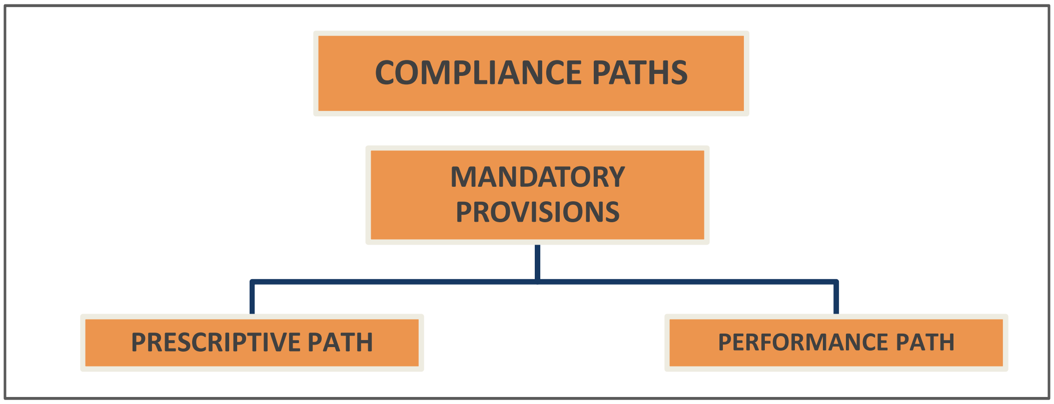

Figure 4: Standard 189.1 - Compliance Paths

2.1.3. Analysis of Code. For the purpose of this thesis, the literature review comprises of a detailed analysis of Standard 90.1 2007 and Code 189.1-2009. These have been analyzed individually as well as in comparison to each other.

The analysis has been carried out in the following way-

- Standard 90.1 - Mandatory and Prescriptive Measures
- Standard 189.1- Mandatory and Prescriptive Measures

Standard 90.1 - Mandatory and Prescriptive Measure.

Section 5: Building Envelope. The building envelope is required to comply with the mandatory provisions and either the prescriptive criteria or the tradeoff option (Energy Cost Budget) approach. Mandatory requirements include - Section 5.4.1 for insulation; Section 5.4.2 for fenestration and doors and Section 5.4.3 for air leakage.

This includes sealing of building envelope penetrations, vestibules and loading docks. In addition, the requirements cover the labeling of insulation, windows and doors. Prescriptive requirements include Section 5.5.1 for building envelope U Values, Section 5.5.2 for Semiheated or unconditioned space, Section 5.5.3 for opaque areas

The prescriptive requirements include requirements for roofs, opaque walls, below-grade walls, foundations, vertical fenestration and skylights. Tabled 5.5.1 – 5.5.8 cover 8 eight different climate zones and specify U-values for all building opaque assemblies and fenestration. [1] There is no minimum visible transmittance requirement of glazing except if the envelope tradeoff method in ASHRAE 90.1-2007 § 5.6 are utilized. Wall window ratio is limited to a maximum of 40% for the prescriptive requirement.

Section 6: Heating Ventilation and Air Conditioning. All heating, ventilation and air conditioning (HVAC) equipment and systems shall comply with the mandatory provisions and the prescriptive criteria. Alternatively, the whole building energy cost approach in the Energy Cost Budget Method (ASHRAE 90.1- 2007) may be used. The mandatory requirements are for minimum equipment efficiency levels, load calculations,

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[1] See Section 5.5. for ASHRAE 90.1 2007.

controls, HVAC distribution system (piping and ductwork), system balancing, and system commissioning.

Section 6.4.1. Minimum Equipment Efficiencies. The cooling and heating equipment is required to either meet or exceed the minimum efficiency requirements. The PRM provides a path to get credit for exceeding the minimum efficiency requirements which are specified in Tables 6.8.1A through 6.8.1J.

Section 6.4.2 Load Calculations. These are required to be carried out in accordance to ASHRAE Handbook of Fundamentals or in accordance to "generally accepted engineering standards."

Section 6.4.3: Controls. System controls specified in ASHRAE 90.1 2007 include thermostatic controls for different building zones, set point overlap restrictions, off-hour controls, ventilation system controls, heat pump auxiliary heat controls, humidifier preheat controls, humidification and dehumidification controls, freeze protection and snow/ice melting controls, and ventilation controls for high occupancy areas. Ventilation controls include damper control, ventilation fan controls, controls for stairs and shafts

Section 6.4.4 HVAC System Construction and Insulation. This section contains provisions for duct and plenum insulation, duct leakage limitations and a requirement for testing leakage on high pressure ducts. Piping insulation requirements cover heating systems with design operating temperatures greater than 40℃ (104℉), cooling systems with temperatures less than 15℃ (59℉). Ductwork i nsulation requirements are provided for supply and return ducts depending on their location.

Prescriptive requirements in ASHRAE -2007 address 9 topics including economizers, simultaneous heating and cooling limitation, air system design and control, hydronic system design and control, heat rejection equipment, energy recovery, exhaust hoods, radiant heating systems, and hot gas bypass limitation.

Section 6.5.1: Economizers. Requirements with regards to economizer control, high limit shut off, dampers, and relief of outside air are specified. Both air side and water side economizers are addressed.

Section 6.5.2: Simultaneous Heating and Cooling Limitations. The simultaneous heating and cooling limitation requires a number of control systems designed to prevent reheating, recooling, mixing of heated and cooled air, or other simultaneous operation of heating and cooling systems to the same zone. Controls include zone thermostatic controls, hydronic system controls, dehumidification and humidification system controls.

Section 6.5.3: Air System Design and Control. The section of air system design and control requires that fan systems be designed to be energy efficient. It applies a fan system power limitation that limits the ratio of the design air flow rate to the fan system power and requires the use of variable air volume (VAV) fan control for motors larger than 10 horsepower. It specifies the process for pressure drop adjustment calculations and fan brake-horse power calculation.

Section 6.5.4: Hydronic System Design and Control. The provisions on hydronic system design and control require that hydronic systems be designed for variable flow, capable of reducing pump flow rates as a function of desired flow or to maintain a minimum required differential pressure.

This section also includes pump isolation requirements, so that that flow in chillers or boilers not in use can be reduced. Chilled and hot water reset controls are specified, with reset controls determined by outside air temperature.

Section 6.5.5: Heat Rejection Equipment. The section of heat rejection equipment requires fan speed controls on motors of more than 7.5 horsepower.

Section 6.5.6: Energy Recovery. The energy recovery provisions require exhaust air energy recovery on systems greater than 5,000 cubic feet per minute (cfm) and with a minimum outdoor air supply of 70% of the design supply air quantity. This section specifies requirements for service water heating, also requires that condenser heat recovery for any building that operates 24 hours a day has a total heat rejection capacity of 6 million Btu/h and a design service water heating load of 1 million Btu/h.

Section 6.5.7: Exhaust Hoods. The section on exhaust hoods requires kitchen hoods larger than 5,000 cfm to be provided with makeup air sized to 50% of exhaust air volume. Fume hoods systems greater than 15,000 cfm must include VAV systems, direct makeup air, or heat recovery.

Section 6.5.8: Radiant Heating Systems. The provisions on radiant heating systems require that radiant heating is used when heating is required for unenclosed spaces.

Section 6.5.9: Hot Gas Bypass Limitation. The hot gas bypass limitation restricts the use of hot gas bypass to cooling systems that have multiple steps of unloading or continuous capacity modulation.

Section 7: Service Water Heating. All service water heating equipment and systems are required to comply with the mandatory and prescriptive provisions. Alternatively, the whole building energy cost approach in the Energy Cost Budget Method may be used. Mandatory requirements include, Section 7.4.1: Load Calculations, Section 7.4.2: Equipment Efficiency, Section 7.4.3: Service Hot water Piping Insulation. Table 6.8.3.specifies piping insulation levels for recirculating system piping, first 8 feet of system piping for a nonrecirculating storage system, pipes that are externally heated etc.

Section 7.4.4: Service Water Heating System Controls. Specifies temperature controls, outlet temperature controls required as well as circulating pump controls.

Section 7.4.5: Pools. Swimming pools shall be provided with a vapor retardant pool cover on or at the water surface. Pools heated to more than 32℃ (90℉) shall have a pool cover with a minimum insulation value of R-2.1 (R-12). Exceptions are pools deriving more than 60% of their energy from site-recovered energy or a solar energy source.

Section 7.4.6: Heat Traps. Prescriptive requirements include permission to use a single boiler to provide both space heating and service water heating if one of three conditions is met:

i. The standby loss of the equipment does not exceed the formula specified in section 7.5.1a.

ii. It can be demonstrated to the authority having jurisdiction, that a single heat source is more energy efficient.

iii. The energy input of the single system is less than 150,000 Btu/h.

Section 9: Lighting: Lighting systems and equipment that apply to interior spaces of buildings, exterior building features and exterior building grounds should comply with the code's mandatory provisions and the prescriptive criteria. Alternatively, the whole building energy cost approach in the Energy Cost Budget Method can be used. Mandatory requirements include:

Section 9.4.1 - Lighting Control. This section includes provisions for automatic lighting shutoff, space control, and exterior lighting control. Automatic lighting shutoff is required to be provided in buildings larger than 5000 sq.ft. This would function either on a scheduled basis, or in the form of an occupant sensor. Exterior lighting controls are required to turn off all exterior lighting when there is sufficient daylight available..

Section 9.4.2 Tandem Wiring. This provision is required for luminaires with lamps greater than 30W.

Section 9.4.3 Exit Signs. Internally illuminated exit signs are required to not exceed 5W/face.

Section 9.4.4 Exterior Building Grounds Lighting

Section 9.4.5 Exterior Building Lighting Power

Prescriptive requirements are provided in terms of interior lighting power (building area method or the space-by-space method) and exterior lighting power requirements. Section 9.5 and 9.6 specify the compliance paths of space-by-space or building area method.

Table 1:

90.1 Mandatory and Prescriptive Requirements

	Section	Description	Applied
5: Buildin g Envelo	5.4.1	Insulation	Y
	5.4.2	Fenestration and Doors	Y

	5.4.3	Air Leakage	Y
	5.5.1.	Conditioned Space	Y
	5.5.2	Unconditioned/ Semiheated Spaces	NA
	5.5.3	Opaque Areas	Y
	5.5.4	Fenestration	Y
Section 6 : Heating, Ventilating and Air Conditioning	6.4.1	Minimum Equipment Efficiencies	Y
	6.4.2.	Load Calculations	Y
	6.4.3.	Controls	Y
		Demand Control Ventilation	N
	6.4.4.	HVAC System Construction and Insulation	Y
		Duct and Plenum Insulation	N
		Duct Leakage	N
	6.5.	Prescriptive Path	
	6.5.1.	Economizer	Y
		Air Side Economizer	Y
		Water Side Economizer	Y
	6.5.2.	Simultaneous Heating and Cooling Limitation	Y
	6.5.3.	Air System Design and Control	Y
	6.5.4.	Hydronic System Design and Control	Y
	6.5.5	Heat Rejection Equipment	Y
	6.5.6.	Energy Recovery	N
	6.5.7.	Kitchen Hoods	N
	6.5.8	Radiant Heating Systems	N
	6.5.9.	Hot Gas Bypass	N
Section 7&9: Lighting and SHW	7.4.1.	Load Calculations	Y
	7.4.2.	Equipment Efficiency	Y
	7.4.3.	Piping Insulation	N
	7.4.4.	SHW System Controls	Y
	7.4.5.	Pools	N
	9.2.1	Building Area Method	Y
	9.4.1.	Lighting Control	Y

Standard 189.1- Mandatory and Prescriptive Measures. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the American National Standards Institute (ANSI), the U.S. Green Building Council (USGBC), and the Illuminating Engineering Society of North America (IESNA), have developed Standard 189.1-2009 Standard for the Design of High-Performance Green Buildings Except Low-Rise Residential Buildings (ASHRAE 2010 and 2007). This standard uses 90.1 2007 as the baseline for determining energy savings and aims at 30% energy savings (Long, Bonnema, & Field, July 2010) compared to Standard 90.1-2007 through several improvements over internal loads (equipment and lighting) as well as HVAC measures etc. The energy efficiency chapter contains a set of mandatory provisions and provides two paths to creating a high-performance green building:

- A *PRESCRIPTIVE GUIDELINE* that provides minimum requirements to meet the Standard.
- *PERFORMANCE* monitoring to ensure compliance.

The measures have been summarized below and analyzed in detail in a later sections of the Standard, applicable to the analysis- (Bryan, 2010)

- Section 5: Site Sustainability (3 mandatory, 1 prescriptive / 1 performance)
- Section 6: Water Use Efficiency (2 mandatory, 3 prescriptive / 2 performance)
- Section 7: Energy Efficiency (3 mandatory, 7 prescriptive / 3 performance)
- Section 8: Indoor Environmental Quality (IEQ) (5 mandatory, 2 prescriptive / 2 performances)

Mandatory Provisions. Standard 189.1-2009 includes mandatory provisions (7.3) for all projects in the following technical areas to meet the 30% goal:

- 7.3.1: Mandatory provisions of Standard 90.1
- 7.3.2: Provision for future on-site renewable energy systems
- 7.3.3: Minimum energy metering.

The energy efficiency chapter includes specific prescriptive recommendations for energy efficiency improvements; these are organized by climate zone in the following technical areas to meet the 30% goal.

Prescriptive Provisions. The prescriptive recommendations include-

- Section 7.4.1: General

  On-site renewable energy requirement of 6.0 kBtu/ft2(68 MJ/m2) of conditioned space (7.4.3.1b lowers this to 4.0 KBtu/ft2[45 MJ/m2])

- Section 7.4.2: Building Envelope
  - Roofs
  - Walls
  - Floors
  - Slabs
  - Doors
  - Vertical glazing
  - Skylights
  - Overhangs
  - Continuous air barrier
- Section 7.4.3: HVAC Equipment and Systems
  - Cooling equipment efficiencies
  - Economizer thresholds
  - Heating equipment efficiencies
  - Energy recovery
  - Fan power limitations
  - Supply fans
  - Ventilation controls for high occupancy areas
  - Variable-speed kitchen hoods
  - Duct sealing

- Duct insulation
- Pipe insulation
- Pipe pressure loss limitations
- Automatic controls for hotel/motel guest rooms
- Section 7.4.4: Service Water Heating
- Equipment efficiencies
- Pipe insulation
- Spa insulation

- Section 7.4.5: Power
  - Load factor/peak load reduction
- Section 7.4.6: Lighting
  - Daylighting controls
  - Occupancy sensor controls
  - Interior electric lighting wattage
  - Exterior lighting controls
  - Exterior electric lighting wattages
- Section 7.4.7: Other Equipment

Most equipment and appliances to comply with ENERGY STAR including high-efficiency ice cube machines, commercial refrigerators and freezers, and commercial clothes washers. Other chapters include mandatory provisions and prescriptive recommendations that affect energy consumption, either by providing energy savings (e.g., lower hot water consumption) or by increasing energy consumption (e.g., increased outdoor air rates).

Chapter 5: Site Sustainability. Section 5.3.2.3: Addresses issues related to the heat island effect, requirement of a high albedo roof (in climate zones 1–3).

Chapter 6: Water Use Efficiency. Includes provisions for-

- Section 6.3.2.1: Interior water use, plumbing fixtures: lower flow rate for hot water
- Section 6.3.2.2: Interior water use, clothes washers/dishwashers: lower hot water consumption
- Section 6.4.2.2: Interior water use, commercial kitchen equipment: lower hot water consumption
- Section 6.4.2.3: Interior water use, medical laboratories: heat recovery from hot water.

Chapter 8: Indoor Environmental Quality. Chapter 8 includes provisions for-

- Section 8.3.4: Daylighting by skylights in low-rise buildings with large spaces (e.g., retail, grocery, warehouse) in climate zones 1–6: daylight to offset electric lights (will likely also reduce cooling, but increase heating)
- Section 8.4.1: Daylighting by vertical fenestration in offices and classrooms: increased window area over Standard 90.1 will increase heat loss and cooling loads caused by solar gains, but will reduce lighting energy consumption.
- Standard 189.1-2009 requires a continuous air barrier. This was modeled with an infiltration reduction of 25% for buildings with fewer than 7 floors or that are in climate zones 4–8.

Table 2

Standard 189.1: Mandatory and Prescriptive Requirements

	Section	Description	Y/N
Chapter 7: Energy Efficiency Requirements	7.4.1.	General - On Site Renewable	Y
	7.4.2.	Building Envelope	Y
	7.4.3.	HVAC Equipment and Systems	Y
		Energy Recovery	N
		Ventilation Controls for High Occupancy Areas	N
		Variable-Speed Kitchen Hoods	N
		Duct Sealing	N
		Duct Insulation	N

		Pipe Insulation	N
		Pipe Pressure Loss Limitation	N
		Automatic Controls for Hotel/Motel Guest Rooms	N
	7.4.4.	Service Water Heating	Y
		Pipe Insulation	N
		Spa Insulation	N
	7.4.5	Power	N
	7.4.6.	Lighting	Y
		Exterior Lighting Controls	N
		Exterior Electric Lighting Wattages	N
	7.4.7.	Other Equipment	Y
		Condenser Waste Heat Recovery	N
		Wastewater Heat Recovery	N
Chapter 5	5.3.2.3.	Heat Island- High Albedo Roof	Y
Chapter 6	6.3.2.1.	Low flow rate fixtures	Y
	6.3.2.2.	Commercial Kitchen Equipment: Lower hot water consumption	Y
	6.4.2.3	Heat Recovery from hot water	N
Chapter 8	8.3.4.	Daylighting by Skylights in low rise buildings	Y
	8.4.1.	Daylighting by vertical fenestration in offices	Y

2.1.4. Performance rating method - 90.1 Appendix D and 189.1 Appendix D.

This section analyzes the performance rating method for 90.1 and 189.1 within the following sections-

1. Interpretation of the Code. Detailed analysis of the performance rating method for 90.1 2007 and 189.1 2009 as well as odentification of aspects varying between the various codes and standards for climate zone 2B.
2. Translation for ECCO. Each code required input is translated to an eQUEST input with its COMMAND, KEYWORD value.
3. Implementation for eQUEST: Global parameters are defined to include the following aspects-

- Building Envelope
- Opaque Assemblies
- Fenestration
- Internal Loads
- Lighting Loads, Equipment Loads, Occupancy Loads
- Daylighting
- Schedule of Operation
- Occupancy, lighting, heating, cooling schedules etc.
- Heating and Cooling Systems
- System Type, Operating Temperatures
- Equipment, Pumps, Motors, Fans
- Economizer, Chiller, Heat Rejection

Appendix G3.1.1.1 Design Mode. *The baseline building design shall be modeled with the same number of floors and identical conditioned floor area as the proposed design.*

Interpretation of the Code. The baseline model and proposed model are required to be identical in terms of the conditioned floor area, the number of floors and the fuel type used.

Translation for ECCO. The proposed design is used as an input file to create the baseline building. Hence the building geometry and fuels used remain identical between both models. All code required provisions are added/substituted with the proposed design.

Implementation for eQUEST. The eQUEST ‘INP’ file of the proposed design becomes the input file for the baseline design.

Appendix G3.1.1.2 Additions and Alteration. These are beyond the scope of this thesis.

Appendix G3.1.1.3 Space Use Classification. Same as proposed design***.***

Interpretation of the Code. Space use classification is required to be same for both proposed and baseline building. For the purpose of this thesis, it is assumed to be "Building Type Method", and calculations have been carried out assuming the same for both standards.

Appendix G3.1.1.4 Schedules. Same as Proposed Design. Exception: Schedules may be allowed to differ between proposed design and baseline building design when necessary to model nonstandard efficiency measures, provided that the revised schedules have the approval of the rating authority. Measures that may warrant use of different schedule include, but are not limited to, lighting controls, natural ventilation, demand control ventilation, and measures that reduce service water heating loads.

Interpretation of the Code. Schedules (occupancy, lighting, equipment, infiltration etc.) have been assumed to be identical for both proposed design and baseline building.

Appendix G3.1.1.5 Building Envelope. *Equivalent dimensions shall be assumed for each exterior envelope component type as in the proposed design; i.e., the total gross area of exterior walls shall be the same in the proposed and baseline building designs. The same shall be true for the areas of roofs, floors, and doors, and the exposed perimeters of concrete slabs on grade shall also be the same in the proposed and baseline building designs. The following additional requirements shall apply to the modeling of the baseline building design:*

a. ***Orientation.*** *The baseline building performance shall be generated by simulating the building with its actual orientation and again after rotating the entire building 90, 180, and*

270 degrees, then averaging the results. The building shall be modeled so that it does not shade itself.

b. ***Opaque Assemblies.*** *Opaque assemblies used for new buildings or additions shall conform with the following common, lightweight assembly types and shall match the appropriate assembly maximum U-factors in Tables 5.5-1 through 5.5-8 (90.1) and Tables A1 through A8 (189.1):*

- *Roofs—Insulation entirely above deck*
- *Above-grade walls—Steel-framed*
- *Floors—Steel-joist*
- *Opaque door types shall match the proposed design and conform to the U-factor requirements from the same tables.*
- *Slab-on-grade floors shall match the F-factor for unheated slabs from the same tables.*

Opaque assemblies used for alterations shall conform with Section 5.1.3 (as modified by 7.3 and 7.4 for 189.1)

c. ***Vertical Fenestration.*** *Vertical fenestration areas for new buildings and additions shall equal that in the proposed design or 40% of gross above grade wall area, whichever is smaller, and shall be distributed on each face of the building in the same proportions in the proposed design (Distributed uniformly in horizontal bands across the four orientations). Fenestration U-factors shall match the appropriate requirements in Tables 5.5-1 through 5.5-8 (Tables A1-A8). Fenestration SHGC shall match the appropriate requirements in Tables 5.5-1 through 5.5-8 (Tables A1-A8 using the value of* $SHGC_{all}$ *provide that the vertical fenestration complies with7.4.2.9. If not then the SHGC for the east and west facades would be uniformly reduced until the vertical fenestration complies with 7.4.2.9. Using the vertical fenestration area specified above, the vertical fenestration visible light transmittance shall be determined so that the vertical fenestration complies with the effective aperture requirements in 8.4.1). All vertical glazing shall be assumed to* *be flush with the exterior wall, and no shading projections shall be modeled (with shading by a permanent projection complying with 7.4.2.5). Manual window shading devices such as blinds or shades shall not be modeled. The fenestration areas for envelope alterations shall reflect the limitations on area, U-factor, and SHGC as described in Section 5.1.3 (as modified by 7.3 and 7.4).*

d. ***Skylights and Glazed Smoke Vents.*** *Skylight area shall be equal to that in the proposed building design or 5% of the gross roof area that is part of the building envelope, whichever is smaller (but not lesser than that required in 8.3.4). If the skylight area of the proposed building design is greater than 5% of the gross roof area, baseline skylight area shall be decreased by an identical percentage in all roof components in which skylights are located to reach the 5% skylight-to-roof ratio. Skylight orientation and tilt shall be the same as in the proposed building design. Skylight U-factor and SHGC properties shall match the appropriate requirements in Tables 5.5-1 through 5.5-8 (Tables A1 through A8 and shall comply with requirements in 8.3.4.2)*

e. ***Roof albedo.*** *All roof surfaces shall be modeled with a reflectivity of 0.30. (Those roof surfaces subject to 5.3.2.3 shall be modeled with a reflectivity of 0.45.)*

f. ***Existing Buildings.*** *For existing building envelopes, the baseline building design shall reflect existing conditions prior to any revisions that are part of the scope of work being evaluated.*

Interpretation of the Code. Standard 189.1 is more stringent for wall insulation, roof insulation and vertical fenestration. Fixed external shades are made mandatory in 189.1 as are skylights. The table below summarizes the comparison on the building envelope component for both 90.1 2007 and 189.1 for climate zone (CZ) 2B.

a. Orientation

The baseline building is simulated for all four orientations and the average energy consumption of the 4 orientations is calculated.

b. Opaque Assemblies

Opaque assemblies include above grade walls, roof assemblies, exposed floors and doors. Below grade walls and basements have been excluded from the scope of this project.

Table 3:

Appendix G&D: Definitions

Opaque Assemblies: Specification method	
Definition	The construction assembly is defined through layers Input, each layer representing a material. With this method, heat transfer is delayed in accord with the thermal mass and other properties of the assembly.
Units	Data Structure : Construction Assemblies
Baseline Rules	See TABLE ABC for description of roof, wall and floor construction assembly.
Opaque Assemblies: Wall Assembly	
Definition	The 4 wall assemblies as specified by the code are a) mass walls, b) metal building walls, c) metal framing walls, and d) wood framing and other walls.
Baseline Rules (90.1 and 189.1)	All walls in the baseline building are modeled as "metal framed." The wall geometry is identical in proposed and baseline building.
Opaque Assemblies: Roof Assembly	
Definition	The 4 roof assemblies as specified by the code are a) attic and other roofs; b) metal building roofs; and c) roofs with insulation entirely above deck.
Baseline Rules (90.1 and 189.1)	All roofs in the baseline building are modeled as “insulation entirely above deck.” The roof geometry is identical in proposed and baseline building.
Opaque Assemblies: Floor Assembly	
Definition	The three floor type categories are: a) mass floor, b) steel joist floor, and c) wood and other floors. These are all for exposed floors and do not include interior floors or slab on grade.

Baseline Rules (90.1 and 189.1)	The baseline building floors shall be of type “steel joist.” the floor geometry would be identical to that of the proposed design.
Opaque Assemblies: Doors	
Definition	The baseline standards classify doors as either: swinging or non-swinging. Non-swinging are generally roll-up doors. Doors that are more than 50% glass are treated as windows and must be entered by the user using the windows building descriptors.
Baseline Rules	The baseline building door type shall be the same as the proposed design. For the purpose of this project all doors are assumed to be "Swinging".

c. Vertical Fenestration

Vertical Fenestration	
Definition	Baseline standards for vertical fenestration determine the thermal performance and solar performance requirement. Specifications for: Nonmetal framing (all); metal framing (curtain wall/storefront); metal framing (entrance door); or metal framing (all other)
Baseline Rules (90.1 and 189.1)	The fenestration geometry and frame is required to be same as the proposed design. For the purpose of this analysis, it is assumed to be metal framing (all other). A maximum window area of 40% of above grade walls is defined by the standard.
Baseline Rules - 90.1	If the gross area of all windows in the building exceeds 40% of the gross above grade exterior wall area in the building, the dimensions of each window in the baseline building shall be reduced in size such that the window area in the baseline building is equal to 40% of the above-grade exterior wall area.
Baseline Rules 189.1	If the gross area of all windows in the building exceeds 40% of the gross above grade exterior wall area in the building, the dimensions of each window for all orientations is reduced, such that window area for no orientation is over 40% of wall area.

Overhangs were applied as a part of the Standard 189.1-2009 analysis. Overhangs with a projection factor of 0.5 were applied to all west, south, and east windows in climate zones 1–5 to comply with section 7.4.2.5 of Standard 189.1-2009. No overhangs were used on the Standard 90.1 models.

d. Skylights and Glazed Smoke Vents

Skylights	
Definition	This classification of skylights determines the thermal performance and solar performance requirement for vertical fenestration. Baseline standards include : Glass skylight with curb; plastic skylight with curb; or skylights with no curb
Baseline Rules (90.1 and 189.1)	The fenestration geometry and frame is required to be same as the proposed design. A maximum skylight area of 5% of roof area is defined by the standard.
Baseline Rules 189.1	If skylights are not provided in proposed design, the baseline building is required to have skylights if all the below defined criteria are met.

Standard 90.1: Skylights are modeled in baseline building, if they have been provided in the proposed design. **Standard 189.1:** Skylights are provided in the baseline buildings if all the following criteria are met:

- Square footage greater than 20,000 ft2
- Floor-to-floor height greater than 15 ft
- Three or fewer floors.

If these criteria were met, skylights were added at the following skylight to floor area percentages according to Table 8.3.4.1 in Standard 189.1-2009:

- 3.0% if the LPD was greater than 0.5 W/ft2 (5 W/m2) but less than 0.9 W/ft2 (10 W/m2)
- 3.3% if the LPD was greater than 0.9 W/ft2 (10 W/m2) but less than 1.3 W/ft2 (14 W/m2)
- 3.6% if the LPD was greater than 1.3 W/ft2 (14 W/m2).

e. Roof Albedo

Roof Albedo

Definition	Exterior surface properties of the roof include emissivity, reflectivity and roughness. Albedo or reflectivity refers to the ability of the roof to reflect light and absorptance is 1-reflectivity. The default value of 1 is assumed for surface roughness.
Baseline Rules	Both codes define the value for roof albedo, which has been input in the form of absorptance for the roof.

Table 4

Appendix G&D 3.1.1.5: Interpretation of the Code

BUILDING ENVELOPE				
S.NO.	**DESCRIPTION**	**90.1 2007**	**189.1 2009**	**COMMENTS**
A	**ORIENTATION**			
	Baseline Building Analyzed for	0° , 90°, 180°, 270°	0° , 90°, 180°, 270°	Both 90.1 2007 and 189.1 require analysis for all four orientations.
B	**OPAQUE ASSEMBLIES**			
1	**ROOF - INSULATION COMPLETELY ABOVE DECK**			
	Roof CI Value	R-20 (Assembly Max. - U-0.048)	R-25 CI (Assembly Max. U-0.039)	Increase in 189.1 for CI requirements.
	Absorptance (1-Reflectance)	0.7 (1-0.3)	0.55 (1-0.45)	189.1 requires roof surfaces in CZ 2B to be modeled with a reflectivity of 0.45.
2	**ABOVE GRADE WALLS- STEEL FRAMED**			
	Wall Cavity Insulation- Effective R Value	8.2 (R-13 Cavity Insulation)	8.2 (R-13 Cavity Insulation)	The cavity insulation requirements are the same for both 90.1 and 189.1
	Wall- Continuous Insulation R Value	None	R-6.7 ci	90.1 has no requirements for CI in steel framed buildings for CZ 2B. 189.1 is an improvement to that.
3	**FLOOR CONSTRUCTION - STEEL JOIST**			
	Slab on Grade (Unheated)	NR F - 0.730	NR F - 0.730	This value is the same for both codes.
	Floors	R-19 (Effective - R-16.369) (Assembly Max- 0.052)	R-30 (Assemble Max. U-0.038)	The insulation requirement for floors has increased in 189.1
4	**OPAQUES DOORS**			

	Swinging	0.7	U - 0.60	
C	**VERTICAL FENESTRATION**			
1	Glazing Area	40% Distributed in same proportion as proposed design	Maximum 40% Distributed uniformly in horizontal bands in all four orientations.	189.1 requires windows distributed uniformly in all orientations, as against the same proportion as required by 90.1
2	**PROPERTIES (Assuming Metal framing with or without frame)**			
	Window U Value	0.75	0.75	Requirements for both the codes is the same
	SHGC	0.25	0.25	Requirements for both the codes is the same
D	**SKYLIGHTS AND GLAZED VENTS**			
3	**SKYLIGHTS**			
	Skylight with Curb, Glass			Skylights are required for compliance with 189.1 in accordance to Section 8.3.5. Daylighting via Toplighting is required for large enclosed spaces which are either 3 stories or less above grade, conditioned or unconditioned spaces greater than 20,000 sq.ft directly under a roof with finished ceiling heights greater than 15 ft that have a LPD equal to or greater than 0.5 W/sq.ft.
	0% - 2%	U Value -1.98 SHGC- 0.36	U Value - 0.71 SHGC- 0.19	
	2.1% - 5%	U Value -1.98 SHGC- 0.19	U Value - 0.71 SHGC- 0.19	
	Skylight with Curb, Plastic			
	0% - 2%	U Value -1.90 SHGC- 0.39	U Value - 1.12 SHGC- 0.27	
	2.1% - 5%	U Value -1.90 SHGC- 0.34	U Value - 1.12 SHGC- 0.27	
	Skylight without Curb, All			
	0% - 2%	U Value -1.36 SHGC- 0.36	U Value - 0.57 SHGC- 0.19	
	2.1% - 5%	U Value -1.36 SHGC- 0.19	U Value - 0.57 SHGC- 0.19	

Translation for eQUEST and ECCO.

Table 5

Appendix G&D 3.1.1.5: Translation for ECCO and eQUEST

Each required parameter is translated to an eQUEST input and a corresponding global parameter for ECCO.

Table 6

Building Envelope: Opaque Assemblies - Wall Construction *Layers*

The layer input specification method is explained for the wall construction layers. Wall construction has been assumed as 2X4 Metal Frame, 24" O.C. The layers for 90.1, 189.1 are defined with the corresponding density, conductivity and thickness. These are also compared with the eQUEST defined layers for the 90.1 2007 ruleset.

Table 7

Building Envelope: Opaque Assemblies - Roof Construction Layers

The layer input specification method is explained for the roof construction layers. The layers for 90.1, 189.1 are defined with the corresponding density, conductivity and thickness. These are also compared with the eQUEST defined layers for the 90.1 2007 ruleset.

Table 8

Building Envelope: Opaque Assemblies – Floor Construction Layers

The layer input specification method is explained for the floor construction layers. The layers for 90.1, 189.1 are defined with the corresponding density, conductivity and thickness. These are also compared with the eQUEST defined layers for the 90.1 2007 ruleset.

Table 5

Appendix G&D 3.1.1.5: Translation for ECCO and eQUEST

BUILDING ENVELOPE				
S.N	**DESCRIPTION**	**COMMAND (KEY-WORD)**	**UNITS**	**GLOBAL PARAM.**
A	**ORIENTATION**			
	Baseline Building Analyzed for	BUILD-PARAMETERS (AZIMUTH)	(Numeric) Dimensionless	Orientation
B	**OPAQUE ASSEMBLIES**			
1	**ROOF - INSULATION COMPLETELY ABOVE DECK**			
	Roof CI Value	MATERIAL (RESISTANCE)	(Numeric) h-sq.ft F/ Btu	Roof-CI
	Absorptance (1-Reflectance)	CONSTRUCTION (ABSORPTANCE)	(Numeric) Dimensionless	Roof-Absorptance
2	**ABOVE GRADE WALLS- STEEL FRAMED**			
	Wall Cavity Insulation-Effective R Value	MATERIAL (RESISTANCE)	(Numeric) h-sq.ft F/ Btu	R-Eff-Wall
	Wall- Continuous Insulation R Value	MATERIAL (RESISTANCE)	(Numeric) h-sq.ft F/ Btu	R-CI-Wall
3	**FLOOR CONSTRUCTION - STEEL JOIST**			
	Slab on Grade (Unheated)	MATERIAL (RESISTANCE)	(Numeric)	NR
	Floors	MATERIAL (RESISTANCE)	(Numeric) h-sq.ft F/ Btu	Floor-R-Value
4	**OPAQUES DOORS**			
	Swinging	CONSTRUCTION (U-VALUE)	(Numeric) Btu/h-sq.ft-F	Door-U-Value
C	**VERTICAL FENESTRATION**			
1	Glazing Area	WINDOW (WIDTH) (HEIGHT)	(Numeric) Percentage	WWR-Multiplier
2	**PROPERTIES (Assuming Metal framing with or without frame)**			
	Window U Value	GLASS-TYPE (GLASS-CONDUCT)	(Numeric) Btu/h-sq.ft-F	Glass-U-Value

	SHGC	GLASS-TYPE (SHADING-COEF)	(Numeric) Dimensionless	Glass-SHGC
D	**SKYLIGHTS AND GLAZED VENTS**			
3	SKYLIGHTS			
	Skylight with Curb, Glass			
	0% - 2%	GLASS-TYPE (GLASS-CONDUCT) (SHADING-COEF)	(Numeric) Btu/h-sq.ft-F Dimensionless	Skylight-U-Value Skylight-SHGC
	2.1% - 5%	GLASS-TYPE (GLASS-CONDUCT) (SHADING-COEF)	(Numeric) Btu/h-sq.ft-F Dimensionless	Skylight-U-Value Skylight-SHGC
	Skylight with Curb, Plastic			
	0% - 2%	GLASS-TYPE (GLASS-CONDUCT) (SHADING-COEF)	(Numeric) Btu/h-sq.ft-F Dimensionless	Skylight-U-Value Skylight-SHGC
	2.1% - 5%	GLASS-TYPE (GLASS-CONDUCT) (SHADING-COEF)	(Numeric) Btu/h-sq.ft-F Dimensionless	Skylight-U-Value Skylight-SHGC
	Skylight without Curb, All			
	0% - 2%	GLASS-TYPE (GLASS-CONDUCT) (SHADING-COEF)	(Numeric) Btu/h-sq.ft-F Dimensionless	Skylight-U-Value Skylight-SHGC
	2.1% - 5%	GLASS-TYPE (GLASS-CONDUCT) (SHADING-COEF)	(Numeric) Btu/h-sq.ft-F Dimensionless	Skylight-U-Value Skylight-SHGC

Table 6

Building Envelope: Opaque Assemblies - Wall Construction Layers

S.No		Material Name	Thickness (ft)	Conductivity (Btu/h-ft-℉)	Density (lb/ft3)	Spec. Heat (Btu/lb-℉)	R-Value (h-ft2-℉/Btu)
	External Wall Layers						
A.		As Modeled (ASHRAE 90.1 2007)					
	1	External Film Resistance					0.2400
	2	Plywd 5/8in (PW04)	0.052	0.0667	34	0.29	0.7796
	3	Bldg Paper Felt (BP01)	n/a	n/a	n/a	n/a	0.0600
	4	R-Wall-Ins1	n/a	n/a	n/a	n/a	0.0100
	5	R-Wall-Ins2	n/a	n/a	n/a	n/a	7.2000
	6	GypBd 1/2in (GP01)	0.042	0.0926	50	0.2	0.4536
	7	Inside Film Resistance					0.6800
	8	Wall Assembly R Value					9.4232
	9	Wall Assembly U Value					0.1061
C.		As Modeled (ASHRAE 189.1 2009)					
	1	External Film Resistance					0.2400
	2	Plywd 5/8in (PW04)	0.052	0.0667	34	0.29	0.7796
	3	Bldg Paper Felt (BP01)	n/a	n/a	n/a	n/a	0.0600
	4	R-Wall-Ins1	n/a	n/a	n/a	n/a	6.5000
	5	R-Wall-Ins2	n/a	n/a	n/a	n/a	7.2000
	6	GypBd 1/2in (GP01)	0.042	0.0926	50	0.2	0.4536
	7	Inside Film Resistance					0.6800
	8	Wall Assembly R Value					15.9132
	9	Wall Assembly U Value					0.0628
B		(According to eQUEST 90.1 Baseline for CZ 2B)					
	1	External Film Resistance					0.240
	2	Stucco 3/8in (SC02)	0.033	0.4167	116	0.2	0.079
	3	GypBd 5/8in (GP02)	0.052	0.0926	50	0.2	0.562
	4	901_NRes_AGWall_Matl	n/a	n/a	n/a	n/a	6.009
	5	GypBd 5/8in (GP02)	0.052	0.0926	50	0.2	0.562
	6	Inside Film Resistance					0.680
	7	Wall Assembly R Value					8.131
	8	Wall Assembly U Value					0.123

Table 7

Building Envelope: Opaque Assemblies - Roof Construction Layers

S.No		Material Name	Thickness (ft)	Conductivity (Btu/h-ft-℉)	Density (lb/ft3)	Spec. Heat (Btu/lb-℉)	R-Value (h-ft2-℉/Btu)
	ROOF CONSTRUCTION LAYERS						
A.		As Modeled (ASHRAE 90.1 2007)					
	1	External Film Resistance					0.240
	2	Blt-Up Roof 3/8in (BR01)	0.031	0.0939	70	0.35	n/a
	3	Plywd 5/8in (PW04)	0.052	0.0667	34	0.29	n/a
	4	Roof-Ins1	n/a	n/a	n/a	n/a	20.0000
	5	GypBd 5/8in (GP02)	0.052	0.0926	50	0.2	n/a
	6	Inside Film Resistance					0.680
	7	Roof Assembly R Value					20.920
	8	Roof Assembly U Value					0.048
B.		As Modeled (ASHRAE 90.1 2007)					
	1	External Film Resistance					0.240
	2	Blt-Up Roof 3/8in (BR01)	0.031	0.0939	70	0.35	n/a
	3	Plywd 5/8in (PW04)	0.052	0.0667	34	0.29	n/a
	4	Roof-Ins1	n/a	n/a	n/a	n/a	25.0000
	5	GypBd 5/8in (GP02)	0.052	0.0926	50	0.2	n/a
	6	Inside Film Resistance					0.680
	7	Roof Assembly R Value					25.920
	8	Roof Assembly U Value					0.039
C.		(According to eQUEST 90.1 Baseline for CZ 2B)					
		External Film Resistance					0.240
		Blt-Up Roof 3/8in (BR01)	0.031	0.0939	70	0.35	0.3301
		Steel Decking	0.004	26	480	0.1	0.0002
		901_NRes_Roof_Matl	n/a	n/a	n/a	n/a	19.1570
		GypBd 5/8in (GP02)	0.052	0.0926	50	0.2	0.5616
		Inside Film Resistance					0.680
		Roof Assembly R Value					20.969
		Roof Assembly U Value					0.048

Table 8

Building Envelope: Opaque Assemblies – Floor Construction Layers

	S. No	Material Name	Thickness (ft)	Conductivity (Btu/h-ft-℉)	Density (lb/ft3)	Spec. Heat (Btu/lb-℉)	R-Value (h-ft2-℉/Btu)
	FLOOR CONSTRUCTION LAYERS						
A.		**As Modeled (ASHRAE 90.1 2007) (Perimeter Insulation)**					
	1	Inside Air Film					0.610
	2	Carpet & Rubber Pad	n/a	n/a	n/a	n/a	1.230
	3	EFloor-Ins	n/a	n/a	n/a	n/a	16.200
	4	Conc HW 140lb 6in	0.5	1	140	0.2	0.500
	5	Soil 12in	1	1	115	0.2	1.000
	6	Floor Assembly R Value					19.540
	7	**Floor Assembly U Value**					**0.058**
B.		**As Modeled (ASHRAE 189.1-2009) (Perimeter Insulation)**					
	1	Inside Air Film					0.610
	2	Carpet & Rubber Pad	n/a	n/a	n/a	n/a	1.230
	3	EFloor-Ins	n/a	n/a	n/a	n/a	24.100
	4	Conc HW 140lb 6in	0.5	1	140	0.2	0.500
	5	Soil 12in	1	1	115	0.2	1.000
	6	Floor Assembly R Value					19.540
	7	**Floor Assembly U Value**					**0.058**
C.		**(According to eQUEST 90.1 Baseline for CZ 2B)**					
	1	Inside Air Film					0.610
	2	Flr (G.S1.U1) BMat	n/a	n/a	n/a	n/a	14.143
	3	901_6in_Concrete	0.5	1.33	140	0.2	0.376
	4	901_Earth	1	0.5	100	0.25	2.000
	5	Floor Assembly R Value					17.129
	6	**Floor Assembly U Value**					**0.058**

Implementation for eQUEST. Most of the building envelope components are irrespective of proposed building aspects. The following aspects would be defined through user inputs-

1. WWR-Multiplier

This value is defined on the basis of proposed building wall window ratio and is then assigned as a multiplier to all windows.

2. Skylight-Multiplier

Skylights would be required to be defined in the proposed model, if not present or area less than 3% of roof area. A global parameter would then be assigned to reduce the area of the skylight to a negligible value for the proposed and baseline case analysis for 90.1 2007. This value is defined on the basis of proposed building skylight to roof area ratio and is then assigned as a multiplier to all skylights.

3. Skylight U Value: Defined on the basis of the proposed skylight type.

4. Skylight SHGC: Defined on the basis of the proposed skylight type.

Table 9

AppendixG&D3.1.1.5 - Implementation for eQUEST

S.No.	Description	Parameter Name	Calculated / Pre-Defined	ASHRAE 90.1 - 2007	ASHRAE-189.1
Appendix G&D 3.1.1.5 - Building Envelope					
1	Orientation (All 4 for Baseline)	Orientation	Pre-Defined	0	0
2	Roof Continuous Insulation	Roof-CI	Pre-Defined	20	25
3	Roof Absorptance value	Roof-Absorptance	Pre-Defined	0.7	0.55
4	Above Grade Walls, Effective R value for Cavity Insulation	R-Eff-Wall	Pre-Defined	7.2	7.2
5	Above Grade Walls - Continuous Insulation	R-CI-Wall	Pre-Defined	0.01	6.5
7	Floor Perimeter Insulation	EFloor-R	Pre-Defined	16.2	
8	Opaque Door U	Door-U-Value	Pre-Defined	0.7	0.6

	Value				
9	WWR Multiplier	WWR-Multiplier	Calculated	0.40	0.40
10	Glass U Value	Glass-U-Value	Pre-Defined	0.75	0.75
11	Glass SHGC	Glass-SHGC	Pre-Defined	0.25	0.25
12	Glass Visible Transmittance	Glass-T-Vis	Pre-Defined	0.9	0.9
13	Skylight Multiplier	Skylight-Multiplier	Calculated	0.9	0.9
14	Skylights-U Value	Skylight-U-Value	Calculated	1.98	1.19
15	Skylights- SHGC	Skylight-SHGC	Calculated	0.36	0.19
16	External Shading - Projection Factor (W,E,S)	PF	Predefined	NR	0.50

Appendix G3.1.1.6 Lighting. *Lighting power in the baseline building design shall be determined using the same categorization procedure (building area or space function) and categories as the proposed design with lighting power set equal to the maximum allowed for the corresponding method and category in Section 9.2 of ASHRAE 90.1 (and section 7.4.6 of 189.1). No automatic lighting controls (e.g., programmable controls or automatic controls for daylight utilization) shall be modeled in the baseline building design, as the lighting schedules used are understood to reflect the mandatory control requirements in this standard.*

(Automatic lighting controls shall be modeled in accordance with Section 9.4.1 of ASHRAE Standard 90.1 and 7.4.3.12 and 7.4.6. No additional lighting controls, such as programmable controls or automatic controls for daylight utilization would be modeled in the baseline building)

Interpretation of the Code. The space-by-space method or the building area method can be used in 90.1 2007 to determine maximum lighting power densities. A 10% LPD reduction over Standard 90.1 is required by 189.1 for all spaces types, except retail, to comply with section 7.4.6.1 of Standard 189.1-2009.

Table 10

Appendix D&G3.1.1.6: Definitions

Lighting Power Densities	
Definition	Total connected lighting power for all regulated interior lighting power. This includes the loads for lamps and ballasts.
Units	W/sq.ft
Baseline Rules	The Building area method or Space-by-Space method is used for determining the LPD for the baseline building. With the building classification method, the product of the lighting power density for the building classification and the floor area of the space is used. The use of Space-by-Space method is beyond the scope of this project.

- **Occupancy Sensors**

Neither Standard 90.1-2004 nor 90.1-2007 requires occupancy sensor controls to reduce electric lighting consumption. However, Standard 189.1 specifies a requirement for occupancy sensors depending on building use and dimensions of the space. This analysis includes these lighting controls in the Standard 189.1-2009 models when applicable. Occupancy sensors were modeled as a 10% LPD reduction for offices.

Occupancy Sensors	
Definition	Occupancy sensors are not required by baseline standard 90.1, however are required by 189.1. These reduce lighting power more or less uniformly over the day and hence are modeled as power adjustment factors. Power adjustment factors represent the percent reduction in lighting power that will approximate the effect of the control. Mentioned in 90.1-2007, Appendix G, Table G3.2 as a 10% reduction over the LPD.
Baseline Rules	PAF is zero for 90.1 2007 and 0.1 or 10% for 189.1 for Occupancy Sensors.

- **Daylighting**

Standard 90.1 2007 does not require daylighting controls in daylit spaces. However, daylighting controls are required in accordance to 189.1 depending on use of building and dimensions of the space (in spaces with area greater than 250sq.ft). Daylighting sensors are required for spaces either side-lit or top-lit. For the purpose of this analysis, one continuous dimming daylighting sensor has been added per zone with a set point of 40 fc (400 lux).

Daylighting Controls	
Definition	The daylighting control has been modeled as continuous dimming. Continuous Dimming controls have a fraction to rated power to fraction of rated output that is a linear interpolation of the minimum power fraction at the minimum diming light fraction to rated power (power fraction = 1.0) at full light output. See figure below.
Baseline Rules	90.1 baseline does not have daylighting controls. These have been provided for 189.1 baseline.

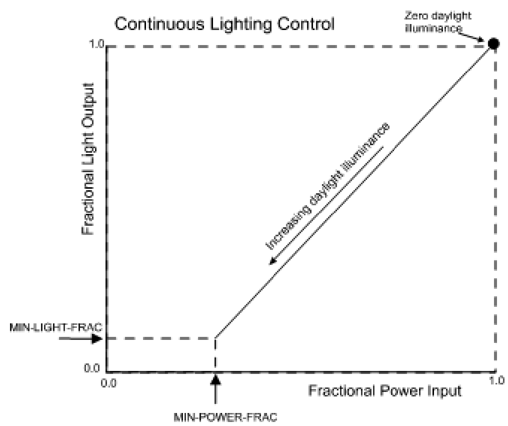

Figure 5: Continuous Lighting Controls

- **Automatic Controls**

Automatic controls are not required by standard 90.1 2007. Standard 189.1 doesn't require automatic controls for offices, hence these have not been considered for the purpose of this study. Automatic controls are required only for hotel and motel guest rooms.

Table 11

Appendix G&D3.1.1.6 Lighting: Interpretation of Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS
1	LPD	1	0.9	189.1 requires LPD 0.9 times the value in 90.1
2	Occupancy Sensors (Yes/No)	NA	10% Less than 90.1 2007	Automatic controls cannot be modeled in 90.1 baseline. However occupancy sensors, are required to be modeled in

				189.1
3	Daylighting (Yes/No)	NO	YES	Daylighting has to be provided in top-lit and side-lit spaces fulfilling the defined requirements, for Standard 189.1. These controls are not required of Standard 90.1

Translation for ECCO.

Table 12

Appendix G&D3.1.1.6 Lighting: Translation for ECCO

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	GLOBAL PARAMETER
1	LPD	SPACE (LIGHTING-W/AREA)	(Numeric) W/sq.ft	LPD
2	Occupancy Sensors (Yes/No)	SPACE (LIGHTING-W/AREA)	(Numeric)	Occupancy-Sensors
3	Daylighting (Yes/No)	SPACE (DAYLIGHTING)	(Existing Symbol)	Enable-Day

Implementation for eQUEST

Table 13

Appendix G&D3.1.1.6: Standard 189.1 - Additional Inputs Required

Standard 189.1 Analysis: Additional Inputs Required	
Skylights	Skylights are required to be provided through design wizard, for Standard 189.1 analysis. Global parameter (Skylight-Multiplier) is assigned for proposed model and 90.1 baseline model analysis. (Refer to Section -AppendixG3.1.1.5 for details on skylight requirement)
	Global Parameter- "Skylight-Multiplier" = 0.01

	"Skylt (T.C17.I49.S1)" = WINDOW
	HEIGHT = {4 * #pa("Skylight-Multiplier")}
	WIDTH = {4 * #pa("Skylight-Multiplier")}

External Shading	A projection-factor (0.5) is required on S,E,W facades. Overhangs are required to be added in the following manner-

	Global Parameter- "PF" = 0.5
	"South Win (G.S1.E1.W1)" = WINDOW HEIGHT = {5*#pa("WWR-Multiplier")} WIDTH = {41*#pa("WWR-Multiplier")} OVERHANG-D = {#l("HEIGHT") * #pa("PF")}
Daylighting	Daylighting controls are required to be provided for Standard 189.1. (Refer to Section AppendixG&D3.1.1.6- Daylighting Controls). Daylighting sensors have been modeled as continuous, 40fc threshold. Global Parameter for Daylighting control has been modeled in the following manner, with value "NO" for 90.1 Baseline and "YES" for 189.1 Baseline.
	Global Parameter- "Daylight-Sensor" = NO
	"East Perim Spc (T.E14)" = SPACE DAYLIGHTING = {#si(#pa("Daylight-Sensor"), "SPACE" , "DAYLIGHTING")}
Occupancy Sensors	Occupancy Sensors are required to be provided for Standard 189.1. (Refer to Section AppendixD&G3.1.1.6- Occupancy Sensors). Occupancy Sensors have been modeled as a 10% reduction over the lighting power density.
	Global Parameter- "Occ-Sensor" = 0.1
	"North Perim Spc (G.N3)" = SPACE LIGHTING-W/AREA = ({#pa("LPD")-(#pa("Occ-Sensor")*#pa("LPD"))})
Equipment Power	A 10% reduction over the equipment power density has been modeled for 189.1 baseline to account for the requirement of Energy Star Appliances.
	Global Parameter "EPD" = 0.1
	"Core Spc (M.C11)" = SPACE LIGHTING-W/AREA = ({#pa("LPD")-(#pa("Occ-Sensor")*#pa("LPD"))}) EQUIPMENT-W/AREA = ({0.75 - (0.75*#pa("EPD"))})
Infiltration	The continuous air barrier requirement has been met through an infiltration reduction of 25%. (Refer to section 5.1.2.2. for details.)
	Global Parameter "Infil-Reduction" = 0.25
	"East Perim Spc (G.E2)" = SPACE INF-METHOD = AIR-CHANGE INF-FLOW/AREA = {0.0251 - (0.0251 * #pa("Infil-Reduction"))}

Appendix G3.1.1.7. Thermal Blocks—HVAC Zones Designed. *Same as Proposed design.*

Appendix G3.1.1.8. Thermal Blocks—HVAC Zones Not Designed. *Same as Proposed design.*

Appendix G3.1.1.9. Thermal Blocks—Multifamily Residential Buildings

Not Applicable

Appendix G3.1.1.10 HVAC System Types. *The HVAC system(s) in the baseline building design shall be of the type and description specified in Section G3.1.1, shall meet the general HVAC system requirements specified in Section G3.1.2, and shall meet any system-specific requirements in Section G3.1.3 that are applicable to the baseline HVAC system type(s).*

(Refer to the following sections for details)

Appendix G3.1.1.11 Service Hot Water Systems. *The service hot-water system in the baseline building design shall use the same energy source as the corresponding system in the proposed design and shall conform to the following conditions:*

i. *Where the complete service hot-water system exists, the baseline building design shall reflect the actual system type using the actual component capacities and efficiencies.*

ii. *Where a new service hot-water system has been specified, the system shall be sized according to the provisions of Section 7.4.1 of 90.1 and the equipment shall match the minimum efficiency requirements in Section 7.4.2. of 90.1 (Section 7.4.4 in the case of 189.1 and the heat recovery requirements in 7.4.7.2 and 7.4.7.3 in Standard 189.1). Where the energy source is electricity, the heating method shall be electrical resistance.*

iii. *Where no service hot-water system exists or has been specified but the building will have service hot-water loads, a service water system(s) using electrical-*

resistance heat and matching minimum efficiency requirements of Section 7.4.2 in the case of 90.1 (Section 7.4.4 in the case of 189.1 and the heat recovery requirements in 7.4.7.2 and 7.4.7.3 in Standard 189.1) shall be assumed and modeled identically in the proposed and baseline building designs.

iv. *For buildings that will have no service hot-water loads, no service hot-water heating shall be modeled.*

v. *Where a combined system has been specified to meet both space heating and service water heating loads, the baseline building system shall use separate systems meeting the minimum efficiency requirements applicable to each system individually.*

vi. *For large, 24-hour-per-day facilities that meet the prescriptive criteria for use of condenser heat recovery systems described in Section 6.5.6.2, a system meeting the requirements of that section shall be included in the baseline building design regardless of the exceptions to Section 6.5.6.2.* ***Exception:*** *If a condenser heat recovery system meeting the requirements described in Section 6.5.6.2 cannot be modeled, the requirement for including such a system in the actual building shall be met as a prescriptive requirement in accordance with Section 6.5.6.2, and no heat-recovery system shall be included in the proposed or baseline building designs.*

vii. *Service hot-water energy consumption shall be calculated explicitly based upon the volume of service hot water required and the entering makeup water and the leaving service hot-water temperatures. Entering water temperatures shall be estimated based upon the location. Leaving temperatures shall be based upon the end-use requirements.*

viii. *Where recirculation pumps are used to ensure prompt availability of service hot water at the end use, the energy consumption of such pumps shall be calculated explicitly.*

ix. *Service water loads and usage shall be the same for both the baseline building design and the proposed design and shall be documented by the calculation procedures described in Section 7.2.1.*

x.

Interpretation of the Code. Service Hot water Systems:

Table 14

Appendix G&D3.1.1.11: Definitions

	Water Heater Type
Definition	Defined in Section 7.8 of Standard 90.1, these can be of the following kind- • Electric water heaters (storage and instantaneous) Small (≤ 12 kW) - Large (> 12 kW) • Gas storage water heaters Small (≤ 75,000 Btu/h) -Medium (> 75,000 and ≤ 155,000 Btu/h) -Large (> 155,000 Btu/h) • Gas instantaneous water heaters Small (> 50,000 and < 200,000 Btu/h) -Large (≥ 200,000 Btu/h) • Oil storage water heaters Small (≤ 105,000 Btu/h) -Medium (> 105,000 and ≤ 155,000 Btu/h) -Large (> 155,000 Btu/h) • Oil instantaneous water heaters Small (≤ 210,000 Btu/h) -Large (> 210,000 Btu/h)
Baseline Rules	The system type is required to be the same for both proposed design and baseline model.

90.1 Compared to 189.1. The service hot water loads (Size Category) for both proposed and baseline is required to be the same for both Standards. However Standard 189.1 supersedes 90.1 through the following amendments-

Section 7.4.4.1 Equipment Efficiencies. This sections specifies higher efficiency requirements for the service hot water systems.

Section 7.4.4.2 Service Hot Water Piping Insulation. 90.1 2007 has no mandatory requirements for piping insulation which have now been added to 189.1. These however have been ignored for the purpose of this study.

Section 6.3.2.1 Plumbing Fixtures and Fittings. Requires the use of low-flow fixtures including water closets, urinals, faucets etc.

Section 6.3.2.2 Appliances. Requires the use of ENERGY STAR appliances (clothes washer, dishwasher etc.) with specified water factors, in order to reduce the amount of water used.

Section 6.3.2.3 HVAC Systems and Equipment. Specifies requirements for cooling towers and evaporative coolers for use of efficient drift eliminators and condensate recovery from AC-units. All have these have been accounted for by a 10% reduction in the tank-storage capacity. (Long, Bonnema, & Field, July 2010)

Tank Efficiency Calculations. Section 7.8 from Standard 90.1 and Table C-12 from Standard 189.1 have been referred to for performance requirements for water heating equipment. This table specifies the Energy Factor, Thermal Efficiency and Standby Loss for hot water systems, depending on the system type, storage capacity and size. The thermal efficiency and tank UA of the service hot water system is dependent on the energy factor and standby loss values, which are determined by the rated volume of the tank.

Energy Factor	
Definition	The energy factor (EF) is the ratio of the energy delivered by the water heater divided by the energy used, in the same units.
Baseline Rules	The EF for the baseline building system shall be determined from Table 7.8 of ASHRAE Standard 90.1-2007.
Thermal Efficiency	
Definition	The full load efficiency of a water heater at rated conditions expressed as a dimensionless ratio of output over input
Baseline Rules	The Thermal Efficiency for the baseline building system shall be determined from Table 7.8 of ASHRAE Standard 90.1-2007.
StandBy Loss	
Definition	The tank standby loss for storage tanks, which includes the effect of recovery efficiency.
Units	Btu/h
Baseline Rules	The standby loss for the baseline building system shall be determined from Table 7.8 of ASHRAE Standard 90.1-2007.

Translation for ECCO

Table 15

Appendix G&D3.1.1.11 Service Hot Water Heating: Translation for ECCO

Calculation Procedure	
STEP 1	Assumptions for Thermal Efficiency, Recovery Efficiency for all DHW System Types Fuel Thermal Efficiency Recovery Efficiency Electric 98% 98% Gas 80% 75% Oil 78% 73% * Based on the Standard Efficiencies prevalent at the time the code was released. * Energy Model Input Translator, Rocky Mountain Institute.
STEP 2	Calculate EF or Standby loss in accordance to input power and system type corresponding to values in Table 7.8 for Standard 90.1 2007.
STEP 3	Tank UA = (1 / EF - 1 / RE) / (67.5 * (24 / 41094 - 1 / (RE * Power))) *EERE Water Heater Analysis Model (WHAM)
STEP 4	Service Hot Water Plant Heat Input Ratio = 1/EF

Implementation for eQUEST

Equest .INP file Input –

```
"DHW Plant 1 Wtr Htr (1)"     = DW-HEATER
  TYPE                        = GAS
  TANK-VOLUME                 = 639
  HEAT-INPUT-RATIO            = {#pa("DHW-HIR")}
  HIR-FPLR                    = "DW-Gas-Pilotless-HIR-fPLR"
  TANK-UA                     = {#pa("Tank-UA")}
  LOCATION                    = ZONE
  ZONE-NAME                   = "Pl Zn (G.6)"
  DHW-LOOP                    = "DHW Plant 1 Loop (1)"
```

Appendix G3.1.1.12 Receptacle and Other Loads. Other systems, such as motors covered by Section 10 of 90.1 (7.4.7 of 189.1), and miscellaneous loads shall be modeled as identical to those in the proposed design including schedules of operation and control of the equipment. Where there are specific efficiency requirements in Section 10 of 90.1 (and in 6.3.2, 6.4.2, 7.4.7) these systems or components shall be modeled as having the lowest efficiency allowed by those requirements. Where no efficiency requirements exist, power and energy rating or capacity of the equipment shall be identical between the baseline building and the proposed design with the following exception: variations of the power requirements, schedules, or control sequences of the equipment modeled in the baseline building from those in the proposed design may be allowed by the rating authority based upon documentation that the equipment installed in the proposed design represents a significant verifiable departure from documented conventional practice. The burden of this documentation is to demonstrate that accepted conventional practice would result in baseline building equipment different from that installed in the proposed design. Occupancy and occupancy schedules may not be changed.

Interpretation of the Code. With regards to plug loads, both 90.1 2007 and 189.1 have a similar ruling where receptacle loads and other process loads are required to be considered as identical in both proposed and baseline design. The various sections mentioned add the following requirements-

*Section 7.4.7.1 Electric Motors***.** Minimum efficiency requirements for motors have been improved. Motors are required to comply with the minimum efficiency requirements in Table C-13 in Normative Appendix C for Standard 189.1 as against Table 10.8 of ASHRAE 90.1 2007.

*Section 7.4.7.3 ENERGY STAR Equipment***.** This section mandates the use of ENERGY STAR equipment for any of the following purposes

- Appliances -Clothes washer, dishwasher, water coolers, and dehumidifiers.

- Heating and Cooling - Pumps, boilers, programmable thermostats, ventilating fans.
- Electronics- Phones, DVDs, TV
- Office Equipment - Computer, laptop, printers, scanners
- Lighting
- Commercial Food Service

Table 16

Appendix G&D3.1.1.12: Definitions

Receptacles and Other Plug Loads	
Definition	Receptacle power includes equipment loads normally served through electrical receptacles, such as office equipment and printers, but does not include either task lighting or equipment used for HVAC purposes. Equipment power values are controlled by the equipment schedule, which is the same for both proposed and baseline buildings. Largely dependent on user behavior, credit has not been offered for equipment use in Standard 90.1. and hence, receptacle power has been considered an unregulated load. Identical conditions have been required for both the baseline building and the proposed design.
Units	W/sq.ft
Baseline Rules	90.1 2007 requires equipment power to be the same in both baseline and proposed building. 189.1 mandate the use of ENERGY STAR certified equipment, which has been simulated in the form of a 10% reduction in the Equipment Power Densities (EPD) in the baseline building.

Table 17

Appendix G&D3.1.1.12: Interpretation of Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS
1	EPD	As Proposed	10% Less than 90.1 2007	189.1 require the use of Energy Star equipment for all applications. The NREL study assumes a 10% decrease from 90.1 2007, which has been assumed for this study as well.

*Translation for ECCO***.** This analysis accounts for this measure in the 189.1-2009 model. However, it does not account for the energy savings associated with each piece of equipment in each model. Receptacle loads have been assumed to be identical for baseline and proposed designs for 90.1 2007. For the case of 189.1, the tool assumes a reduction of 10% to represent efficient miscellaneous equipment. (Long, Bonnema, & Field, July 2010)

Table 18

Appendix G&D3.1.1.12: Translation for ECCO

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	GLOBAL PARAMETER
1	EPD	SPACE (EQUIPMENT-W/AREA)	(Numeric) W/SQ.FT	EPD

*Implementation for eQUEST***.** Refer to Section Appendix G3.1.1.6 : Lighting – Implementation for eQUEST

Appendix G3.1.1.13 Modeling Limitations to the Simulated Program

Same as Proposed Design.

Appendix G3.1.1 Baseline HVAC System Type and Description. *HVAC systems in the baseline building design shall be based on usage, number of floors, conditioned floor area, and heating source as specified in Table G3.1.1A and shall conform to the system descriptions in Table G3.1.1B. For systems 1, 2, 3, and 4, each thermal block shall be modeled with its own HVAC system. For systems 5, 6, 7, and 8, each floor shall be modeled with a separate HVAC system. Floors with identical thermal blocks can be grouped for modeling purposes.*

Interpretation of the Code. Baseline system types are determined in accordance to building floor area, number of floors and heating fuel type. All of these systems have specific performance requirements. *The code requires the thermal blocks to be grouped in accordance to the system type.*

Table 19

Appendix G&D3.1.1. Definitions

Cooling Source	
Definition	The source of cooling for the system. The choices are: - Chilled water - Direct expansion (DX)
Baseline Rules	The baseline building cooling source is shown in the table below. See Figure below for HVAC System Mapping.
Heating Source	
Definition	The source of heating for the heating and preheat coils. The choices are: - Hot water - Electric resistance - Electric heat pump - Gas furnace - Oil furnace - Heat recovery (for preheat coils in proposed designs)
Baseline Rules	The baseline building heating source is shown in the table below. See Figure below for HVAC System Mapping.
Fan Control	
Definition	A description of how the supply (and return/relief) fan(s) are controlled. The options include: - Constant volume - Variable-flow, variable speed drive (VSD) - Two-speed - Constant volume, cycling (fan cycles with heating and cooling) - Fan Curve- Based on fan part load ratios.
Baseline Rules	Based on the prescribed system type. Refer to the HVAC System Map.

Table 20

Baseline System Descriptors

Baseline System Descriptors (Table G3.1.1B for 90.1 and Table D3.1.1B for 189.1)			
System Type	Fan Control	Cooling Type	Heating Type
3. PSZ-AC	Constant Volume	DX	FF Furnace
4. PSZ-HP	Constant Volume	DX	Electric Heat Pump
5. PVAV with Reheat	VAV	DX	HW Boiler

6. PVAV with PFP Boxes	VAV	DX	Electric Resistanc e
7. VAV with Reheat	VAV	CHW	HW Boiler
8. VAV with PFP Boxes	VAV	CHW	Electric Resistanc e

Table 21

Appendix G&D3.1.1: Interpretation of Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS
1	System Type This value for the baseline building is defined on the basis of the conditioned floor area (CFA), number of floors and fuel type.	PSZ	PSZ	Baseline system type is defined on the basis of building area, number of floors and fuel type, and is the same for both 90.1 and 189.1.
2	System Heat Source	HOT-WATER (System Specific)	HOT-WATER (System Specific)	Baseline system heat source is defined on the basis of the baseline system type and design model fuel type.
3	System Cool Source	ELEC-DX (System Specific)	ELEC-DX (System Specific)	Baseline system cool source is defined on the basis of the baseline system type and design model fuel type.
4	Fan control depends upon system type. For system 3-4 = CV, 5-8 it is variable speed.	CONSTAN T-VOLUME (System Specific)	CONSTANT-VOLUME (System Specific)	The fan control is dependent on the baseline system type, and is same for both standards.

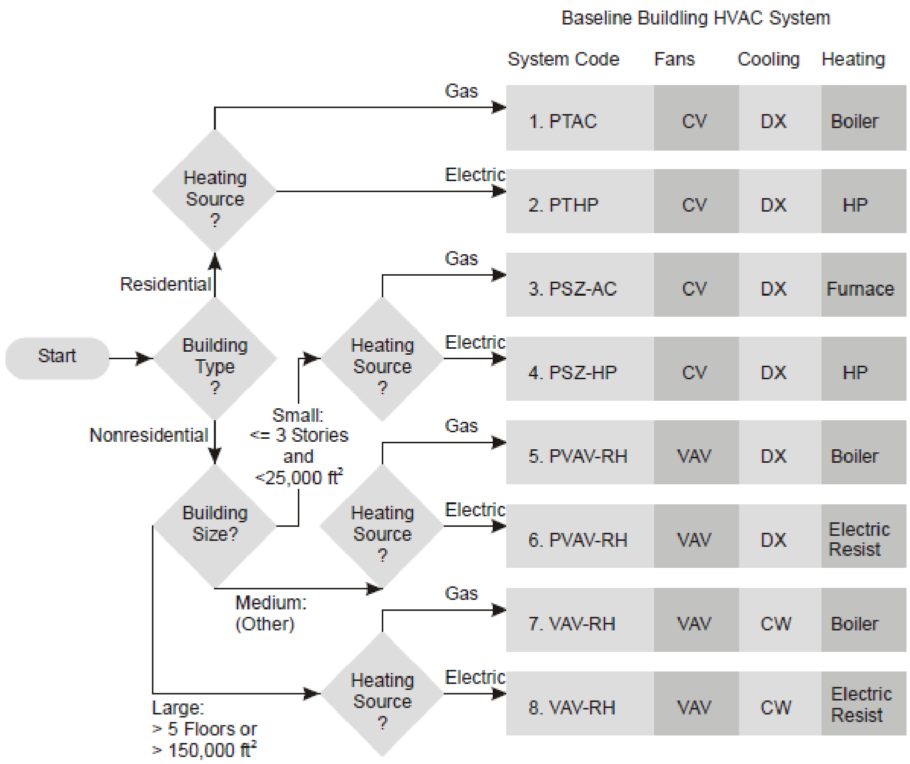

Figure 6: HVAC System Mapping (COMNET, 2010)

Translation for ECCO

Table 22

AppendixG&D3.1.1. Translation for ECCO

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (GLOBAL PARAMETER)
1	System Type This value for the baseline building is defined on the basis of the conditioned floor area (CFA), number of floors and fuel type.	SYSTEM (TYPE)	Existing Symbol (Dimensionless)	Calculated - By ECCO User-Assigned
2	System Heat Source	SYSTEM (HEAT-SOURCE)	Existing Symbol (Dimensionless)	Calculated - By ECCO User-Assigned
3	System Cool Source	SYSTEM (COOL-SOURCE)	Existing Symbol (Dimensionless)	Calculated - By ECCO User-Assigned

4	Fan control depends upon system type. For system 3-4 = CV, 5-8 it is variable speed.	FAN-CONTROL	Existing Symbol	Pre-Defined (Fan-Control)

*Implementation for eQUEST***.** Refer to Appendix C for eQUEST Templates for all System Types.

Appendix G3.1.2.1 Equipment Efficiencies. *All HVAC equipment in the baseline building design shall be modeled at the minimum efficiency levels, both part load and full load, in accordance with Section 6.4 (Section 7.4.3.1). Where efficiency ratings, such as EER and COP, include fan energy, the descriptor shall be broken down into its components so that supply fan energy can be modeled separately.*

Interpretation of the Code. Cooling equipment efficiencies for the Standard 189.1-2009 analysis have been determined through Tables C-1 through C-5. System sizes are defined through the proposed model and used for the baseline calculations for both standards. Heating equipment efficiencies were determined from Table C-6 and Table C-7 (depending on system type). In the 90.1 analysis, Tables 6.8.1 were used to determine the HVAC equipment efficiencies. Details on HVAC equipment efficiency calculations are presented in Appendix A.

All efficiency values calculated are at ARI rated conditions, i.e., without corrections for temperature or part load. Also, fan electric energy consumption is calculated and subtracted from this value to prevent double counting of supply fan electric energy.

For commercial systems the default value of heating electric input ration (EIR) includes compressor and outdoor fan energy, but not indoor fan energy. Imbedding the fan energy into the heating efficiency value is valid only if the fan is constant volume and INDOOR-FAN-MODE = INTERMITTENT; i.e. the fan cycles on/off with the compressor. If the fan runs continuously during occupied hours, as it is required by the code, or the fan is variable volume, then the fan energy cannot be included in the HEATING-EIR (or COOLING-EIR). Refer to AppendixG3.1.2.9 on the procedure followed for this purpose.

Table 23

Appendix G&D3.1.2.1: Definitions

Direct Expansion Cooling Efficiency	
Definition	The cooling efficiency of a direct expansion (DX) cooling system at ARI rated conditions as a ratio of output over input in Btu/h per W, excluding fan energy. The software must accommodate user input in terms of either the Energy Efficiency Ratio (EER) or the Seasonal Energy Efficiency Ratio (SEER).
Baseline Rules	System EER value look up- Table 6.8.1A and Table 6.8.1B in ASHRAE Standard 90.1-2007, Table C-1 and C-2 in 189.1 2009. The total cooling capacity of the baseline building is looked up to determine the size category.

Chiller Rated Efficiency	
Definition	The COP (Coefficient of Performance) for chillers at rated conditions.
Baseline Rules	For ASHRAE Standard 90.1-2007 baseline, the minimum value of efficiency is determined from either Table 6.8.1C for various types of chillers or the values from Tables 6.8.1H, 6.8.1I or 6.8.1J for centrifugal chillers. For ASHRAE Standard 189.1 2009, the minimum values of efficiency are determined from Table C-3 for various types of chillers.

Electric Heat Pump Heating Efficiency	
Definition	The heating efficiency of a heat pump at ARI rated conditions as a dimensionless ratio of output over input. Values in terms of either the Coefficient of Performance (COP) or the Heating Season Performance Factor (HSPF) are converted to Heat Pump Electric Input Ratio
Baseline Rules	For ASHRAE Standard 90.1-2007 baseline, the minimum value of efficiency is determined from Table 6.8.1C (PTHP are not considered for the purpose of this study). For ASHRAE Standard 189.1 2009, the minimum values of efficiency is determined from Table C-3.

The baseline system is auto sized in eQUEST for the size category.

Boiler Efficiency	
Definition	The full load efficiency of a boiler is expressed as one of the following: - Annual Fuel Utilization Efficiency (AFUE) is a measure of the boiler's efficiency over a predefined heating season. - Thermal Efficiency (Et) is the ratio of the heat transferred to the water divided by the heat input of the fuel. - Combustion Efficiency (Ec) is the measure of how much energy is extracted from the fuel and is the ratio of heat transferred to the combustion air divided by the heat input of the fuel.
Input Criteria	• Annual Fuel Utilization Efficiency (AFUE), for all gas and oil-fired boilers with less than 300,000 Btu/h capacity. • Thermal Efficiency (Et), for all gas and oil-fired boilers with capacities between 300,000 and 2,500,000 Btu/h. • Combustion Efficiency (Ec), for all gas and oil-fired boilers with capacities above 2,500,000 Btu/h.
Calculation Procedure	The full load efficiency of a boiler at rated conditions expressed as a dimensionless ratio of output over input. The value is provided as either Et or AFUE. Where AFUE is provided, Et shall be calculated as follows: - 75% <= AFUE <80% Et = 0.1 * AFUE + 72.5% - 80% <= AFUE <= 100% Et = 0.875 * AFUE + 10.5%
Baseline Rules	Boilers for the baseline design are required to have minimum efficiency as listed in Table 6.8.1F from ASHRAE Standard 90.1-2007, Table C-6 for Standard 189.1 2009.

Translation For ECCO

Table 24

Appendix G&D3.1.2.1: Translation for ECCO

SYSTEM 3-6 Cooling Efficiency

1	The EIR, or 1/(COP), for the cooling unit at ARI rated conditions. The program defines EIR to be the ratio of the electric energy input to the rated capacity, when both are expressed in the same units.	SYSTEM (COOLING-EIR)	Numeric (Dimensionless)	Calculated (User Assigned)
SYSTEM 7-8 Cooling Efficiency				
2	EIR, or 1/(heating COP), for the chiller. This EIR is at ARI rated conditions. ECCO calculated CHILLER-EIR does not include fan power and heat.	CHILLER (ELEC-INPUT-RATIO)	Calculated (Dimensionless)	Chiller-EIR
System 3- Heating Efficiency				
3	Furnace Heat Input Ratio- Ratio of fuel used by the furnace to the heating energy produced.	SYSTEM (FURNACE-HIR)	Numeric (Dimensionless)	Calculated (User Assigned)
System 4- Heating Efficiency				
4	EIR, or 1/(heating COP), for the HP. This EIR is at ARI rated conditions. ECCO calculated HEATING-EIR does not include fan power and heat.	SYSTEM (HEATING-HIR)	Numeric	Calculated (User Assigned)
System 5,7 – Heating Efficiency				
5	The ratio of fuel heat input to boiler heating capacity at full load (i.e., at the rated conditions).	BOILER (HEAT-INPUT-RATIO)	Numeric (Dimensionless)	Boiler-HIR

Implementation for eQUEST. For all HVAC System Type definitions, refer to Appendix C. For all HVAC systems efficiency calculations procedure, refer to Appendix B

Appendix G3.1.2.2 Equipment Capacities. *The equipment capacities for the baseline building design shall be based on sizing runs for each orientation (per Table G3.1, No. 5a) and shall be oversized by 15% for cooling and 25% for heating, i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be 1.15 for cooling and 1.25 for heating.*

**Unmet Heating and Cooling Hours have not been analyzed.*

Interpretation of the Code

Table 25

Appendix G&D3.1.2.2: Interpretation of the Code

S.No	Description	90.1 2007	189.1 2009	Comments
1	System Sizing Ratio	Max- 1.00	Max- 1.00	The sizing ratios are calculated on the basis of the proposed system sizes and the baseline system sizes as defined by eQUEST.
2	Cooling Equipment Sizing	Max- 1.15	Max- 1.15	
3	Heating Equipment Sizing	Max- 1.25	Max- 1.25	
4	Unmet Heating and Cooling Load Hours	The unmet load hours are not analyzed by the tool and user intervention is required for this purpose.		

Translation for ECCO

Table 26

Appendix G&D3.1.2.2 Translation for ECCO

S.No.	Description	Command (KeyWord)	Units	ECCO Procedure (Global-Parameter)
1	System Sizing Ratio	SYSTEM (SIZING-RATIO)	Numeric (Dimensionless)	Calculated (Sizing-Ratio)
2	Cooling Equipment Sizing	SYSTEM (COOL-SIZING-RATIO)	Numeric (Dimensionless)	Calculated (Cool-Ratio)
3	Heating Equipment Sizing	SYSTEM (HEAT-SIZING-RATIO)	Numeric (Dimensionless)	Calculated (Heat-Ratio)
4	Unmet Heating and Cooling Load Hours	The unmet load hours are not analyzed by the tool and user intervention is required for this purpose.		

*Implementation for eQUEST***.** The sizing ratio has been calculated as a building average. Based on the sum of all baseline and proposed system capacities, the sizing ratio has been determined which is applied as a global parameter.

Appendix G3.1.2.3 Preheat Coils. If the HVAC system in the proposed design has a preheat coil and a preheat coil can be modeled in the baseline system, the baseline system shall be modeled with a preheat coil controlled in the same manner as the proposed design.

A. INTERPRETATION OF THE CODE

Preheat coils have been included, if present in proposed building design.

Appendix G3.1.2.4 Fan System Operation

Supply and return fans shall operate continuously whenever spaces are occupied and shall be cycled to meet heating and cooling loads during unoccupied hours. If the supply fan is modeled as cycling and fan energy is included in the energy-efficiency rating of the equipment, fan energy shall not be modeled explicitly. Supply, return, and/or exhaust fans will remain on during occupied and unoccupied hours in spaces that have health and safety mandated minimum ventilation requirements during unoccupied hours.

Interpretation of the Code

Table 27

Appendix G3.1.2.4: Definitions

	Fan Operation
Definition	• eQUEST: INDOOR-FAN-MODE Takes a code-word that specifies how the indoor fan is controlled. Applicable to DX cooling system types (PSZ) and not to chilled water systems or packaged variable air volume systems. • CONTINUOUS The indoor fan always runs when it is scheduled on by FAN-SCHEDULE or NIGHT-CYCLE-CTRL. • INTERMITTENT The indoor fan operates as in CONTINUOUS, but only for that fraction of the hour required for space heating or cooling. All other system types run the fans continuously when enabled by the fan schedule, with exceptions for a few system types (not within the scope of this project)
Baseline Rules	Fans are required to operate continuously during occupied hours.

Night Cycle Control	
Definition	The code requires the system to enable cycling of fans to meet loads during unoccupied hours, when zone temperature goes above throttling range.
Baseline Rules	Fans are required to cycle to meet heating and cooling loads during unoccupied hours.

Fan Energy	
Definition	Design full-load power of the supply fan per unit of supply air flow rate at sea level.
Baseline Rules	The fan power calculations have been carried out in accordance to Appendix G3.1.2.9 for 90.1 and AppendixD3.1.2.9 for 189.1. Fan energy has been modeled explicitly.

Table 28

AppendixG&D3.1.2.4: Interpretation of the Code

S.No.	Description	ASHRAE 90.1 2007	ASHRAE 189.1 2009	Explanation
1	Night cycle control. Appendix G- Supply and return fans should be cycled to meet loads during unoccupied hours.	CYCLE-ON-ANY	CYCLE-ON-ANY	Both codes require fans to cycle during unoccupied hours.
2	Fan System Operation	CONTINUOUS	CONTINUOUS	

Translation for ECCO

Table 29

AppendixG&D3.1.2.4: Translation for ECCO and eQUEST

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (G-P)
1	Night cycle control. Appendix G- Supply and return fans should be cycled to meet loads during unoccupied hours.	SYSTEM (NIGHT-CYCLE-CONTROL)	Existing Symbol	Pre-Defined (Night-Cycle-Ctrl)

2	Fan System Operation	SYSTEM (INDOOR-FAN-MODE)	Existing Symbol	Pre-Defined (Fan-Control)

Implementation for eQUEST

Refer to the "Fan Power Calculator Tool" in Appendix A for details on the fan power calculation procedure. Refer to the System Input Templates in Appendix B for eQUEST Parameters for fan power calculations.

Appendix G3.1.2.5 Ventilation

Minimum outdoor air ventilation rates shall be the same for the proposed and baseline building designs (and shall comply with Section 8.3.1.1.).

Exception: *When modeling demand-control ventilation in the proposed design when its use is not required by Section 6.4.3.8 (by Section 7.4.3.2 in the case of 189.1).*

Interpretation of the Code. Both codes require minimum ventilation rate to be the same for proposed as well as baseline buildings.

Translation for ECCO and eQUEST. Standard 90.1 requires ventilation rates to be the same for both proposed and baseline design. The tool requires extracts minimum outside air ratios from the proposed design and calculates the same for the baseline case.

A system level minimum OA ratio value is calculated, which has to be input by the user at the Energy-Performance stage. As a limitation to the scope of this project, individual zone level OA ratios have not been assigned, and a system level value is assigned.

Table 30

Appendix G&D3.1.2.5: Translation for ECCO and eQUEST

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (GLOBAL PARAMETER)
1	Minimum Outside Air	SYSTEM (MIN-OUTSIDE-	Numeric (Dimensionless)	Calculated (Min-OA)

		AIR)		

Implementation for eQUEST

Refer to Appendix A for the calculation procedures for minimum outside air.

Appendix G3.1.2.6 Economizers

Outdoor air economizers shall not be included in baseline HVAC Systems 1 and 2. Outdoor air economizers shall be included in baseline HVAC Systems 3 through 8 based on climate as specified in Table G3.1.2.6A. (OA Economizers shall be included on all baseline HVAC systems unless the individual unit size does not exceed the capacity specified in Section 7.4.3.4 and Table 7.4.3.4.A. If an economizer is not required by Section 7.4.3.4.1 and Table 7.4.3.4.A, including footnote 'a', OA economizer shall not be included in baseline systems 1, 2. If an economizer is not required by Section 7.4.3.4.2 and Table 7.4.3.4.A, including footnote 'a', OA economizers shall be included in baseline systems 3-8 based on climate as specified in Table D3.1.2.6)

Appendix G3.1.2.7 Economizer High-Limit Shutoff

The high limit shutoff shall be a dry-bulb switch with set point temperatures in accordance with the values in Table G3.1.2.6B. (Table 7.4.3.4.A)

*Interpretation of the Code***.**

- **Standard 90.1 Table G3.1.2.6A**

Standard 90.1 requires economizers to be provided for CZ 2B, for systems 3-8.

- **Standard 189.1 Table D3.1.2.6**

In the Standard 189.1-2009 analysis, economizers have been applied as well. The standard requires economizers to be modeled in systems 3-8 irrespective of system size for CZ 2B.

- **Standard 189.1 Section 7.4.3.4.** Requires economizers to be modeled with differential enthalpy control or differential dry bulb. Differential enthalpy refers to the enthalpy difference between the return air and outside air. Since the climate zone under consideration here is 2B (hot and dry) a differential dry bulb economizer has been modeled. Economizers can be eliminated for CZ2B for 15% (or greater) cooling efficiency improvement.

Table 31

Appendix G&D3.1.2.7: Definitions

Economizer High Temperature LockOut	
Definition	It is the outside air setpoint temperature above which the economizer will return to minimum position.
Baseline Rules	Table G3.1.2.6B defines the value as 75 F for 90.1.

Economizer Control Type	
Definition	Air-side economizer increases outside air ventilation during periods when refrigeration loads can be reduced from increased outside air flow. The control types include: **- Fixed dry-bulb** The system shifts to 100% outside air and shuts off the cooling when the temperature of the outside air is equal to or lower than the supply air temperature. - **Differential dry-bulb** The system shifts to 100% outside air when the temperature of the outside air is lower than the return air temperature but continues to operate the cooling system until the outside air temperature reaches the supply air temperature.
Baseline Rules	AppendixG&D3.1.2.6 requires economizers to be provided for CZ2B. A fixed dry bulb economizer has been provided for 90.1 and a differential dry bulb economizer has been modeled for Standard 189.1.

Table 32

AppendixG&D3.1.2.7: Interpretation of the Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS
1	Economizer High Limit Shut off	75	75	A dry-bulb economizer has been modeled for the 90.1 baseline. A differential temperature economizer has been modeled for 189.1.
2	Air Side Economizer Cycle-OA control method.	OA-TEMP	DUAL-TEMP	

Translation for ECCO and eQUEST

- Standard 90.1 2007

  Outside air economizers have been provided for baseline systems 3 through 8, with fixed outside air temperature control, as specified in Table 6.5.1.1.3A. The high-limit shut off control has been specified as 75℉ as spec ified in Appendix G3.1.2.6B.

- Standard 189.1 2009

  Outside air economizers have been provided for systems 3 through 8 as specified in Table 7.4.3.4B, with differential dry bulb control. The differential DT is specified as 0℉. This implies that the economizer operates when ever the outside air temperature is less than the return air temperature.

Table 33

AppendixG&D3.1.2.7: Translation for ECCO

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (GLOBAL PARAMETER)
1	Economizer High Limit Shut off	SYSTEM (ECONO-LIMIT-T)	Numeric (℉)	
2	Air Side Economizer Cycle- OA control method.	SYSTEM (OA-CONTROL)	Existing Symbol	Pre-Defined (OA-Control)

Implementation for eQUEST

Refer to Appendix C for the eQUEST template for systems and Economizers.

Appendix G3.1.2.8 Design Airflow Rates

System design supply airflow rates for the baseline building design shall be based on a supply-air-to-room-air temperature difference of 20℉ or the required ventilation air or makeup air, whichever is greater. If return or relief fans are specified in the proposed design, the baseline building design shall also be modeled with fans serving the same functions and sized for the baseline system supply fan air quantity less the minimum outdoor air, or 90% of the supply fan air quantity, whichever is larger.

Interpretation of the Code

Table 34:

Appendix G&D3.1.2.8: Definitions

Minimum Supply Air Temperature	
Definition	The minimum temperature of the air delivered to the zone. Minimum supply air temperature and zone temperature are used to size the capacity of the cooling coil and supply air flow rate. The supply air flow rates needed to satisfy the heating and cooling requirements are compared and the greater of the two quantities is used for the system air flow rate.
Baseline Rules	The minimum SAT has been fixed at 55F for both Standards.
Zone Cooling/Heating Temperature Setpoint	
Definition	The space temperature that the program uses to calculate the supply air flow rate required to meet design-day cooling loads for the zone. During the HVAC sizing procedures, these temperatures are used to estimate a temperature difference across interior surfaces which in turn is used to estimate peak cooling and heating loads when sizing HVAC airflows
Baseline Rules	The zone temperature setpoint has been kept at 75°F for Cooling and 72℉ for heating.

Table 35

AppendixG&D3.1.2.8: Interpretation of the Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS
1	Minimum supply air temperature	55	55	Both Standards require supply design air flow rates to be sized on the basis of a 20F Delta T.
2	Zone Design Air Temperature	75	75	

Translation for ECCO

Table 36

AppendixG&D3.1.2.8: Translation for ECCO

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (G-P)
1	Minimum supply air temperature	SYSTEM (MIN-SUPPLY-T)	Numeric (℉)	Pre-Defined (Minimum-SAT)

2	Zone Design Air Temperature	SYSTEM (DESIGN-COOL-T)	Numeric (℉)	Pre-Defined (Zone-Temp)

Implementation for eQUEST

Refer to Appendix C for the System Input Templates and implementation for design air flow rates requirements.

Appendix G3.1.2.9 System Fan Power

System fan electrical power for supply, return, exhaust, and relief (excluding power to fan powered

VAV boxes) shall be calculated using the following formulas:

For systems 3 through 8,

- P_{fan} = *bhp × 746 / Fan Motor Efficiency.*

Where

- P_{fan} = *electric power to fan motor (watts)*
- *bhp = brake horsepower of baseline fan motor from Table G3.1.2.9 (Table D3.1.2.9 for Standard 189.1)*
- *Fan Motor Efficiency = the efficiency from Table 10.8 for the next motor size greater than the bhp using the enclosed motor at 1800 rpm. (Table C-13 for Standard 189.1)*
- CFM_S *= the baseline system maximum design supply fan airflow rate in cfm*

Table 37

Baseline Fan Power Limitations: Standard 90.1 and 189.1

Baseline Fan Power Limitations (I-P) (Table G3.1.2.9 for 90.1 and Table D3.1.2.9 for 189.1)		
	Constant Volume System (3 and 4)	Variable Volume System (5-8)
90.1 2007	bhp = CFM * 0.00094 + A	Bhp = CFM * 0.0013 + A
189.1 2009	Bhp = CFM * 0.000846 + A	Bhp = CFM * 0.00117 + A

Where A is calculated according to Section 6.5.3.1.1 of ASHRAE Standard 90.1 using pressure drop adjustment from the proposed building design and the design flow rate of the baseline building design.

Interpretation of the Code. Fan power calculations have changed from Standard 90.1. The table for baseline fan power limitations indicates the same. Appendix A elaborates on the calculations used for both 90.1 2007 as well as 189.1 2009 to calculate fan power for baseline systems as well as cooling efficiencies.

Table 38

Appendix G&D3.1.2.9: Definitions

Fan Brake HorsePower	
Definition	The design shaft brake horsepower of the supply fan(s).
Baseline Rules	Table G3.1.2.9 in Standard 90.1 specified Baseline Brake Horsepower for systems 3-8, as well as rules for pressure drop calculations. Table D3.1.2.9 Specifies the Baseline Fan Power Limitation for Standard 189.1.
Static Pressure	
Definition	The design static pressure for the supply fan. This is important for both fan electric energy usage and duct heat gain calculations.
Baseline Rules	External Static pressure is specified on the basis of the system cooling load, through the ANSI/AHRI Standard 340/360. The internal static pressure is the same as the proposed design, and is user-specified.
Motor Efficiency	
Definition	The full-load efficiency of the motor serving the supply fan.
Baseline Rules	For Standard 90.1 2007, it is a look up value from Table 10.8, and Table C-13 for 189.1. For both codes, it is based on the motor hp, for a 1800 RPM enclosed motor. The next high value is considered for calculations.

Table 39

Appendix G&D3.1.2.9: Interpretation for ECCO

S.No.	Description	ASHRAE 90.1 2007	ASHRAE 189.1 2009	Explanation

1	System Fan Power Design full-load power of the supply fan per unit of supply air flow rate at sea level.	0.002 (System Specific Calculation)	0.002 (System Specific Calculation)	The fan power reduces from approximated 10% from 90.1 to 189.1. The process for calculation of fan power is defined in table - FAN POWER CALCULATIONS.
2	Supply Delta T	#l("SUPPLY-KW/FLOW") * 3090	#l("SUPPLY-KW/FLOW") * 3091	Temperature rise in the air stream across the supply fan. The eQUEST default is the SUPPLY-KW/FLOW * 3090

Translation for ECCO. The baseline system calculator determines fan power (kW/CFM) for supply (return and exhaust are omitted for the purpose of this study); and it calculates compressor COP and EIR and Heat Pump COP for System-4. The fan power calculations require the user to enter supply CFM (Supply Fan Ratio is assumed to be 1), cooling load and internal static (inches of water). Pressure drop adjustments are required to be selected by the user from the form “Fan Power”. After all inputs have been determined, the allotted baseline fan power can be calculated, which is done in accordance to ASHRAE 90.1-2007 section G3.1.2.9.

Compressor COP for baseline systems the baseline EER is determined from the total capacity and ASHRAE 90.1-2007 Tables 6.8.1A & B.

Table 40:

Appendix G&D 3.1.2.9: Translation for ECCO

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (GLOBAL PARAMETER)
1	System Fan Power Design full-load power of the supply fan per unit of supply air flow rate at sea level.	SYSTEM (SUPPLY-KW/FLOW)	Numeric (KW/CFM)	Calculated (User-Assigned)
2	Supply Delta T	SYSTEM (SUPPLY-DELTA-T)	Numeric (℉)	Calculated (User-Assigned)

*Implementation for eQUEST***.** Refer to Appendix B for detailed explanation of the procedure for calculation of system fan power.

Appendix G3.1.3 System-Specific Baseline HVAC System Requirements

Baseline HVAC systems shall conform with provisions in this section, where applicable, to the specified baseline system types as indicated in section headings

Appendix G3.1.3.1: Heat Pumps (Systems 2 and 4).

Electric air source heat pumps shall be modeled with electric auxiliary heat. The systems shall be controlled with multistage space thermostats and an outdoor air thermostat wired to energize auxiliary heat only on the last thermostat stage and when outdoor air temperature is less than 40℉.

Interpretation of the Code. System 4 applies to -

i. Floors 3 or less

ii. Conditioned floor area less that 25,000 sq.ft

iii. Heating source - electric.

Table 41

Appendix G&D3.1.3.1: Definitions

Electric Heat Pump Supplemental Heating Source	
Definition	The auxiliary heating source for a heat pump heating system. The common control sequence is to lock out the heat pump compressor when the supplemental heat is activated. Other building descriptors may be needed if this is not the case. Choices for supplemental heat include: - Electric resistance - Gas furnace - Oil furnace - Hot water - Other
Baseline Rules	Both standards require the supplemental heat to be Electric Resistance
Electric Heat Pump Supplemental Heating Capacity	
Definition	The design heating capacity of a heat pump supplemental heating coil at ARI conditions
Units	Btu/h

Baseline Rules	Autosize
Electric Supplemental Heating Control Temp	
Definition	The outside dry-bulb temperature below which the heat pump supplemental heating is allowed to operate
Baseline Rules	As Designed or Default to 40°F for both the Standards
Electric Heat Pump Supplemental Heating Source	
Definition	Outdoor dry-bulb temperature below which the heat pump turns off
Baseline Rules	As Designed or Default to 10°F for both the Standards
Space Thermostat Throttling Range	
Definition	The number of degrees that the room temperature must change to cause the HVAC system to go from no heating or cooling (i.e., space temperatures floating) to full heating or cooling.
Units	Degrees Fahrenheit (℉)
Baseline Rules	The prescribed value is 2℉. Else, s ame as proposed design.
Space Thermostat Control	
Definition	This value specifies the type of thermostat used to control the zone temperature. The same type of thermostat action for both cooling and heating. The applicable Values are- **PROPORTIONAL** The heat addition rate (or heat extraction rate) is throttled in linear proportion to the difference between the zone set point temperature and the actual zone temperature. **TWO-POSITION** Heating is fully on when the zone temperature is below the heating setpoint, cooling is fully on when the zone temperature is above the cooling setpoint, and there is neither heating nor cooling when the zone temperature is between the heating and cooling setpoints. This code-word is usually not used for hot and chilled water system controls. **REVERSE-ACTION** Similar to PROPORTIONAL except that the thermostat reverses its signal on a request for heating.
Baseline Rules	Both standards require a "Proportional" thermostat.

Table 42

AppendixG&D3.1.3.1: Interpretation of Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS

1	Heat Pumps modeled with electric auxiliary heat.	ELECTRIC	ELECTRIC	Both standards require the supplemental heat source to be an electric resistance heater
2	Outdoor DBT below which HP turns off	10	10	This value is the same for both Standards.
3	Outdoor DBT below which HP turns on.	40	40	This value is the same for both Standards.
4	Type of thermostat used to control zone temperature	PROPORTIONAL	PROPORTIONAL	This value is the same for both Standards.
5	Throttling Range for System 4.	2	2	This value is the same for both Standards.

Table 43

AppendixG&D3.1.3.1. : Translation for ECCO

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (G-P)
1	Heat Pumps modeled with electric auxiliary heat.	SYSTEM (HP-SUPP-SOURCE)	Existing Symbol	Pre-Defined (Elec-Aux-Heat)
2	Outdoor DBT below which HP turns off	SYSTEM (MIN-HP-TEMP)	Numeric (℉)	Pre-Defined (Min-HP-T)
3	Outdoor DBT below which HP turns on.	SYSTEM (MAX-HP-TEMP)	Numeric (℉)	Pre-Defined (Max-HP-T)
4	Type of thermostat used to control zone temperature	ZONE (THERMOSTAT-TYPE)	Existing Symbol	Pre-Defined (Therm-Ctrl)
5	Throttling Range for System 4.	ZONE (THROTTLING-RANGE)	Numeric (℉)	Pre-Defined (Throttling-Range)

Implementation for eQUEST. Refer to Appendix C for eQUEST System Input Templates.

Appendix G3.1.3.2 Type and Number of Boilers (Systems 1, 5, and 7)

The boiler plant shall use the same fuel as the proposed design and shall be natural draft, except as noted in Section G3.1.1.1 (Section D3.1.1.1). The baseline building *design boiler plant shall be modeled as having a single boiler if the baseline building design plant serves a conditioned floor area of 15,000 ft^2 or less and as having two equally sized boilers for plants serving more than 15,000 ft^2. Boilers shall be staged as required by the load.*

Interpretation of the Code

- Standard 90.1-2007 and 189.1-2009. Both codes have similar requirements for boilers. Natural draft hot water boilers are required to be modeled, with their capacity ratios being defined in accordance to the conditioned floor are. For conditioned floor areas >15,000 ft^2 , two boilers with capacity ratio of 0.5 are modeled. Table 6.8.1F (90.1-2007) and Table C-7 (189.1-2009) are referred to for boiler efficiency.

Table 44:

Appendix G&D3.1.3.2: Definitions

Boilers	
Definition	The boiler type. Choices include: -Steam Boiler -Hot Water Boiler -Heat-Pump Water
Baseline Rules	The boiler type will be a hot water boiler for baseline systems 5 and 7, according to the baseline system descriptions from Table G3.1.1B. All other system types do not have a boiler.
Boiler Draft Type	
Definition	Boiler draft type refers to how the combustion airflow is drawn through the boiler. Choices are: -Natural Draft - Mechanical Draft Natural draft boilers use natural convection to draw air for combustion through the boiler. These are subject to outside air conditions and the temperature of the flue gases. Mechanical draft boilers enhance the air flow in one of three ways: 1) Induced draft (ambient air) 2) Forced draft (Fans) 3) Balanced draft (both induced draft and forced draft methods)
Baseline Rules	Both standards require the baseline boiler to be Natural Draft.
Boiler Capacity Ratio	
Definition	The ratio of boiler full load capacity, depending on the number of identical units for staging. The boiler is sized to be 25% larger than the peak loads of the

	baseline building. Baseline boilers shall be sized using weather files containing 99.6% heating design temperatures and 1% dry-bulb and 1% wet-bulb cooling design temperatures.
Baseline Rules	Both the standards require one boiler (Capacity Ratio = 1) for conditioned floor arae of 15,000 sq.ft or less, and two boilers, (Capacity Ratio = 0.5), for conditioned floor area of 15,000 or more.

Table 45

AppendixG&D3.1.3.2: Interpretation of the Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS
1	Boiler Type. This is defined in Appendix G as Natural draft, or HW-boiler.	HW-BOILER	HW-BOILER	Both standards require Hot water, natural draft boilers.
2	Boiler capacity ratio, depends on the number of boilers (Minimum 1 for system 5,7 and maximum 2)	0.5 (Calculated through ECCO)	0.5 (Calculated through ECCO)	This requirement is the same for both the standards. Boiler capacity ratio is 0.5 for two boilers and 1 for 1 boiler.

Translation for ECCO and eQUEST

Table 46

AppendixG&D3.1.3.2: Translation for ECCO and eQUEST

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (GLOBAL PARAMETER)
1	Boiler Type. This is defined in Appendix G as Natural draft, or HW-boiler.	BOILER (TYPE)	Existing Symbol (Dimensionless)	Pre-Defined (Boiler-Type)
2	Boiler capacity ratio, depends on the number of boilers (Minimum 1 for system 5,7 and maximum 2)	BOILER (CAPACITY-RATIO)	Numeric (Dimensionless)	Calculated (Boiler-Capacity-Ratio)

Implementation for eQUEST. Refer to Section – AppendixG&D3.1.2.1 – Implementation for eQUEST for boiler efficiency and capacity ratio calculations. Refer to Section – AppendixG&D3.1.3.3. – Implementation for eQUEST for boiler hot water loop definitions.

The Appendix G&D requirements for hot-water boiler are met through the following steps-

i. AppendixG&D3.1.2.1 – Equipment Efficiency Calculations

ii. AppendixG&D3.1.3.3 – Hot Water Loop Definition

   a. Appendix G&D3.1.3.4 - HW Reset Schedule

   b. Process Load Schedule

   c. AppendixG&D3.1.3.5 - Hot Water Loop Pumps

   d. Appendix G&D3.1.3.3 - Hot Water Circulation Loop

      - Assign: Hot Water Pump

      - Assign : Hot Water Reset Schedule

      - Assign : Process Load Schedule

iii. AppendixG&D3.1.3.2 – Hot Water Boiler Definition

$This definition is used during the sizing Run and replaced with the following definition during 'Energy performance' if the Baseline system is 5/7.

```
"ASHRAE-Boiler-1"              = BOILER
  TYPE                         = HW-BOILER
  HW-LOOP                      = "ASHRAE-HW-Loop"
..
```

$This definition is used only during 'Energy Performance' if Baseline System Type is 5 or 7

```
"ASHRAE-Boiler-1"              = BOILER
  TYPE                         = HW-BOILER
  CAPACITY-RATIO               = {#pa("Boiler-Capacity-Ratio")}
  HEAT-INPUT-RATIO             = {#pa("Boiler-HIR")}
  HW-LOOP                      = "ASHRAE-HW-Loop"
..
```

Appendix G3.1.3.3 Hot-Water Supply Temperature (Systems 5 and 7)

Hot-water design supply temperature shall be modeled as 180℉ and design return temperature as 130℉.

Appendix G3.1.3.4 Hot-Water Supply Temperature Reset (Systems 5 and 7)

Hot-water supply temperature shall be reset based on outdoor dry-bulb temperature using the following schedule: 180℉ at 20℉ and bel ow, 150℉ at 50℉ and above, and ramped linearly between 180℉ and 150℉ at temperat ures between 20℉ and 50℉.

Interpretation of the Code

- Standard 90.1-2007 and 189.1-2009. Both codes have similar requirements for hot water supply temperature and return temperature.

Table 47

Appendix G&D3.1.3.4: Definitions

	Hot Water Supply Temperature
Definition	The temperature of the water produced by the boiler and supplied to the hot water loop
Units	Degrees Fahrenheit (℉)
Baseline Rules	AppendixG&D require 180℉ for baseli ne boiler (G3.1.3.3).
	Hot Water Return Temperature
Definition	The temperature of the water returning to the boiler from the hot water loop
Units	Degrees Fahrenheit (℉)
Baseline Rules	Appendix G&D require 130℉ for basel ine boiler design, hence the

	delta t = 50F
Heating Supply Air Temperature Control	
Definition	The loop temperature control sequence. Choices are: -Fixed (constant) -LOAD-RESET - Reset by coldest zone - OA-RESET- Reset by outside air dry-bulb temperature - SCHEDULED- Scheduled setpoint
Baseline Rules	Reset by outside air dry bulb temperature.
Hot Water Supply Temperature Reset	
Definition	A linear reset schedule that represents the HW supply temperature or) as a function of outdoor air dry-bulb temperature. This schedule is defined by the following data points: -The HW design Supply temperature - The corresponding (Low) outdoor air dry-bulb threshold -The coolest HW Supply Temperature -The corresponding (High) outdoor air dry-bulb threshold
Baseline Rules	Both standards require a design high of 180F at outside low of 20F, and a Design low of 150F at an outside high of 50F.

Table 48

AppendixG&D3.1.2.4: Interpretation of the Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS
1	Hot Water Design Supply Temperature	180	180	This value is the same for both Standards. Defined by Section 3.1.3.3
2	Hot Water Loop Delta T (Based on Design Return Temperature)	50 (Return Temperature -130)	50 (Return Temperature -130)	This value is the same for both Standards. Defined by Section 3.1.3.3
3	HW Reset Control	RESET-TEMP	RESET-TEMP	This value is the same for both Standards. Defined by Section 3.1.3.4
4	HW Reset Schedule - Outside High Temperature	50	50	This value is the same for both Standards. Defined by Section 3.1.3.4
5	HW Reset Schedule - Outside Low Temperature	20	20	This value is the same for both Standards. Defined by Section

				3.1.3.4
6	HW Reset Schedule - HW Supply Temperature at Outside Low	180	180	This value is the same for both Standards. Defined by Section 3.1.3.4
7	HW Reset Schedule - HW Supply Temperature at Outside High Temperature	150	150	This value is the same for both Standards. Defined by Section 3.1.3.4

Translation for ECCO and eQUEST. The boiler hot water loop has been defined in accordance to this section. The table below defines the inputs specified for hot water loop definition.

1. Appendix G&D3.1.3.4 - HW Reset Schedule
2. Process Load Schedule
3. AppendixG&D3.1.3.5 - Hot Water Loop Pumps
4. Appendix G&D3.1.3.3 - Hot Water Circulation Loop
    a. Assign : Hot Water Pump
    b. Assign : Hot Water Reset Schedule
    c. Assign : Process Load Schedule

*Implementation for eQUEST***.** For Baseline system type 5 and 7, Boilers with the define hot water loop are assigned. A minimal process load assigned to the loop during the sizing run prevents the simulation error caused if no system/load is assigned to the loop. This process load is assigned the "Process Load Schedule" for minimal loads to the loop.

eQUEST Text Input-

```
$HW Supply Temperature Reset
    "HW-RESET-DAY"      = DAY-SCHEDULE-PD
      TYPE              = RESET-TEMP
      OUTSIDE-HI        = 50
    OUTSIDE-LO          = 20
      SUPPLY-HI         = 150
      SUPPLY-LO         = 180
```

Table 49

Implementation for ECCO

S.NO	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (G-P)
1	Hot Water Design Supply Temperature	CIRCULATION-LOOP (LOOP-DESIGN-DT)	Numeric (℉)	Pre-Defined (NR)
2	Hot Water Loop Delta T (Based on Design Return Temperature)	CIRCULATION-LOOP (DESIGN-HEAT-DT)	Numeric (℉)	Pre-Defined (NR)
3	HW Reset Control	CIRCULATION-LOOP (HEAT-SETPT-CTRL)	Existing Symbol (Dimensionless)	Pre-Defined (NR)
4	HW Reset Schedule - Outside High Temperature	DAY-SCHEDULE (OUTSIDE-HI)	Numeric (℉)	Pre-Defined (NR)
5	HW Reset Schedule - Outside Low Temperature	DAY-SCHEDULE (OUTSIDE-LO)	Numeric (℉)	Pre-Defined (NR)
6	HW Reset Schedule - HW Supply Temperature at Outside Low	DAY-SCHEDULE (SUPPLY-HI)	Numeric (℉)	Pre-Defined (NR)
7	HW Reset Schedule - HW Supply Temperature at Outside High Temperature	DAY-SCHEDULE (SUPPLY-LO)	Numeric (℉)	Pre-Defined (NR)

```
$CHW Supply Temperature Reset
        "CHW-RESET-DAY"      = DAY-SCHEDULE-PD
          TYPE               = RESET-TEMP
          OUTSIDE-HI         = 80
          OUTSIDE-LO         = 60
          SUPPLY-HI          = 54
          SUPPLY-LO          = 44
          ..
$Process Load day and Design Day
        "Process-Load-Day"   = DAY-SCHEDULE-PD
          TYPE               = MULTIPLIER
          VALUES                     = ( 0 )
          ..
        "Process-Load-Design-Day" = DAY-SCHEDULE-PD
          TYPE               = MULTIPLIER
          VALUES                     = ( 0.1 )
```

```
      ..
$ -------------------------------------------------------
$           Week Schedules
$ -------------------------------------------------------

$HW Supply Temperature Reset
     "HW-RESET-WK"          = WEEK-SCHEDULE-PD
       TYPE                 = RESET-TEMP
       DAY-SCHEDULES        = (“HW-RESET-DAY" )
       ..
$ CHW Supply Temperature Reset
     "CHW-RESET-WK"         = WEEK-SCHEDULE-PD
       TYPE                 = RESET-TEMP
       DAY-SCHEDULES        = ( "CHW-RESET-DAY" )
      ..
$Process Load Week Schedule
     "Process-Load-Week"    = WEEK-SCHEDULE-PD
       TYPE                 = MULTIPLIER
       DAY-SCHEDULES        = ( "Process-Load-Day", &D, &D, &D, &D, &D,
     &D, &D,
         "Process-Load-Design-Day", "Process-Load-Design-Day" )
       ..
```

$ ---
$ Annual Schedules
$ ---

```
$HW Supply Temp Reset
     "HW-Reset-ASHRAE-Sch"       = SCHEDULE-PD
       TYPE                      = RESET-TEMP
       MONTH                     = ( 12 )
       DAY                       = ( 31 )
       WEEK-SCHEDULES                 = ( "HW-RESET-WK" )
       ..
$CHW Supply Temp Reset
     "CHW-Reset-ASHRAE-Sch"      = SCHEDULE-PD
       TYPE                      = RESET-TEMP
       MONTH                     = ( 12 )
       DAY                       = ( 31 )
       WEEK-SCHEDULES                 = ( "CHW-RESET-WK" )
       ..
$Process Load Annual Schedule
     "Process-Load-Annual"       = SCHEDULE-PD
       TYPE                      = MULTIPLIER
       MONTH                     = ( 12 )
       DAY                       = ( 31 )
       WEEK-SCHEDULES            = ( "Process-Load-Week" )
       ..
```

Appendix G3.1.3.5 Hot-Water Pumps (System 5 and 7)

The baseline building design hot-water pump power shall be 19 W/gpm. The pumping system shall be modeled as primary-only with continuous variable flow. Hot-water systems serving 120,000 ft2 or more shall be modeled with variable-speed drives, and systems serving less than 120,000 ft2 shall be modeled as riding the pump curve.

Interpretation of the Code

- Standard 90.1-2007 and 189.1-2009. Both codes have similar requirements for hot water pumps. The hot water pump control is defined on the basis of the conditioned floor area. Each boiler would be assigned with a single hot water pump with a head of 60ft, motor efficiency of 1 and mechanical efficiency of 0.66.[2] Two-way valves are assumed at the heating coils with a modulating bypass valve at the end of the loop. The bypass valve shall open as necessary to maintain minimum flow through the boiler when the system is activated. This will establish the minimum flow through the system.

Table 50

Appendix G&D3.1.3.5: Definitions

	Number of Pumps
Definition	The number of identical pumps in service in a particular loop, e.g. the heating hot water loop, chilled water loop, or condenser water loop
Baseline Rules	The baseline specifies one pump for the HW Loop for the boiler, and one CHW pump and CW pump for the chiller.
	Water Loop Design
Definition	The heating and cooling delivery systems can consist of a simple primary loop system, or primary/secondary loops or primary/secondary/tertiary loops.
Baseline Rules	Appendix G&D require a primary only loop to be modeled for the HW loop, and a primary/secondary loop for the CHW loop.
	Pump Motor Modeling - Power/Unit Flow
Definition	The pump motor power is specified as power/unit flow or W/gpm.
Units	Degrees Fahrenheit (℉)

[2] ASHRAE 90.1 2007 User's Manual

Baseline Rules	Appendix G&D require HW pump power to be 19 W/gpm. eQUEST does not have a direct way to input pump power, which is then input as the pump head, motor efficiency and impeller efficiency.
Pump Control Type	
Definition	The type of control for the pump. Choices are: - ONE-SPEED-PUMP - Fixed speed, variable flow. Two-way valves are required. - TWO-SPEED-PUMP - Two-speed - VAR-SPEED-PUMP - Variable speed, variable flow
Baseline Rules	When the conditioned floor area < than 120,000 ft², HW pump = variable flow pump (riding the pump curve). If CFA > 120,000 ft², HW-Pump = a variable speed pump on a primary loop.

Table 51

AppendixG&D3.1.3.5: Interpretation of the Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS
1	The sum of the maximum head of coils, the maximum head of chiller/boiler and the loop head loss, with the sum adjusted by HEAD-RATIO.	60	60	HW Pump Head (for 19W/gpm), as defined by the User manual for 90.1 2007. This value is the same for 189.1 2009.
2	The impeller efficiency of the pump.	0.6	0.6	HW Impeller efficiency (for 19W/gpm), as defined by the User manual for 90.1 2007. This value is the same for 189.1 2009.
3	The efficiency of the pump's motor. This value is based on the nameplate power and the efficiency classification of the motor.	1	1	HW Pump Motor Efficiency (for 19W/gpm), as defined by the User manual for 90.1 2007. This value is the same for 189.1 2009.
4	Defines how the pump modulates as the flow varies	ONE-SPEED-PUMP	ONE-SPEED-PUMP	This value is dependent on the CFA of the building. One Speed Pump/ Variable speed pump.

Translation for ECCO and eQUEST

Table 52

AppendixG&D3.1.3.5: Translation for ECCO and eQUEST

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (G-P)
1	The sum of the maximum head of coils, the maximum head of chiller/boiler and the loop head loss, with the sum adjusted by HEAD-RATIO.	PUMP (HEAD)	Numeric (Feet)	Pre-Defined (NR)
2	The impeller efficiency of the pump.	PUMP (MECH-EFF)	Numeric (Dimensionless)	Pre-Defined (NR)
3	The efficiency of the pump's motor. This value is based on the nameplate power and the efficiency classification of the motor.	PUMP (MOTOR-EFF)	Numeric (Dimensionless)	Pre-Defined (NR)
4	Defines how the pump modulates as the flow varies	PUMP (CAP-CTRL)	Existing Symbol (Dimensionless)	Calculated (HW-Pump-Cap-Ctrl)

Implementation for eQUEST. For systems 5 and 7, hot water loops with the defined pumps are assigned during the sizing run. During the later stage of energy performance, the global parameter for the pump capacity control is assigned, the value for which is calculated by ECCO.

eQUEST Inputs

```
$HW Pump Sizing Run
        "ASHRAE-HW-Loop-Pump"     = PUMP
          HEAD                    = 60
          MECH-EFF                = 0.6
          MOTOR-EFF               = 1
          ..
$HW Pump Energy Performance
        "ASHRAE-HW-Loop-Pump"     = PUMP
          HEAD                    = 60
          MECH-EFF                = 0.6
          MOTOR-EFF               = 1
          CAP-CTRL                = {#SI(#PA("HW-Pump-Cap-
        Ctrl"), "PUMP" , "CAP-CTRL")}
          ..
```

Appendix G3.1.3.6 Piping Losses (Systems 1, 5, 7, and 8)

Piping losses shall not be modeled in either the proposed or baseline building designs for hot water, chilled water, or steam piping.

Interpretation of the Code. Standard 90.1-2007 and 189.1-2009. Both codes have similar requirements for piping losses, which are not required to be modeled.

Translation for ECCO. Piping losses are identified as the heat lost through the hot water pipes, or heat gained through the chilled water pipes. This value is ignored and the PEAK loads of the circulation loops are considered instead of the NET loads (which included heat gains through pipes and motors in the CHW loop) on the circulation loops.

Appendix G3.1.3.7 Type and Number of Chillers (Systems 7 and 8)

Electric chillers shall be used in the baseline building design regardless of the cooling energy source, e.g., direct-fired absorption, absorption from purchased steam, or purchased chilled water. The baseline building design's chiller plant shall be modeled with chillers having the number and type as indicated in Table G3.1.3.7 (Table D3.1.3.7) as a function of building peak cooling load.

Interpretation of the Code

Table 53

Appendix G&D3.1.3.7: Definitions

Chiller Type	
Definition	The type of chiller, either a vapor-compression chiller or an absorption chiller. Vapor compression chillers operate on the reverse-Rankin cycle, using mechanical energy to compress the refrigerant, and include: - Reciprocating – uses pistons for compression - Screw – uses two counter rotating screws for compression - Scroll – uses two interlocking spirals or scrolls to perform the compression - Centrifugal – uses rotating impeller blades to compress the air - Absorption chillers – use heat to vaporize a working fluid - Single Effect Absorption – use a single generator & condenser - Double Effect Absorption – use two generators/concentrators and condensers.

Baseline Rules	The baseline chiller type is dependent of the building peak cooling load. - Peak Load <600 Tons: Water Chiller Screw Chiller - Peak Load >= 600 Tons : Centrifugal chiller.
Number of Chillers	
Definition	The number of units for staging. This defines the capacity ratio for each chiller.
Baseline Rules	Both Standards define a requirement of one chiller if the cooling load is 300 tons or less, two equally sized chillers for loads between 300 and 600 tons. For loads above 600 tons, two or more chillers of equal size are used, with no chiller larger than 800 tons.
Chiller Fuel	
Definition	The fuel source for the chiller. The choices are: - Electricity (for all vapor-compression chillers) - Gas (Directly fired absorption chillers) - Oil (Directly fired absorption chillers) - Hot Water (Indirectly fired - absorption chillers) - Steam (Indirectly fired- Absorption chillers)
Baseline Rules	Both standards require the baseline system to be an electric chiller.

Table 54

AppendixG&D3.1.3.7: Interpretation of the Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS
1	Chiller Type- Is defined on the basis of the cooling load. (For baseline system type 7 and 8)	ELEC-SCREW	ELEC-SCREW	This value is defined on the basis of the building cooling load, and is the same for both 90.1 and 189.1

Translation for ECCO and eQUEST. The Appendix G&D requirements for chillers are met through the following steps-

a. AppendixG&D3.1.2.1 – Equipment Efficiency Calculations

b. AppendixG&D3.1.3.7 – Chiller Type and Number

c. AppendixG&D3.1.3.8&9 – Chilled Water Loop Definition

    i. Appendix G&D3.1.3.9 -CHW Reset Schedule

    ii. Process Load Schedule

iii. AppendixG&D3.1.3.10 - Chilled Water Loop Pumps

d. AppendixG&D3.1.3.11 – Condenser Water Loop and Pumps

e. AppendixG&D3.1.3.11 – Heat Rejection

Table 55

AppendixG&D3.1.3.7: Translation for ECCO

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (G-P)
1	Chiller Type- Is defined on the basis of the cooling load. (For baseline system type 7 and 8)	CHILLER (TYPE)	Existing Symbol (Dimensionless)	Calculated (User-Assigned)
2	Chiller Capacity Ratio (Number of Chillers)	CHILLER (CAPACITY-RATIO)	Numeric (Dimensionless)	Calculated (User-Assigned)

Implementation for eQUEST

eQUEST Input

```
$Sizing Run
    "ASHRAE-CHW-Chiller-Pump"       = PUMP
      HEAD                          = 75
      MECH-EFF                      = 0.6
      MOTOR-EFF                     = 1
      CAP-CTRL                      = ONE-SPEED-PUMP
      ..
$Energy Performance
    "ASHRAE-CHW-Chiller-Pump"   = PUMP
      HEAD                          = 75
      MECH-EFF                      = 0.6
      MOTOR-EFF                     = 1
      CAP-CTRL                      = {#SI(#PA("CHW-
    Pump-Cap-Ctrl"), "PUMP" , "CAP-CTRL")}
      ..
$Condenser Water Pump- Stage: Sizing Run
    "ASHRAE-CW-Loop-Pump"           = PUMP
      HEAD                          = 75
      MECH-EFF                      = 0.6
      MOTOR-EFF                     = 1
      CAP-CTRL                      = ONE-SPEED-PUMP
      ..
$CHW Secondary Pump Sizing Run
```

```
        "ASHRAE-CHW-Sec-Loop-Pump"        = PUMP
          HEAD                            = 50
          MECH-EFF                        = 1
          CAP-CTRL                        = ONE-SPEED-PUMP
          MIN-SPEED                       = 0.6
          VALVE-TYPE-2ND                  = THREE-WAY
          HEAD-SENSOR-LOCN                = AT-COILS
          ..
$CHW Secondary Pump Energy Performance
        "ASHRAE-CHW-Sec-Loop-Pump"        = PUMP
          HEAD                            = 50
          MECH-EFF                        = 1
          CAP-CTRL                        =  {#SI(#PA("Sec-
        Pump-Cap-Ctrl"), "PUMP" , "CAP-CTRL")}
          MIN-SPEED                       = 0.6
          VALVE-TYPE-2ND                  = THREE-WAY
          HEAD-SENSOR-LOCN                = AT-COILS
          ..
$ --------------------------------------------------------
$          Circulation Loops
$ --------------------------------------------------------
$CHW Primary Circulation Loop
          "ASHRAE-CHW-Loop"         = CIRCULATION-LOOP
          TYPE                      = CHW
          SUBTYPE                   = SECONDARY
          LOOP-DESIGN-DT            = 12
          PIPE-HEAD                 = 26
          LOOP-OPERATION            = DEMAND
          DESIGN-COOL-T             = 44
          COOL-SETPT-CTRL           = OA-RESET
          COOL-RESET-SCH            = "CHW-Reset-ASHRAE-Sch"
          MAX-RESET-T               = 54
          LOOP-PUMP                 = "ASHRAE-CHW-Loop-Pump"
          PROCESS-LOAD              = ( 0.01 )
          PROCESS-SCH               = ( "Process-Load-Annual" )
          ..
$CW Circulation Loop
        "ASHRAE-CW-Loop"            = CIRCULATION-LOOP
         TYPE                       = CW
         DESIGN-COOL-T              = 82 $ ashrae = lesser of ( wb
        +10, or 85  )
         COOL-SETPT-CTRL            = FIXED
        COOL-SETPT-T                = 70
        LOOP-OPERATION              = STANDBY
        PROCESS-LOAD                = ( 0.01 )
        LOOP-PUMP                   = "ASHRAE-CW-Loop-Pump"
        PROCESS-SCH                 = ( "Process-Load-Annual" )
          ..
```

```
$CHW Secondary Loop
        "ASHRAE CHW Secondary Loop" = CIRCULATION-LOOP
          TYPE                      = CHW
          SUBTYPE                   = SECONDARY
          PRIMARY-LOOP              = "ASHRAE-CHW-Loop"
          LOOP-PUMP                 = "ASHRAE-CHW-Sec-Pump"
          HEAD-SENSOR-LOCN          = AT-COILS
          PROCESS-LOAD              = ( 0.01 )
          PROCESS-SCH               = ( "Process-Load-Annual" )
          ..
$ -----------------------------------------------------
$         Chillers
$ -----------------------------------------------------
          "ASHRAE-Chiller-1"        = CHILLER
          TYPE                      = ELEC-HERM-CENT
          DESIGN-CHW-T              = 44
          RATED-CHW-T               = 44
          CAPACITY-RATIO            = 0.65
          VARIABLE-SPEED            = NO
          ELEC-INPUT-RATIO          = 0.141
          CHW-LOOP                  = "ASHRAE-CHW-Loop"
          CHW-PUMP                  = "ASHRAE-Chiller-Pump"
          CONDENSER-TYPE            = WATER-COOLED
          CW-LOOP                   = "ASHRAE-CW-Loop"
          MIN-COND-T                = 60
          ..
$ -----------------------------------------------------
$         Heat Rejection
$ -----------------------------------------------------

        "ASHRAE-Heat-Rejection"     = HEAT-REJECTION
        TYPE                        = OPEN-TWR
        CW-LOOP                     = "ASHRAE-CW-Loop"
        ..
```

Appendix G3.1.3.8 Chilled-Water Design Supply Temperature (Systems 7 and 8)

Chilled-water design supply temperature shall be modeled at 44℉ and return water temperature at 56℉.

Appendix G3.1.3.9 Chilled-Water Supply Temperature Reset (Systems 7 and 8)

Chilled-water supply temperature shall be reset based on outdoor dry-bulb temperature using the following schedule: 44℉ at 80℉ and abov e, 54℉ at 60℉ and below, and ramped linearly between 44℉ and 54℉ at temperatur es between 80℉ and 60℉.

Interpretation of the Code

- Standard 90.1-2007 and 189.1-2009. Both codes have similar requirements for chilled water supply temperature.

Table 56

Appendix G&D3.1.3.9: Definitions

Chilled Water Supply Temperature	
Definition	The temperature of the water produced by the chiller and supplied to the chilled water loop
Units	Degrees Fahrenheit (℉)
Baseline Rules	AppendixG&D requires 44℉ for baseli ne chiller (G3.1.3.8).
Chilled Water Return Temperature	
Definition	The temperature of the water returning to the Chiller from the chilled water loop
Units	Degrees Fahrenheit (℉)
Baseline Rules	AppendixG&D requires 56℉ for baseline boiler desig n, hence the delta t = 12F
Chilled Water Supply Temperature Control	
Definition	The loop temperature control sequence. Choices are: -Fixed (constant) -LOAD-RESET - Reset by coldest zone - OA-RESET- Reset by outside air dry-bulb temperature - SCHEDULED- Scheduled setpoint
Baseline Rules	Reset by outside air dry bulb temperature.
Chilled Water Supply Temperature Reset	
Definition	A linear reset schedule that represents the CHW supply temperature or) as a function of outdoor air dry-bulb temperature. This schedule is defined by the following data points: -The CHW design Supply temperature - The corresponding (Low) outdoor air dry-bulb threshold -The coolest CHW Supply Temperature -The corresponding (High) outdoor air dry-bulb threshold

Baseline Rules	The baseline chilled water supply temperature is reset from 44°F to 54°F based on outdoor air temperature as shown in t he figure below. Both standards require a supply design high of 54F at outside low of 60F, and a Design low of 44F at an outside high of 80F.
Condenser Type	
Definition	The type of condenser for a chiller. The choices are: - Air-Cooled - Water-Cooled - Evaporative-Cooled Air-cooled chillers use air to cool the condenser coils. Water-cooled chillers use cold water to cool the condenser and additionally need either a cooling tower or a local source of cold water. Evaporatively-cooled chillers are similar to air-cooled chillers, except they use a water mist to cool the condenser coil which makes them more
Baseline Rules	The baseline chiller is always assumed to have a water-cooled condenser, although the chiller type will change depending on the design capacity. If the chiller size is less than 600 tons, the baseline chiller is a water-cooled screw; if the capacity is greater than or equal to 600 tons, the baseline chiller is a water-cooled centrifugal chiller.

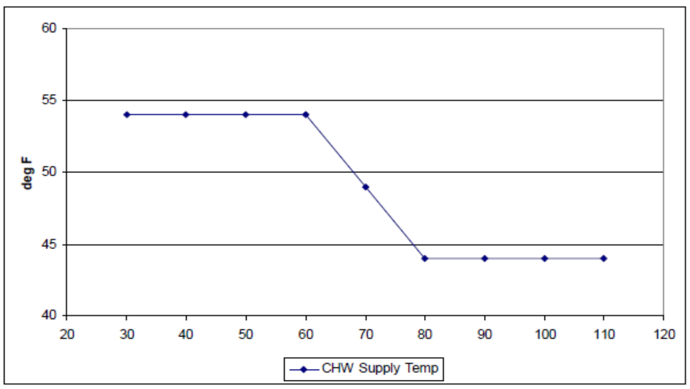

Figure 7:

Chilled Water Supply Temperature Reset (COMNET, 2010)

Table 57

AppendixG&D3.1.3.8 and 9- Interpretation of the Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS
1	Chilled Water Design Supply Temperature	44	44	This value is the same for both Standards. Defined by Section 3.1.3.8

2	Chilled Water Loop Delta T (Based on Design Return Temperature)	12 (Return Temperature -56)	12 (Return Temperature -56)	This value is the same for both Standards. Defined by Section 3.1.3.8
3	CHW Reset Control (CW Reset Is not Specified in the Standard)	RESET-TEMP	RESET-TEMP	This value is the same for both Standards. Defined by Section 3.1.3.4
4	CHW Reset Schedule - Outside High Temperature	80	80	This value is the same for both Standards. Defined by Section 3.1.3.9
5	CHW Reset Schedule - Outside Low Temperature	60	60	This value is the same for both Standards. Defined by Section 3.1.3.9
6	CHW Reset Schedule - HW Supply Temperature at Outside Low	44	44	This value is the same for both Standards. Defined by Section 3.1.3.9
7	CHW Reset Schedule - HW Supply Temperature at Outside High Temperature	54	54	This value is the same for both Standards. Defined by Section 3.1.3.9

Translation for ECCO

Table 58

AppendixG&D3.1.3.8 and 9- Translation for ECCO and eQUEST

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (G.P.)
1	Chilled Water Design Supply Temperature	CIRCULATION-LOOP (LOOP-DESIGN-DT)	Numeric (°F)	Pre-Defined (NR)
2	Chilled Water Loop Delta T (Based on Design Return Temperature)	CIRCULATION-LOOP (DESIGN-HEAT-DT)	Numeric (°F)	Pre-Defined (NR)

3	CHW Reset Control (CW Reset Is not Specified in the Standard)	CIRCULATION-LOOP (HEAT-SETPT-CTRL)	Existing Symbol (Dimensionless)	Pre-Defined (NR)
4	CHW Reset Schedule - Outside High Temperature	DAY-SCHEDULE (OUTSIDE-HI)	Numeric (°F)	Pre-Defined (NR)
5	CHW Reset Schedule - Outside Low Temperature	DAY-SCHEDULE (OUTSIDE-LO)	Numeric (°F)	Pre-Defined (NR)
6	CHW Reset Schedule - HW Supply Temperature at Outside Low	DAY-SCHEDULE (SUPPLY-HI)	Numeric (°F)	Pre-Defined (NR)
7	CHW Reset Schedule - HW Supply Temperature at Outside High Temperature	DAY-SCHEDULE (SUPPLY-LO)	Numeric (°F)	Pre-Defined (NR)

eQUEST Inputs

```
$CHW Supply Temperature Reset
        "CHW-RESET-DAY"      = DAY-SCHEDULE-PD
          TYPE               = RESET-TEMP
          OUTSIDE-HI         = 80
          OUTSIDE-LO         = 60
          SUPPLY-HI          = 54
          SUPPLY-LO          = 44
          ..
$Process Load day and Design Day
        "Process-Load-Day"   = DAY-SCHEDULE-PD
          TYPE               = MULTIPLIER
          VALUES                     = ( 0 )
          ..
        "Process-Load-Design-Day" = DAY-SCHEDULE-PD
          TYPE               = MULTIPLIER
          VALUES                     = ( 0.1 )
          ..
$ ---------------------------------------------------------
$         Week Schedules
$ ---------------------------------------------------------

$ CHW Supply Temperature Reset
        "CHW-RESET-WK"       = WEEK-SCHEDULE-PD
          TYPE               = RESET-TEMP
          DAY-SCHEDULES      = ( "CHW-RESET-DAY" )
         ..
$Process Load Week Schedule
        "Process-Load-Week"  = WEEK-SCHEDULE-PD
```

```
      TYPE                    = MULTIPLIER
      DAY-SCHEDULES     = ( "Process-Load-Day", &D, &D, &D, &D, &D,
    &D, &D,
         "Process-Load-Design-Day", "Process-Load-Design-Day" )
      ..
$ ------------------------------------------------------
$           Annual Schedules
$ ------------------------------------------------------

$CHW Supply Temp Reset
    "CHW-Reset-ASHRAE-Sch"      = SCHEDULE-PD
      TYPE                      = RESET-TEMP
      MONTH                     = ( 12 )
      DAY                       = ( 31 )
      WEEK-SCHEDULES            = ( "CHW-RESET-WK" )
      ..
$Process Load Annual Schedule
    "Process-Load-Annual"       = SCHEDULE-PD
      TYPE                      = MULTIPLIER
      MONTH                     = ( 12 )
      DAY                       = ( 31 )
      WEEK-SCHEDULES                    = ( "Process-Load-Week" )
      ..
```

Appendix G3.1.3.10 Chilled-Water Pumps (Systems 7 and 8)

The baseline building design pump power shall be 22 W/gpm. Chilled-water systems with a cooling capacity of 300 tons or more shall be modeled as primary/secondary systems with variable-speed drives on the secondary pumping loop. Chilled-water pumps in systems serving less than 300 tons cooling capacity shall be modeled as primary/secondary systems with secondary pump riding the pump curve.

Interpretation of Code

- Standard 90.1-2007 and 189.1-2009. Both codes have similar requirements for chilled water pumps. Please refer to Section AppendixG3.1.3.5 for definitions.

Table 59

AppendixG&D3.1.3.10: Interpretation of the Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS
1	The sum of the maximum head of coils, the maximum head of	For Primary - 20	For Primary - 20	CHW Pump Head (for 22W/gpm), as defined by the User manual for

	chiller/boiler and the loop head loss, with the sum adjusted by HEAD-RATIO.	For Secondary - 50	For Secondary - 50	90.1 2007. This value is the same for 189.1 2009.
2	The impeller efficiency of the pump.	0.6	0.6	CHW Impeller efficiency (for 22W/gpm), as defined by the User manual for 90.1 2007. This value is the same for 189.1 2009.
3	The efficiency of the pump's motor. This value is based on the nameplate power and the efficency classification of the motor.	1	1	CHW Pump Motor Efficiency (for 22W/gpm), as defined by the User manual for 90.1 2007. This value is the same for 189.1 2009.
4	Defines how the pump modulates as the flow varies	Primary - ONE-SPEED-PUMP Secondary - ONE-SPEED-PUMP / VAR-SPEED-PUMP	Primary - ONE-SPEED-PUMP Secondary - ONE-SPEED-PUMP / VAR-SPEED-PUMP	Primary Pumps are Constant Volume and ride the pump curve. This value is dependent on the CFA of the building. One Speed Pump/Variable speed pump.

Translation for ECCO

Table 60

AppendixG&D3.1.3.10: Translation for ECCO and eQUEST

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (G-P)
1	The sum of the maximum head of coils, the maximum head of chiller/boiler and the loop head loss, with the sum adjusted by HEAD-RATIO.	PUMP (HEAD)	Numeric (Feet)	Pre-Defined (NR)

2	The impeller efficiency of the pump.	PUMP (MECH-EFF)	Numeric (Dimensionless)	Pre-Defined (NR)
3	The efficiency of the pump's motor. This value is based on the nameplate power and the efficiency classification of the motor.	PUMP (MOTOR-EFF)	Numeric (Dimensionless)	Pre-Defined (NR)
4	Defines how the pump modulates as the flow varies	PUMP (CAP-CTRL)	Existing Symbol (Dimensionless)	Calculated (Sec-Pump-Cap-Ctrl)

Implementation for eQUEST. The following steps are required for the implementation of chilled water reset in eQUEST-

- AppendixG&D3.1.3.9 – Define Chilled Water Reset Schedule
- Define Process Load Schedule
- AppendixG&D3.1.3.10 – Define Chilled Water Pumps
- AppendixG&D3.1.3.8 – Define Chilled Water Loop

For Baseline system type 7 and 8, chillers with the defined chilled water loops are assigned. A minimal process load assigned to the loops during the sizing run prevents the simulation error caused if no system/load is assigned to the loop. This process load is assigned the “Process Load Schedule” for minimal loads to the loop. User input is required for the secondary chilled water loop pump capacity control. This is assigned through the user-form as shown below. All other parameters are predefined and assigned through the text input file as mentioned above. Refer to APPENDIX D for more details on the interpretation of 90.1 and 189.1 requirements and its translation to eQUEST parameters.

eQUEST Inputs are required for one CHW Loop – Primary, One CHW Loop-Secondary and One CW Loop. Pumps: one to the Secondary CHW Loop, One to CW Loop, One for each chiller, attached to the Primary CHW Loop and CW Loop.

eQUEST Inputs

```
$Sizing Run
        "ASHRAE-CHW-Chiller-Pump"   = PUMP
          HEAD                                  = 75
```

```
MECH-EFF                = 0.6
MOTOR-EFF               = 1
CAP-CTRL                = ONE-SPEED-PUMP
                        $Constant Volume primary
                        Pump
..

$Add More CHW Chiller Pumps, depending on the number of Chillers.
$ASHRAE-CHW-Chiller-Pump2 if the Number of Chillers is 2.
$ASHRAE-CHW-Chiller-Pump3 if the Number of Chillers is 3.

$CHW Secondary Pump Sizing Run
"ASHRAE-CHW-Sec-Loop-Pump"        = PUMP
  HEAD                            = 50
  MECH-EFF                = 1
  CAP-CTRL                = ONE-SPEED-PUMP
  MIN-SPEED               = 0.6
  VALVE-TYPE-2ND          = THREE-WAY
  HEAD-SENSOR-LOCN                = AT-COILS
  ..
$CHW Secondary Pump Energy Performance
"ASHRAE-CHW-Sec-Loop-Pump"        = PUMP
  HEAD                            = 50
  MECH-EFF                = 1
  CAP-CTRL                =  {#SI(#PA("Sec-Pump-Cap-
Ctrl"), "PUMP" , "CAP-CTRL")}
  MIN-SPEED               = 0.6
  VALVE-TYPE-2ND          = THREE-WAY
  HEAD-SENSOR-LOCN                = AT-COILS
  ..
```

Appendix G3.1.3.11 Heat Rejection (Systems 7 and 8)

The heat rejection device shall be an axial fan cooling tower with two speed fans. Condenser water design supply temperature shall be 85℉ or 10℉ approaching design wet-bulb temperature, whichever is lower, with a design temperature rise of 10℉. The tower shall be controlled to maintain a 70℉ leavin g water temperature where weather permits, floating up to leaving water temperature at design conditions. The baseline building design condenser-water pump power shall be 19 W/gpm. Each chiller shall be modeled with separate condenser water and chilled-water pumps interlocked to operate with the associated chiller.

Interpretation of the Code

- Standard 90.1-2007 and 189.1-2009. Both codes have similar requirements for heat rejection system. The water cooled condenser, an open tower with axial cooling fan is required by both standards. A condenser water loop, with design supply temperature of 70F and pump with 19W/gpm power is required.

Table 61

Appendix G&D3.1.3.11: Definitions

Cooling Tower Type	
Definition	The type of cooling tower employed. The choices are: - Open tower, centrifugal fan - Open tower, axial fan - Closed tower, centrifugal fan - Closed tower, axial fan Open cooling towers collect the cooled water from the tower and pump it directly back to the cooling system. Closed towers circulate the evaporated water over a heat exchanger to indirectly cool the system fluid.
Baseline Rules	The baseline cooling tower is an open tower axial fan device with a two-speed fan for both Standards.
Cooling Tower Capacity	
Definition	The tower thermal capacity per cell adjusted to CTI (Cooling Technology Institute) rated conditions of 95 F condenser water return, 85 F condenser water supply, and 78 F wet bulb with a 3 gpm/nominal ton water flow. The default cooling tower curves below are at unity at these conditions.
Baseline Rules	The baseline building chiller is auto sized and increased by 15%. The tower is sized to deliver 85 F condenser water supply at design conditions for the oversized chiller.
Cooling Tower Number of Cells	
Definition	The number of cells in the cooling tower. Each cell is sized equally. Cells are subdivisions in cooling towers into individual cells, each with their own fan and water flow, and allow the cooling system to respond more efficiently to lower load conditions.
Baseline Rules	One cell per tower and one tower per chiller.
Cooling Tower Total Fan Horsepower	
Definition	The sum of the nameplate rated horsepower (hp) of all fan motors on the cooling tower.

Baseline Rules	For minimum compliance with ASHRAE Standard 90.1-2007, must be atleast 38.2 gpm/hp for an axial fan cooling tower and at least 20.0 gpm/hp for a centrifugal fan cooling tower. (Table 6.8.1G) Not applicable since pump power is specified as 19 watts/gpm.
Cooling Tower Capacity Control	
Definition	Describes the modulation control employed in the cooling tower. - Fluid Bypass: Divert some of the condenser water around the cooling tower at part-load conditions - Fan Cycling - simple method of capacity control where the tower fan is cycled on and off. - Two-Speed Fan - Motor runs at part-load conditions (instead of the full sized motor) and saves fan energy when the tower load is reduced. - Variable Speed Fan- A variable frequency drive is installed for the tower fan so that the speed can be modulated.
Baseline Rules	Both the standards require the cooling tower capacity control to be set to TWO-SPEED-FAN.

Table 62

AppendixG&D3.1.3.11 - Interpretation of the Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS
1	Type of heat rejection device	OPEN-TWR	OPEN-TWR	This value is defined by the Standard, and is same for both 90.1 and 189.1
2	Condenser Water Loop- Assigned to the Cooling Tower	ASHRAE-CW-Loop	ASHRAE-CW-Loop	This value is defined by the Standard, and is same for both 90.1 and 189.2
3	Cooling Tower Efficiency (Electric Input Ratio)	0.013	0.013	This value is defined by the Standard, and is same for both 90.1 and 189.3
4	Cooling Tower Capacity Control	TWO-SPEED-FANS	TWO-SPEED-FANS	This value is defined by the Standard, and is same for both 90.1 and 189.4

Translation for ECCO and eQUEST

Table 63

AppendixG&D3.1.3.11 - Translation for ECCO and eQUEST

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE

				(G-P)
1	Type of heat rejection device	HEAT-REJECTION (TYPE)	Existing Symbol (Dimensionless)	Pre-Defined (NR)
2	Condenser Water Loop- Assigned to the Cooling Tower	HEAT-REJECTION (CW-LOOP)	Existing Symbol (Dimensionless)	Pre-Defined (NR)
3	Cooling Tower Efficiency (Electric Input Ratio)	HEAT-REJECTION (ELEC-INPUT-RATIO)	Numeric (Dimensionless)	Calculated (HR-Fan-Control)
4	Cooling Tower Capacity Control	HEAT-REJECTION (CAPACITY-CTRL)	Existing Symbol (Dimensionless)	Calculated (Cooling-Tower-EIR)

Table 64

Cooling Tower Efficiency Calculation Procedure

Cooling Tower Calculations			
(Source : Energy Model Input Translator, August 2010, Rocky Mountain Institute)			
User Input :		Condenser Water Flow (gpm)	
Code Defined Value		Cooling Tower Fan Type- Axial	
		Condenser Water DT (°F)	
		Code Minimum Efficiency (gpm/hp)	
No.	Description	Calculation	Explanation
STEP 1	Calculate total Heat Rejected by cooling tower	0.5 * gpm * DT	
STEP 2	Calculate nameplate horsepower- hp (not bhp)	gpm/ Minimum Efficiency	Minimum Efficiency is defined by Table 6.8.1G for 90.1 and C-8 for 189.1
STEP 3	Calculate Cooling tower COP	Heat Rejected / (hp * 2.5467)	This value is the total heat reject/ fan power
STEP 4	Cooling Tower EIR	1/COP	The reciprocal of the COP

Implementation for eQUEST

eQUEST Input

1. Condenser Water Pump
2. Condenser Water Circulation Loop
3. Cooling Tower

```
$Condenser Water Pump
    "ASHRAE-CW-Loop-Pump"            = PUMP
      HEAD                           = 75
      MECH-EFF                       = 0.6
      MOTOR-EFF                      = 1
      CAP-CTRL                       = ONE-SPEED-PUMP
      ..
    $Add More CW Chiller Pumps, depending on the number of Chillers.
    $ASHRAE-CW-Loop-Pump2 if the Number of Chillers is 2.
    $ASHRAE-CW-Loop-Pump3 if the Number of Chillers is 3.

$Condenser Water Circulation Loop
    "ASHRAE-CW-Loop"                 = CIRCULATION-LOOP
      TYPE                           = CW
      DESIGN-COOL-T                  = 82 $ ashrae = lesser of ( wb
                                 +10, or 85  )
      COOL-SETPT-CTRL                = FIXED
      COOL-SETPT-T                   = 70
      LOOP-OPERATION                 = STANDBY
      PROCESS-LOAD                   = (0.01)
      LOOP-PUMP                      = "ASHRAE-CW-Loop-Pump"
      PROCESS-SCH                    = (“Process-Load-Annual" )
      ..
$Heat Rejection : Cooling Tower
    "ASHRAE-Heat-Rejection"          = HEAT-REJECTION
      TYPE                           = OPEN-TWR
      CAPACITY-RATIO                 = 1
      NUMBER-OF-CELLS                = 2
      CELL-CTRL                      = MIN-CELLS
      ELEC-INPUT-RATIO               = 0.013 $ BTU/BTU
      CAPACITY-CTRL                  = TWO-SPEED-FAN
      DESIGN-APPROACH                = 10
      DESIGN-WETBULB                 = 70  $ For CZ2B, see ASHRAE
    90.1 Table D-1
      CW-LOOP                        = "ASHRAE-CW-Loop"
      ..
```

Appendix G3.1.3.12 Supply Air Temperature Reset (Systems 5 through 8).

The air temperature for cooling shall be reset higher by 5°F under the minimum cooling load conditions.

Interpretation of the Code

Table 65

Appendix G&D3.1.3.12: Definitions

Cooling Supply Air Temperature Control	
Definition	The method of controlling the supply air temperature. Choices are: - CONSTANT- Fixed (constant) - WARMEST-Reset by warmest zone - RESET-Reset by outside air dry-bulb temperature - SCHEDULED -Scheduled setpoint
Baseline Rules	For baseline building systems 1 through 4, the SAT control is not applicable. For systems 5 through 8, the SAT control shall be reset by outside dry-bulb temperature.

From Equest Doe-2 Help: Cool-Control. Takes a code-word that specifies how the air temperature leaving the system cooling coil is controlled.

- WARMEST -

  Sets the cooling coil (cold deck) temperature each hour to adequately cool the zone with the highest temperature. The limits on the supply air temperature are then governed by COOL-MAX-RESET-T, COOL-MIN-RESET-T, coil capacities, and cooling schedules.
- For VAV systems, THROTTLING-RANGE should be increased to 4-6F (2-3K).

Table 66

AppendixG&D3.1.3.12 - Interpretation of the Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS
1	SAT Reset Control	WARMEST	WARMEST	Both standards require the SAT to be reset in accordance to the warmest zone.
2	Maximum Temperature for	5	5	SAT is reset higher by 5F for both Standards.

	Reset Control			

Translation for ECCO. The approach is to choose reset>warmest>airflow first.(For VAV system the airflow will reduce first to satisfy load then the supply air temperature would rise at the minimum air flow rate.) The DeltaT for reset is specified according to ASHRAE 90.1. 2007, to 5°F. The SAT has been reset from 55°F to 60°F.

- For heat pumps (System 4), the throttling range has been set to 2°F.
- For System 7 and 8 (Variable Air Volume systems) the throttling range has been set to 4°F.

Table 67

AppendixG&D3.1.3.12 - Translation for ECCO and eQUEST

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (GP)
1	SAT Reset Control	SYSTEM (COOL-CONTROL)	Existing Symbol (Dimensionless)	Pre-Defined (SAT-Reset)
2	Maximum Temperature for Reset Control	SYSTEM (CCOL-MAX-RESET-T)	Numeric (°F)	Pre-Defined (Max-Reset-Temp)

Implementation for eQUEST. Refer to Appendix C and D for eQUEST system templates as well as details for implementation in ECCO.

Appendix G3.1.3.13 VAV Minimum Flow Setpoints (Systems 5 and 7)

Minimum volume setpoints for VAV reheat boxes shall be 0.4 cfm/ft2 of floor area served or the minimum ventilation rate, whichever is larger.

Interpretation of the Code

- Standard 90.1-2007 and 189.1-2009. Both codes have similar requirements for VAV minimum flow setpoints. The code requires minimum flow setpoints to be calculated at zone level, in accordance to the minimum OA being supplied to the zone. If the OA requirements are greater than 0.4 CFM/ sq.ft, the VAV minimum flow is set to that else the minimum flow requirements are set to 0.4 CFM/sq.ft.

Table 68

Appendix G&D3.1.3.13: Definitions

VAV Minimum Flow Setpoints	
Definition	The minimum airflow that will be delivered by a terminal unit before reheating occurs. Unit less fraction airflow (cfm) or specific airflow (cfm/ft²)
Baseline Rules	This input must be greater than or equal to the outside air ventilation rate. For systems 5 through 8, set the minimum airflow to be the greater of 0.4 cfm/ft² of conditioned floor area or the outside air ventilation rate.

Table 69

AppendixG&D3.1.3.13 Interpretation of the Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS
1	The minimum design supply air flow rate to the zone per unit floor area.	0.4	0.4	This value is the same for both standards and is assigned at zone level.

Translation for ECCO. For ease of calculation the minimum flow value has been assumed to be 0.4 cfm/sq.ft for all zones which is assigned at system level. The user is advised to analyze zones with possibly higher requirements for outdoor air (areas with higher occupancy) individually for higher requirements of outside air.

Table 70

AppendixG&D3.1.3.13 - Translation for ECCO and eQUEST

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (G-P)
1	The minimum design supply air flow rate to the zone per unit floor area.	ZONE (FLOW/AREA)	Numeric (CFM/sq.ft)	Pre-Defined (VAV-Min-Flow)

Implementation for eQuest. Refer to Section AppendixG3.1.3.12

Appendix G3.1.3.14 Fan Power (Systems 6 and 8)

Fans in parallel VAV fan-powered boxes shall be sized for 50% of the peak design flow rate and shall be modeled with 0.35 W/cfm fan power. Minimum volume setpoints for fan-powered boxes shall be equal to 30% of peak design flow rate or the rate required to meet the minimum outdoor air ventilation requirement, whichever is larger. The supply air temperature setpoint shall be constant at the design condition.

Interpretation of the Code

Table 71

Appendix G&D3.1.3.14: Definitions

System 6&8- Zone Terminal Type	
Definition	Defines the type of fan-powered induction box. This is either : - SERIES-PIU -Series - PARALLEL-PIU - Parallel
Baseline Rules	Applicable for baseline building systems 6 and 8 and the fan powered box type is parallel.
System 6&8- Zone Fan Power	
Definition	The rated power input of the fan in a fan-powered box.
Units	W or W/cfm
Baseline Rules	For baseline building systems 6 and 8, power is prescribed at 0.35 W/cfm.
System 6&8- Parallel PIU - Induction Ratio	
Definition	The ratio of induction-side airflow of a fan-powered box at design heating conditions to the primary airflow Ratio
Baseline Rules	Both standards require this value to be 50%

Table 72

AppendixG&D3.1.3.14 - Interpretation of the Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS
1	ZONE-FAN-RATIO times the design primary air flow rate gives design flow rate of the	0.5	0.5	This value is the same for both standards and is

	PIU fan for ZONE:TERMINAL-TYPE = PARALLEL-PIU.			assigned at zone level.
2	Zone Fan Power The power of the fan per unit flow rate for ZONE: TERMINAL-TYPE =PARALLEL-PIU.	0.00035	0.00035	This value is the same for both standards and is assigned at zone level.
3	Zone Minimum design flow ratio Minimum allowable zone air supply flow rate, expressed as a fraction of design flow rate. This value can be specified at System level (applies to all zones) or zone level.	0.3	0.3	This value is the same for both standards and is assigned at system level.
4	Terminal Type For Fan Powered VAV systems, can be Series, or Parallel.	PARALLEL-PIU	PARALLEL-PIU	This value is the same for both standards and is assigned at zone level.

Translation for ECCO and eQUEST

Table 73

AppendixG&D3.1.3.14- Translation for ECCO and eQUEST

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (GP)
1	ZONE-FAN-RATIO times the design primary air flow rate gives design flow rate of the PIU fan for ZONE:TERMINAL-TYPE = PARALLEL-PIU.	ZONE (ZONE-FAN-RATIO)	Numeric (Dimensionless)	Pre-Defined (Zone-Fan-Ratio)
2	Zone Fan Power The power of the fan per unit flow rate for ZONE: TERMINAL-TYPE =PARALLEL-PIU.	ZONE (ZONE-FAN-KW/FLOW)	Numeric (KW/CFM)	Pre-Defined (Zone-Fan-Power)

3	Zone Minimum design flow ratio Minimum allowable zone air supply flow rate, expressed as a fraction of design flow rate. This value can be specified at System level (applies to all zones) or zone level.	SYSTEM (MIN-FLOW-RATIO)	Numeric (Dimensionless)	Pre-Defined (Zone-Min-Flow-Ratio)
4	Terminal Type For Fan Powered VAV systems, can be Series, or Parallel.	ZONE (TERMINAL-TYPE)	Existing Symbol (Dimensionless)	Pre-Defined (Terminal-Type)

Implementation for eQUEST. Please refer to Section AppendixG3.1.3.12

Appendix G3.1.3.15 VAV Fan Part-Load Performance (Systems 5 through 8)

VAV system supply fans shall have variable speed drives, and their part-load

performance characteristics

shall be modeled using either Method 1 or Method 2 specified in Table G3.1.3.15 (Table D3.1.3.15).

Interpretation of the Code

Table 74

Appendix G&D3.1.3.15: Definitions

	VAV Fan Part Load Curve
Definition	A VAV Fan part load curve represents the percentage full-load power draw of the supply fan as a function of the percentage full-load air flow. The curve is typically represented as a quadratic equation with an absolute minimum power draw specified.
Baseline Rules	Both standards define the part load performance for the VAV fan curve. Method 1 has been used for both standards to model this.

Table 75

Standard 90.1 and 189.1 VAV Fan Part Load Performance Requirements

Part-Load Performance for VAV Fan Systems (Table G3.1.3.15 for 90.1 and Table D3.1.3.15 for 189.1)	
Fan Part-Load ratio	Fraction of Full-Load-Power 90.1-2007 and 189.1-2009

0.00	0.00
0.10	0.03
0.20	0.07
0.30	0.13
0.40	0.21
0.50	0.30
0.60	0.41
0.70	0.54
0.80	0.68
0.90	0.83
1.00	1.00

Table 76

AppendixG&D3.1.3.15 - Interpretation of the Code

S.NO.	DESCRIPTION	90.1 2007	189.1 2009	COMMENTS
1	Fan Control - Based on Fan Curve. Fan control method is user specified using the U-name of a curve as input to FAN-EIR-FPLR	FAN-EIR-FPLR	FAN-EIR-FPLR	This value is the same for both standards and is assigned at system level.
2	VAV Fan Part Load Performance Curve. This is defined in accordance to Table G&D3.1.3.15.	Appendix G Part Load Curve	Appendix D Part Load Curve	This value is the same for both standards and is assigned at system level.

Translation for ECCO

Table 77

AppendixG&D3.1.3.15 - Translation for ECCO and eQUEST

S.NO.	DESCRIPTION	COMMAND (KEY-WORD)	UNITS	ECCO PROCEDURE (GP)
1	Fan Control - Based on Fan Curve. Fan control method is user specified using the U-name of a curve as	SYSTEM (FAN-CONTROL)	Existing Symbol (Dimensionless)	Pre-Defined (Fan-Control)

	input to FAN-EIR-FPLR			
2	VAV Fan Part Load Performance Curve. This is defined in accordance to Table G&D3.1.3.15.	SYSTEM (FAN-EIR-FPLR)	Existing Symbol (Dimensionless)	Pre-Defined (Fan-Curve)

Implementation for eQUEST. Refer to Appendix C for input templates for all system types. eQUEST inputs are required to assign the defined fan curve as well as the fan control. The system input templates in Appendix C elaborate on the process for the same. The performance curve for the fan part load performance is defined through the eQUEST input as defined below.

eQUEST Input

```
$ *********************************************************
$ **            Performance Curves
$ *********************************************************

"AppendixG Part Load Curve"        = CURVE-FIT
  TYPE                             = QUADRATIC
  INPUT-TYPE                       = DATA
  INDEPENDENT                      = ( 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9,
1 )
  DEPENDENT                        = ( 0, 0.03, 0.07, 0.13, 0.21, 0.3, 0.41, 0.54,
0.68,
      0.83, 1 )
  ..
```

1.2. APPLICATION PROCESS FLOW

This section illustrates the application process of the tool. The values determined through the Development Process Flow are segregated in the stages defined below. Appendix C enlists the various parameters defined and their corresponding stages.

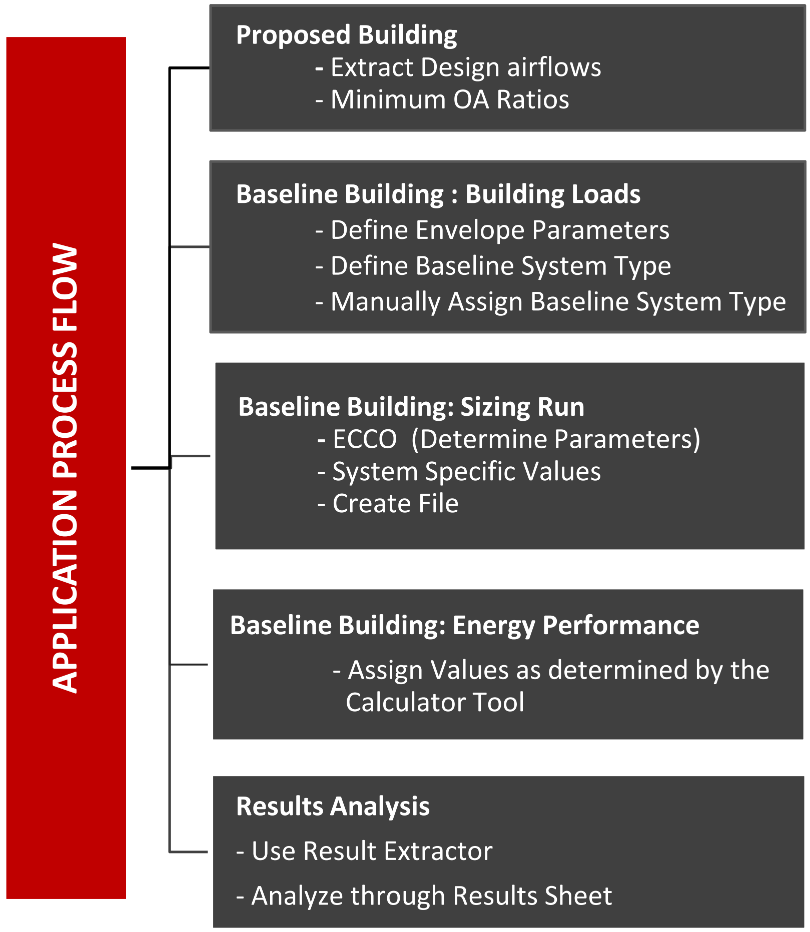

Figure 8: Methodology: Application Process Flow

1.2.1. Proposed Building

1.2.2. Baseline Building : Loads Calculation

1.2.3. Baseline Building: Sizing Runs

1.2.4. Baseline Building : Energy performance

1.2.5. Baseline Building: Results Analysis

The flow diagram below outlines a detail methodology for the Application Process Flow. Each of the five stages are explained in detail in the later sections-

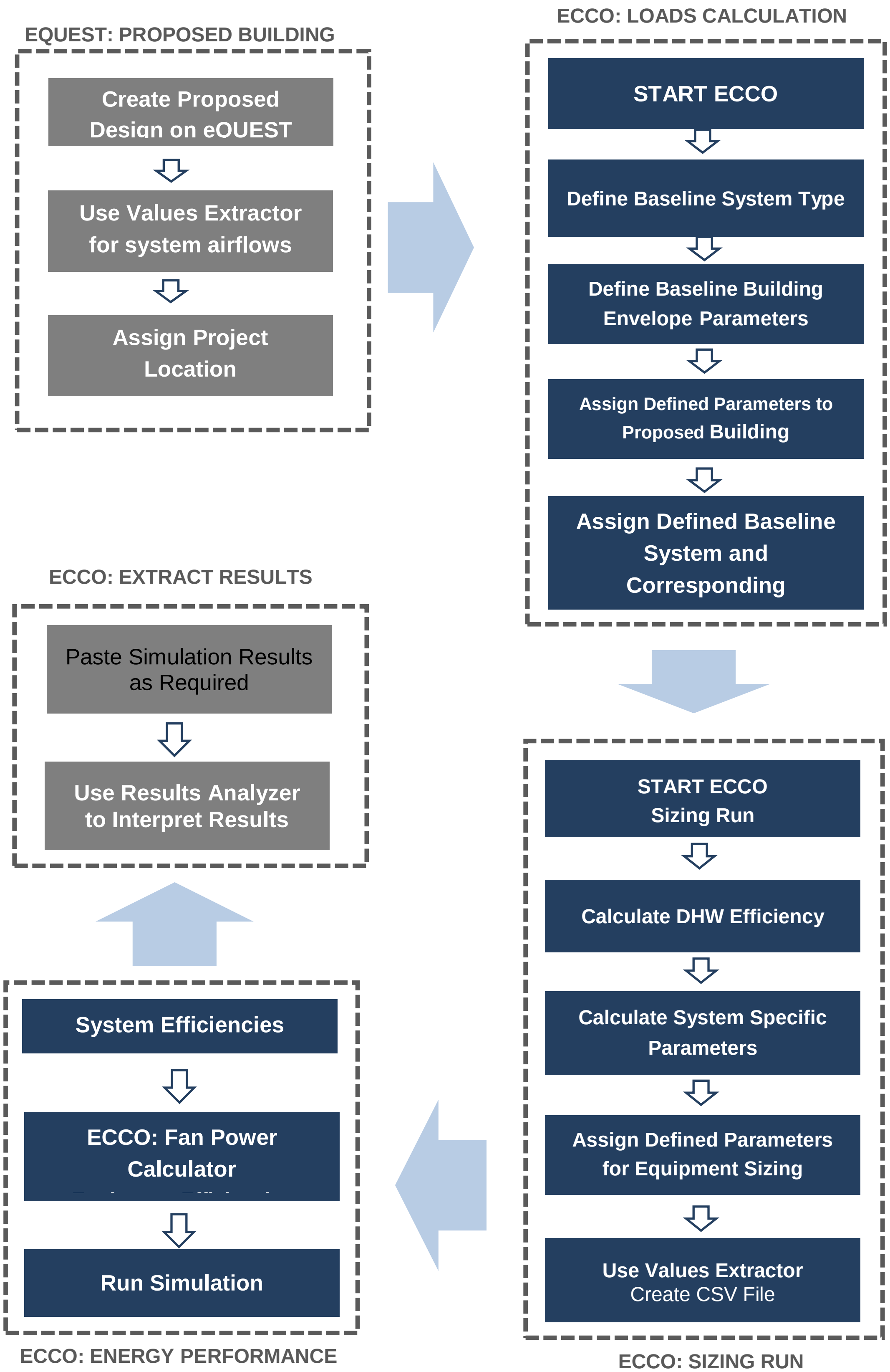

Figure 9: Stages in the Tool Design and Application Process Flow

2.2.1. Proposed Building Design

For Standard 90.1. The "Values Extractor" is used to extract proposed design system details such as design supply flow, system heating and cooling capacity.

For Standard 189.1. For 189.1 analyses, a few parameters have to be defined in the wizard stage and eQUEST and assigned a global parameter. (Please refer to Chapter 2, Appendix G3.1.1.6 lighting, for details.)

2.2.2. Baseline Building : Loads Calculation

The user-forms for each step are defined in Appendix A, along with the user inputs required for each form and the corresponding value calculated. The "Loads Calculation" stage aims at defining the building load components, in terms of the envelope construction, internal loads and infiltration, its corresponding global parameters and their values for the applicable standard.

The table below shows the global parameters defined during this stage. Development Process Flow, Appendix G3.1.1.5, defines the methodology for defining the parameters and Appendix A indicates the user forms used for each step of this process.

Table 78

Baseline Building: Load Calculation Parameters

List side-by-side the runs you want to create from variable values to facilitate data input review				
RUN	yes	yes	yes	yes
Base Filename	Project 47-90-1	Project 47-90-1	Project 47-90-1	Project 47-90-1
Batch Run Label	90.1 -0	90.1 -90	90.1- 180	90.1 -270
Location	Phoenix	Phoenix	Phoenix	Phoenix
PARAMETER SUBSTITUTIONS	yes	yes	yes	yes
Orientation	0	0	0	0
Roof-CI	20	20	20	20
Roof-Absorptance	0.7	0.7	0.7	0.7
R-Eff-Wall	7.2	7.2	7.2	7.2
R-CI-Wall	0.01	0.01	0.01	0.01
EFloor-R	16.2	16.2	16.2	16.2
Door-U-Value	0.7	0.7	0.7	0.7

WWR-Multiplier	0.80	0.80	0.80	0.80
Glass-U-Value	0.75	0.75	0.75	0.75
Glass-SHGC	0.25	0.25	0.25	0.25
LPD	1	1	1	1
Skylight-Multiplier	1	1	1	1
Skylight-UValue	1.9	1.9	1.9	1.9
Skylight-SHGC	0.34	0.34	0.34	0.34

2.2.3. Baseline Building : Sizing Run

The user-forms for each step are defined in Appendix A, along with the user inputs required for each form and the corresponding value calculated. The "Sizing Runs" stage calculates all parameters for sizing of the equipment, air flows, fan control and performance curves and domestic hot water parameters. The following table illustrates the global parameters defined at this stage and their corresponding values.

The user is then required to assign these values and create batch files for all four orientations. The "Values Extractor" is then used to extract all values for air flows, minimum outside air ratio, system sizes and loop loads.

Table 79

Baseline Building: Sizing Runs

List side-by-side the runs you want to create from variable values to facilitate data input review				
RUN	yes	yes	yes	yes
Base Filename	Project 47-90-1	Project 47-90-1	Project 47-90-1	Project 47-90-1
Batch Run Label	90.1 -0	90.1 -90	90.1- 180	90.1 -270
Location	Phoenix	Phoenix	Phoenix	Phoenix
PARAMETER SUBSTITUTIONS	yes	yes	yes	yes
Orientation	0	0	0	0
Roof-CI	20	20	20	20
Roof-Absorptance	0.7	0.7	0.7	0.7
R-Eff-Wall	7.2	7.2	7.2	7.2
R-CI-Wall	0.01	0.01	0.01	0.01
EFloor-R	16.2	16.2	16.2	16.2
Door-U-Value	0.7	0.7	0.7	0.7

WWR-Multiplier	0.80	0.80	0.80	0.80
Glass-U-Value	0.75	0.75	0.75	0.75
Glass-SHGC	0.25	0.25	0.25	0.25
LPD	1	1	1	1
Skylight-Multiplier	1	1	1	1
Skylight-UValue	1.9	1.9	1.9	1.9
Skylight-SHGC	0.34	0.34	0.34	0.34
OA-Control	OA-TEMP	OA-TEMP	OA-TEMP	OA-TEMP
Econo-High-Limit	75	75	75	75
Night-Cycle-Control	CYCLE-ON-ANY	CYCLE-ON-ANY	CYCLE-ON-ANY	CYCLE-ON-ANY
DHW-HIR	1.25	1.25	1.25	1.25
Tank-UA	85.92	85.92	85.92	85.92
System Sizing Ratio	1	1	1	1
Cooling Sizing Ratio	1.15	1.15	1.15	1.15
Min-SAT	55	55	55	55
Zone-Design-T	75	75	75	75
Zone-Heat-Source	HOT-WATER	HOT-WATER	HOT-WATER	HOT-WATER
Reheat-Delta-T	40	40	40	40
SAT-Reset	WARMEST	WARMEST	WARMEST	WARMEST
Max-Reset-Temp	60	60	60	60
CHW-Valve-Type	TWO-WAY	TWO-WAY	TWO-WAY	TWO-WAY
Chiller-Type	ELEC-SCREW	ELEC-SCREW	ELEC-SCREW	ELEC-SCREW
HW-Valve-Type	TWO-WAY	TWO-WAY	TWO-WAY	TWO-WAY
No-Cells	2	2	2	2
HW-Pump-Cap-Ctrl	ONE-SPEED-PUMP	ONE-SPEED-PUMP	ONE-SPEED-PUMP	ONE-SPEED-PUMP
Sec-Pump-Cap-Ctrl	VAR-SPEED-PUMP	VAR-SPEED-PUMP	VAR-SPEED-PUMP	VAR-SPEED-PUMP
HR-Fan-Control	TWO-SPEED-FAN	TWO-SPEED-FAN	TWO-SPEED-FAN	TWO-SPEED-FAN
Cooling-Tower-EIR	0.013	0.013	0.013	0.013
Fan-Control	FAN-EIR-FPLR	FAN-EIR-FPLR	FAN-EIR-FPLR	FAN-EIR-FPLR
VAV-Min-Flow	0.4	0.4	0.4	0.4
Fan-Curve	AppendixG	AppendixG	AppendixG	AppendixG

	Part Load Curve	Part Load Curve	Part Load Curve	Part Load Curve
Heat-Set-T	95	95	95	95

2.2.4. Baseline Building : Energy Performance

The user-forms for each step are defined in Appendix A, along with the user inputs required for each form and the corresponding value calculated. Appendix B explains the “Calculator” tool and the procedure followed for fan power calculations, minimum outside air ratio calculations and system efficiency calculations.

The following table defines the values calculated for each baseline system type. These need to be assigned by the user to the batch files created by ECCO.

Table 80

Baseline Building Energy Performance Parameters

S.No.	Description	Calculation Procedure	Command	Keyword
SYSTEM 3				
1	System: Minimum Outside Air Ratio	Minimum OA Calculator	SYSTEM	MIN-OUTSIDE-AIR
2	Cooling Electric Input Ratio	Fan Power Calculator	SYSTEM	COOLING-EIR
3	Furnace Heat Input Ratio	System 3-Efficiency Calculator	SYSTEM	FURNACE-HIR
4	System Fan Power	Fan Power Calculator	SYSTEM	SUPPLY-KW/FLOW
SYSTEM 4				
1	System: Minimum Outside Air Ratio	Minimum OA Calculator	SYSTEM	MIN-OUTSIDE-AIR
2	Cooling Electric Input Ratio	Fan Power Calculator	SYSTEM	COOLING-EIR
3	Heat Pump Electric Input Ratio	Fan Power Calculator	SYSTEM	HEATING-EIR
4	System Fan Power	Fan Power Calculator	SYSTEM	SUPPLY-KW/FLOW
SYSTEM 5				
1	System: Minimum	Minimum OA	SYSTEM	MIN-

	Outside Air Ratio	Calculator		OUTSIDE-AIR
2	Cooling Electric Input Ratio	Fan Power Calculator	SYSTEM	COOLING-EIR
3	System Fan Power	Fan Power Calculator	SYSTEM	SUPPLY-KW/FLOW
4	Boiler HIR	Boiler Efficiency Calculator	BOILER	HEAT-INPUT-RATIO
5	Boiler Sizing Ratio	Boiler Efficiency Calculator	CIRCULATION-LOOP	SIZING-OPTION
SYSTEM 6				
1	System: Minimum Outside Air Ratio	Minimum OA Calculator	SYSTEM	MIN-OUTSIDE-AIR
2	Cooling Electric Input Ratio	Fan Power Calculator	SYSTEM	COOLING-EIR
3	System Fan Power	Fan Power Calculator	SYSTEM	SUPPLY-KW/FLOW
SYSTEM 7				
1	System: Minimum Outside Air Ratio	Fan Power Calculator	SYSTEM	MIN-OUTSIDE-AIR
2	System Fan Power	Fan Power Calculator	SYSTEM	SUPPLY-KW/FLOW
3	Boiler HIR	Boiler Efficiency Calculator	BOILER	HEAT-INPUT-RATIO
4	Boiler Sizing Ratio	Boiler Efficiency Calculator	CIRCULATION-LOOP	SIZING-OPTION
5	Chiller EIR	Chiller Efficiency Calculator	CHILLER	ELEC-INPUT-RATIO
SYSTEM 8				
1	System: Minimum Outside Air Ratio	Fan Power Calculator	SYSTEM	MIN-OUTSIDE-AIR
2	System Fan Power	Fan Power Calculator	SYSTEM	SUPPLY-KW/FLOW
3	Chiller EIR	Chiller Efficiency Calculator	CHILLER	ELEC-INPUT-RATIO

2.2.5. Baseline Building : Results Analysis

ECCO interprets results and compares the three cases of-

- Proposed Design (or Design)
- Standard 90.1 Baseline Building (or Average)
- Standard 189.1 Baseline Building (or Target)

The values for annual electricity consumption and gas consumption are required to be pasted into the designated field from the ‘EG_MoEU_ED.csv’ file.

2.i. ECCO Results: Concept

a. EnergyStar Target Finder

Target Energy Performance Results (estimated)			
Energy	**Design**	**Target**	**Average Building**
Energy Performance Rating (1-100)	87	100	50
Energy Reduction (%)	42	70	0
Source Energy Use Intensity (kBtu/Sq. Ft./yr)	142	72	243
Site Energy Use Intensity (kBtu/Sq. Ft./yr)	44	23	76
Total Annual Source Energy (kBtu)	4,967,839	2,533,470	8,503,987
Total Annual Site Energy (kBtu)	1,547,809	789,343	2,649,552
Total Annual Energy Cost ($)	$ 43,845	$ 22,360	$ 75,055
Pollution Emissions			
CO2-eq Emissions (metric tons/year)	249	127	426
CO2-eq Emissions Reduction (%)	42%	70%	0%

Facility Information Edit

Office
85281
United States

Facility Characteristics Edit	
Space Type	**Gross Floor Area (Sq. Ft.)**
Office	35,000
Total Gross Floor Area	35,000

* The Average Building is equivalent to an EPA Energy Performance Rating of 50.

Estimated Design Energy Edit			
Energy Source	**Units**	**Estimated Total Annual Energy Use**	**Energy Rate ($/Unit)**
Electricity - Grid Purchase	kWh	427,838	$ 0.100/kWh
Natural Gas	kBtu	88,026	$ 0.012/kBtu

Source: Data adapted from DOE-EIA. See EPA Technical Description.

Figure 10: Results: Energy Star Target Finder

The Energy Star Target Finder analyzes the Design building in comparison to the average and target building. It estimates the energy consumption for the Average and target buildings, on the basis of the internal loads and occupancy pattern of the design building, to enable the user to compare the design building to the average and target.

This concept has been adopted in ECCO as well, to enable the user to benchmark the design building in comparison to the 90.1 baseline and 189.1 baseline.

b. HEED Program

Home Energy Efficient Design, a tool developed by UCLA, is an easy to use tool for analysis of energy use in residences. The results displayed in HEED address the design building, a “Meets Energy Code” case and “More Energy Efficient” case. A similar approach has been adopted by ECCO for the “Average” and Target” buildings.

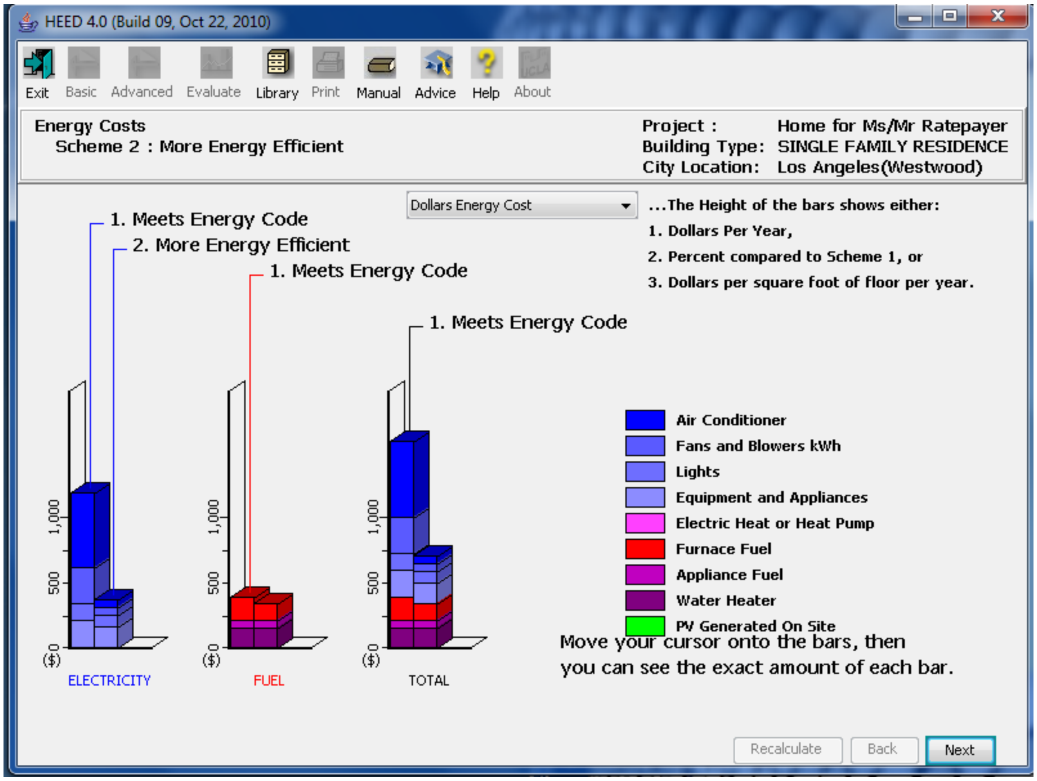

Figure 11. Results: HEED

c. Advanced Energy Design Guides

The “Results” part of ECCO includes design strategies for 30% energy savings over the “Average” to 90.1 2007 baseline building. These have been referenced from the Advanced Energy Design Guides for Small and Medium Offices. (Liu, LcBride, Nall, Colliver, McConahey, & all, 2011)

The purpose of the guides it to inform the user on strategies for energy savings, for end uses such as lighting, heating and cooling.

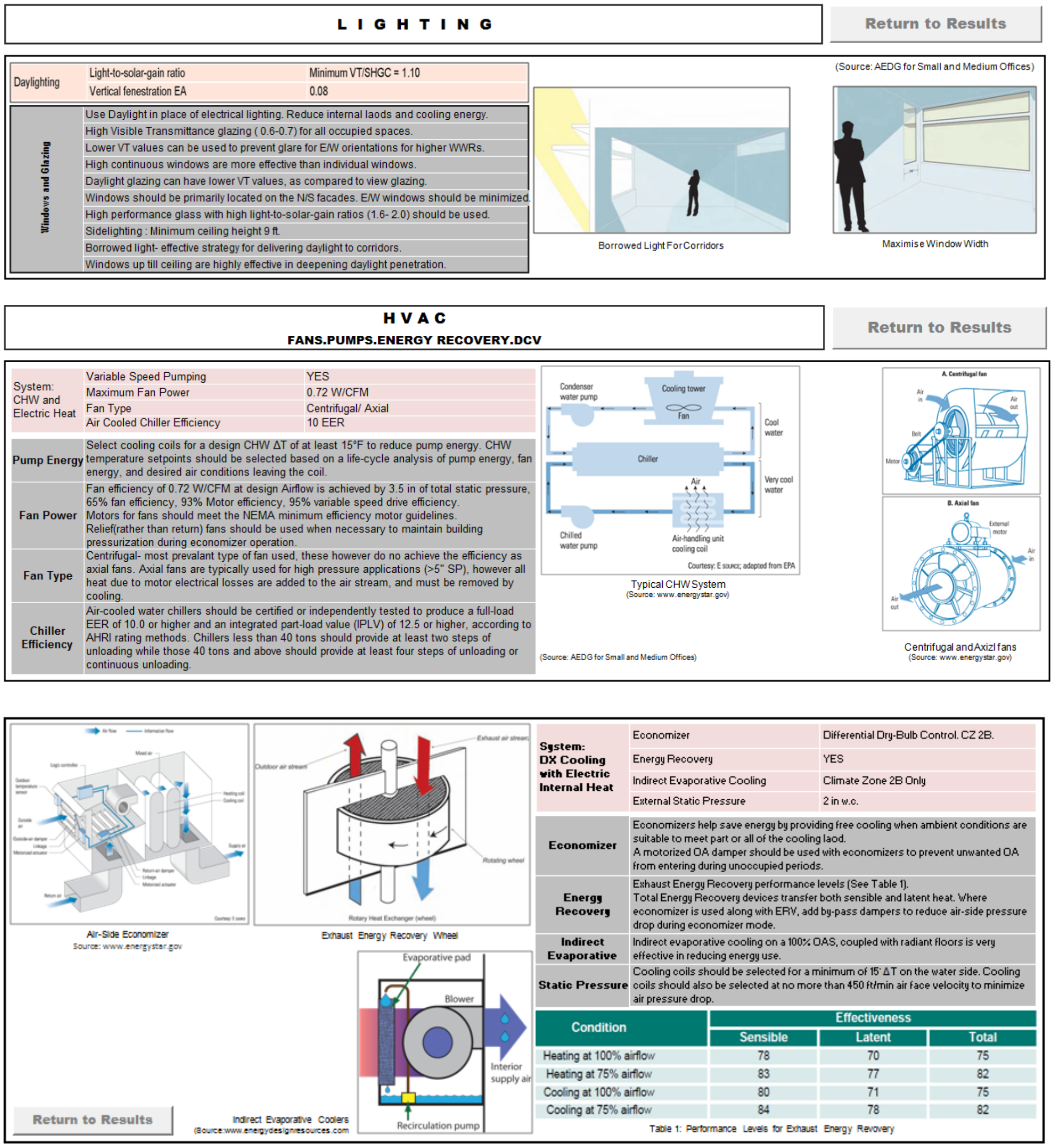

Figure 12: ECCO Design Guides

5.ii. ECCO Results: Display

The Energy Code Compliance Tool combines aspects of both the tools to provide a summary, which assumes 90.1 baseline to the “Average”, 189.1 baseline to be the “Target”. It graphically defines the total electricity consumption, total gas consumption and annual energy use by end use, in a manner similar to HEED. It also then provides suggestions for the “Design” building to reach “Target” building.

The figure below is a snapshot of the results as displayed in ECCO.

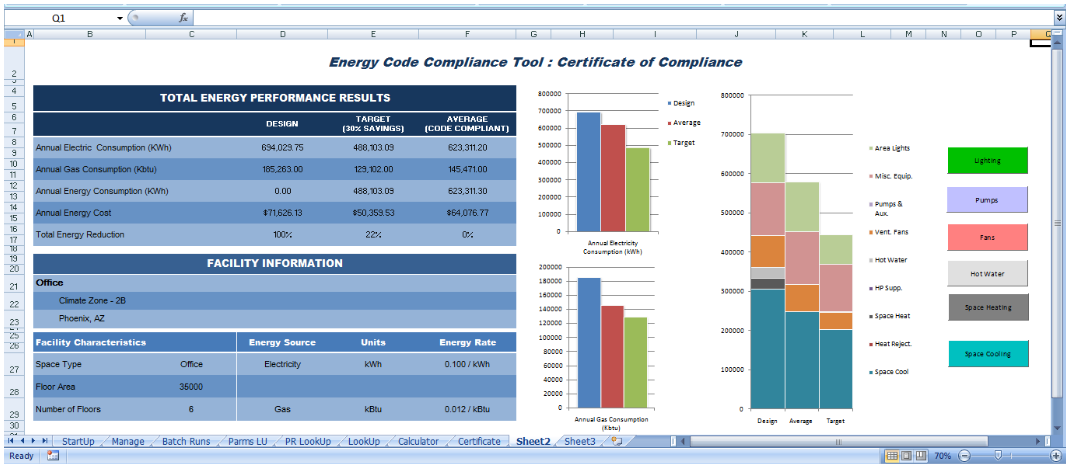

Figure 13. ECCO Results Display

5.iii. Values Extractor

The table below summarizes the reports analyzes and corresponding results extracted.

Table 81

Values Extractor: Reports Analyzed

ECCO : VALUES EXTRACTOR				
Report	**Description**	**Key Descriptor**	**Secondary Descriptor**	**Units**
i. Minimum Outside Air Calculations				
SV-A	System Name	System Design Parameters for	-	-
SV-A	System Supply Airflow	SUPPLY	CAPACITY (CFM)	CFM
SV-A	Minimum Outside Air Ratio	OUTSIDE AIR RATIO	-	-
ii. System Sizing Ratio Calculations				
SV-A	System Cooling Capacity	COOLING CAPACITY (KBTU/HR)	-	KBtu/hr
SV-A	System Heating Capacity	HEATING CAPACITY (KBTU/HR)	-	KBtu/hr
iii. Fan Power Calculations				
SV-A	Supply fan- Internal Static	SUPPLY	STATIC PRESSURE (IN-WATER)	in-w

iv. Circulation Loop Loads				
PS-D	Hot Water Loop Loads	ASHRAE-HW-Loop	PEAK	KBtu/hr
PS-D	Chilled Water Loop Loads	ASHRAE-CHW-Loop	PEAK	KBtu/hr

The Values Extractor creates a CSV file for each project – Proposed, 90.1 Baseline as well as 189.1 Baseline. The user is required to input data, from the CSV file created, as required for calculations during the Energy Performance stage.

Chapter 3

VALIDATION OF THE TOOL

ECCO has been validated for accuracy through comparison with the 90.1 Ruleset in eQUEST as well as simulations using the DOE Reference Buildings, to compare the Energy Use Intensities (EUI) of the simulated building, against the same as defined by NREL. (Long, Bonnema, & Field, July 2010)

3.1. eQUEST 90.1 Ruleset

The tool has been validated for accuracy against the 90.1 Ruleset in eQUEST. The following are the values it has been analyzed for-

1. System 3: Cooling EIR and Furnace HIR
2. System 4: Cooling EIR and Heat Pump Electric Input Ratio
3. System 5: Cooling Electric Input Ratio and Boiler Heat Input Ratio
4. System 7: Supply fan power, Boiler HIR and Chiller Electric Input Ratio

Table 82

Validation of ECCO

System Type	System Name	eQUEST 90.1 Ruleset Value	ECCO Value
PSZ-AC	Cool Electric Input Ratio		
	PSZ- Air Conditioner	0.3457	0.3300
	Furnace Heat Input Ratio		
	PSZ- Air Conditioner	1.2407	1.25
PSZ-HP	Cool Electric Input Ratio		
	PSZ- Heat Pump	0.3457	0.3300
	Heat Electric Input Ratio		
	PSZ-Heat Pump	0.3164	0.3097
PVAV- with REHEAT	Cool Electric Input Ratio		
	System 1	0.3600	0.3598
	Boiler		
	Boiler Heat Input Ratio	1.2407	1.2500
VAV with REHEAT	Supply Fan Power		
	Sys1 (VAVS) (G)	0.00109 KW/CFM	0.00098 KW/CFM

	Boiler Efficiency		
	Boiler	1.253	1.25
	Chiller Efficiency		
	Chiller	0.202	0.1639

ECCO calculated values match up with the eQUEST 90.1 Ruleset values for system efficiency and fan power calculations.

3.2. DOE Reference Buildings

The Energy Code COmpliance Tool has been analyzed with two sample runs based on DOE Reference Building. (Deru, et al., 2011) (Huang & Gowri, 2011) The DOE Reference Buildings represent reasonably realistic building characteristics and construction practices. These serve as starting points for energy efficiency research and have been referenced for the definition of the "Proposed Design" parameters and characteristics.

The DOE Reference Buildings define 15 commercial building types and one multifamily residential building, developed as a consensus between the DOE, the National renewable Energy Laboratory, Pacific Northwest National Laboratory, and Lawrence Berkeley National Laboratory. These buildings represent approximately two-thirds of the commercial building stock.

The new construction version of the reference buildings has been utilized to define the proposed design. This defines the building geometry, construction assemblies and U-Values, operation schedules, HVAC parameters, controls and efficiencies. The new construction model requirements comply to the minimum requirements of 90.1 2004. ASHRAE 90.1 2004 has been referred to for equipment efficiencies, fan power calculation procedure, sizing ratios etc.

3.2.1. Medium Office

The following table outlines the building characteristics and simulation inputs for the cases.

i. Proposed Design - Based on DOE Reference Buildings for New Construction and ASHRAE 90.1 2004.

ii. Average Building- Based on 90.1 2007 Performance Rating Method.

iii. Target Building- Based on 189.1 2009 Performance Rating Method.

Table 83

Medium Office Parameters

S.No.	Description	Proposed Design	90.1 2007	189.1 2009 Baseline
General				
1	Building Prototype	Medium Office	Medium Office	Medium Office
2	Total Floor Area	53,600	53,600	53,600
3	Building Shape	Rectangle	Rectangle	Rectangle
4	Aspect Ratio	1.5	1.5	1.5
5	Number of Floors	3	3	3
6	Window Fraction	33%	33%	33%
7	Shading Geometry	None	None	None
8	Thermal Zoning	Perimeter Zone Depth: 15ft Each floor has 4 perimeter zones and one core zone.	Perimeter Zone Depth: 15ft Each floor has 4 perimeter zones and one core zone.	Perimeter Zone Depth: 15ft Each floor has 4 perimeter zones and one core zone.
9	Floor to Floor Height	13	13	13
10	Floor to Ceiling Height (ft)	9	9	9
Construction Assemble Type				
1	Exterior Wall Construction	Steel Frame	Steel Frame	Steel Frame
2	Roof Construction	Insulation Entirely Above Deck	Insulation Entirely Above Deck	Insulation Entirely Above Deck
3	Foundation	8" Slab-on-Grade (Unheated)	8" Slab-on-Grade (Unheated)	8" Slab-on-Grade (Unheated)
4	Interior Partitions	2 X 4 Uninsulated Stud Wall	2 X 4 Uninsulated Stud Wall	2 X 4 Uninsulated Stud Wall
Construction - U-Values				
1	Wall U Value	U = 0.124	U = 0.124	U = 0.077

		(R-13 Batt)	(R-13 Batt)	(R-13 Batt + R-5 ci)
2	Roof U-Value	U = 0.063 (R-15)	U = 0.048 (R-20)	U = 0.039 (R-25)
3	Unheated Slab on Grade (8")	U = 0.052 (R-19)	U = 0.052 (R-19)	U = 0.038 (R-30)
4	Window U-Value	1.22	0.75	0.75
5	Window SHGC	0.25	0.25	0.25
Internal Loads				
1	Interior LPD	Table 9.5.1. - Office	1	0.9
2	Exterior LPD	Not Analyzed	Not Analyzed	Not Analyzed
3	Infiltration	0.0454 CFM/sq.ft	Same as Proposed	25% Reduction over 90.1 Value
4	Equipment Loads	Building Average 0.76	Same as Proposed	10% Reduction over 90.1 Value
5	Occupancy	100 Sqft/ person	Same as Proposed	Same as Proposed
6	Occupancy Sensors	NO	NO	YES- 10% Reduction over LPD
7	Daylighting	NO	NO	YES (40 fc. 30% light, 30% Power)
HVAC				
1	System Type	PVAV	PVAV	PVAV
2	Heating System	HW- Gas Boiler	HW- Gas Boiler	HW- Gas Boiler
3	Cooling System	DX Coils	DX Coils	DX Coils
4	Equipment Efficiencies	90.1 2004	90.1 2007	189.1 2009
5	Distribution and Terminal Units	VAV Terminal Box	VAV Terminal	VAV Terminal
HVAC Control				
1	Thermostat Setpoint	75F Cooling/ 72F Heating	Same as Proposed	Same as Proposed
2	Thermostat Setback	80F Cooling/60 F Heating	Same as Proposed	Same as Proposed
3	Supply Air Temperature	Maximum 110F, Minimum 52F	Same as Proposed	Same as Proposed
4	Ventilation	20 CFM/Person	Same as Proposed	Same as Proposed
5	Demand Control	No	Same as	Same as

	Ventilation		Proposed	Proposed
6	Energy Recovery	No	Same as Proposed	Same as Proposed
Supply Fan				
1	Fan Type	Variable Air Volume	Variable Air Volume	Variable Air Volume
2	Supply Fan Power	Calculated based on supply CFM and Fan Static	Calculated based on supply CFM and Fan Static	Calculated based on supply CFM and Fan Static
3	Supply Fan DT			
Service Water Heating				
1	SWH Type	Storage Tank	Storage Tank	Storage Tank
2	Fuel Type	Natural Gas	Natural Gas	Natural Gas
3	Thermal Efficiency	80%	90.1 2007	189.1 2009
4	Tank Volume	260 Gallons	Same as Proposed	10% Reduction over 90.1 Value
5	Water Temperature Setpoint	120F	Same as Proposed	Same as Proposed

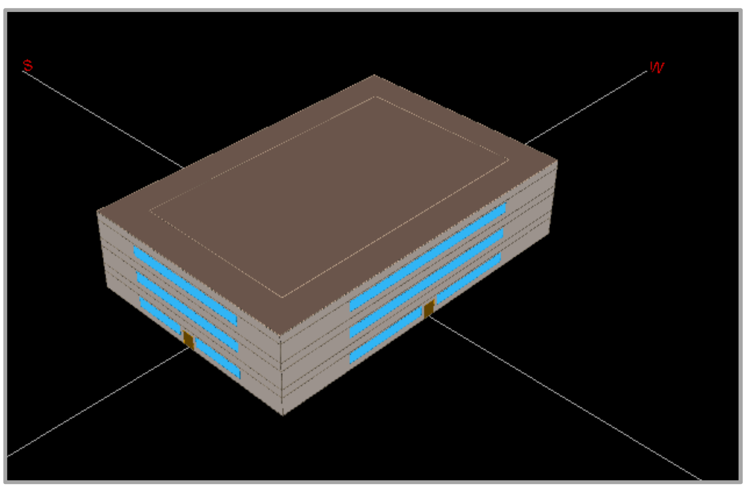

Figure 14: eQUEST: Medium Office

Analysis: Building Loads. Analysis has been carried out for both building loads and building energy. The graph below indicates the peak building cooling load components (KBTU/h) for the medium office building. Each of these components has then been analyzed for their requirement in the standard as well as the corresponding effect with building loads.

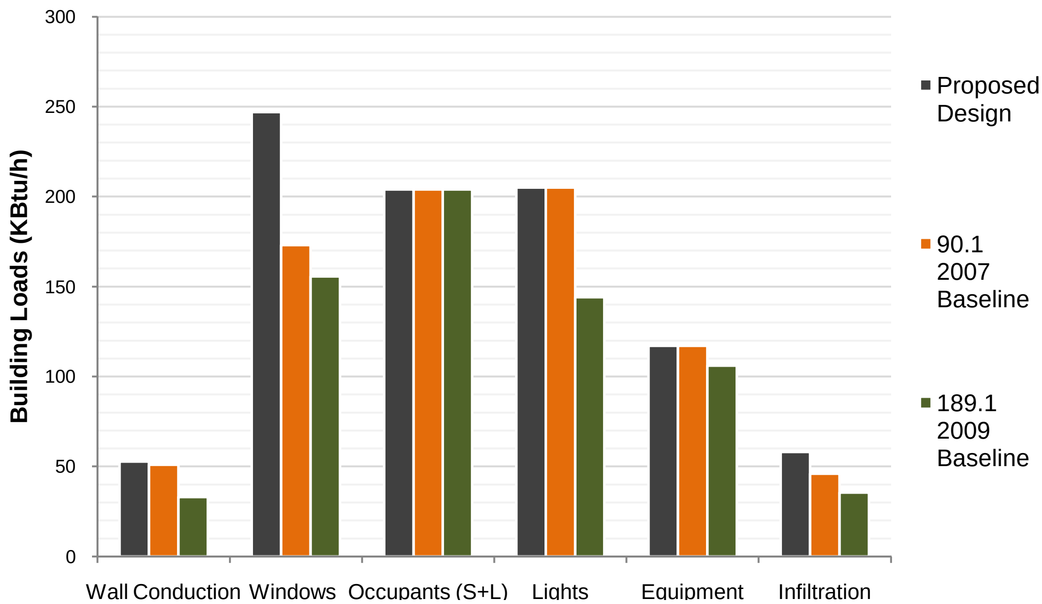

Figure 15: Analysis of Standard 90.1 and 189.1 for Building Load Components

Wall Conduction. Significant reduction in conduction through wall which is primarily due to the additional requirement of R-5 continuous insulation in 189.1

Windows. Glass properties (U-Value and SHGC) are essentially the same in both the Standards. Reduction in heat gain through windows is primarily due to the requirement for external shading; hence this reduction is in the direct solar heat gain as against the conduction heat gain component.

Occupant Loads. Remain the same as these are modeled same as the proposed design

Lighting. Use of daylight sensors, occupancy sensors, and lower lighting power density in 189.1 reduces lighting loads by over 25%.

Equipment. Higher efficiency equipment reduces the equipment power density by 10% in 189.1. (Long, Bonnema, & Field, July 2010)

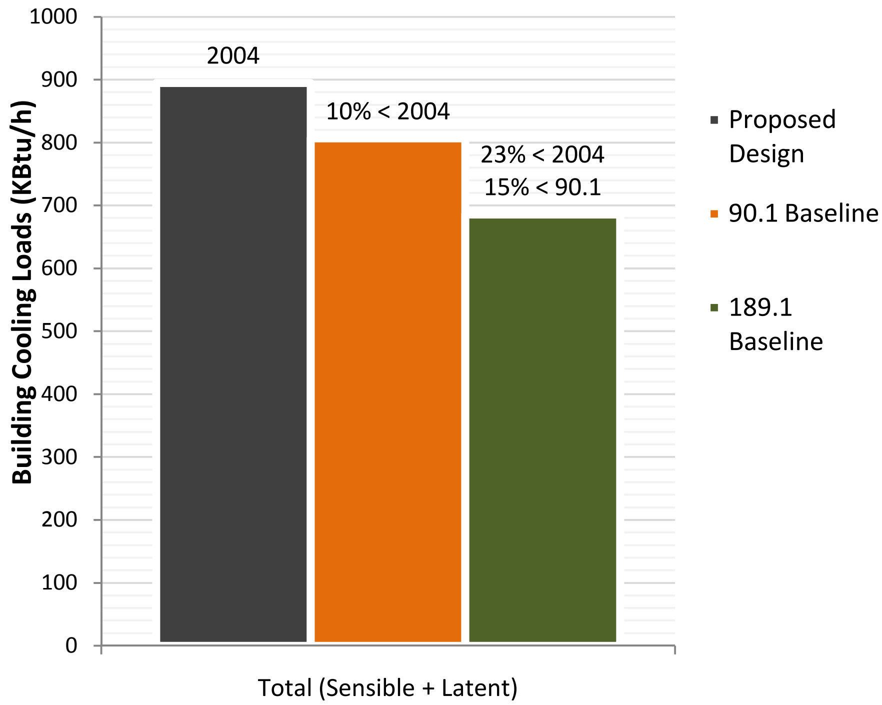

Figure 16: Analysis of 90.1 and 189.1 for Building Cooling Loads

Analysis: Building Energy. Compliance to Standard 189.1 results in 30% more energy savings, 20% through energy efficiency measures and 10% through renewable energy sources. Standard 189.1 requires 4 KBTU/sq.ft/yr to be provided through renewable energy sources and hence building types like offices see greater savings due to lower EUI (40- 50 KBTU/sq.ft/yr) as compared to buildings with higher EUI. It is for this reason that unregulated loads such as equipment loads and process loads become more crucial to a buildings energy consumption and the need for regulation of the same becomes important.

The graph below indicates the annual electricity consumption and annual gas consumption for all three cases (design, average and target). The total energy consumption is then broken down to the various end-uses in the following graph, for further analysis.

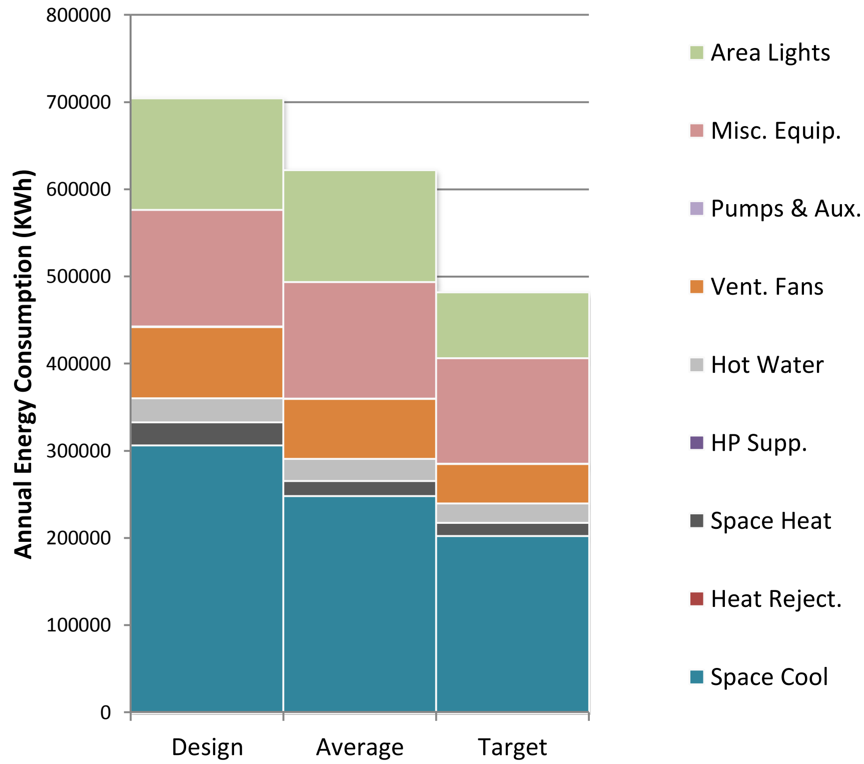

Figure 17: Medium Office: Annual Energy Consumption by End Use (KWH)

Standard 189.1 significantly reduces building loads resulting in corresponding reduction in lighting energy and space cooling. However, this reduction in internal loads might result in a penalty in space heating for larger buildings. Space heating constitutes an insignificant portion of annual energy use for Climate Zone 2B, hence the increase in this end use component might be negligible. A large office building has been analyzed in the next section.

3.2.2. Large Office

The following table outlines the building characteristics and simulation inputs for the 3 cases (Leach, Lobato, Hirsch, Pless, & Torcellini, 2010)

- Proposed Design

  Based on DOE Reference Buildings for New Construction and ASHRAE 90.1 2004.

- Average Building

  Based on 90.1 2007 Performance Rating Method.

- Target Building

Based on 189.1 2009 Performance Rating Method.

Table 84

Large Office Parameters

Description	Proposed Building	90.1 2007 Baseline	189.1 2009 Baseline
General			
Building Prototype	Large Office	Large Office	Large Office
Total Floor Area	498,588	498,588	498,588
Building Shape	Rectangle	Rectangle	Rectangle
Aspect Ratio	1.5	1.5	1.5
Number of Floors	12 (Basement Not Considered)	12 (Basement Not Considered)	12 (Basement Not Considered)
Window Fraction	38%	38%	38%
Shading Geometry	None	None	Projection Factor = 0.5
Thermal Zoning	Perimeter Zone Depth: 15ft	Perimeter Zone Depth: 15ft	Perimeter Zone Depth: 15ft
Floor to Floor Height (ft)	13	13	13
Floor to Ceiling Height (ft)	9	9	9
Construction Assemble Type			
Exterior Wall Construction	Mass	Steel Frame	Steel Frame
Roof Construction	Insulation Entirely Above Deck	Insulation Entirely Above Deck	Insulation Entirely Above Deck
Foundation	8" Slab-on-Grade (Unheated)	8" Slab-on-Grade (Unheated)	8" Slab-on-Grade (Unheated)
Interior Partitions	2 X 4 Uninsulated Stud Wall	2 X 4 Uninsulated Stud Wall	2 X 4 Uninsulated Stud Wall
Construction - U-Values			
Wall U Value	0.58	U = 0.124 (R-13 Batt)	U = 0.077 (R-13 Batt + R-5 ci)
Roof U-Value	0.034 (R-18)	U = 0.048 (R-20)	U = 0.039 (R-25)
Unheated Slab on	U = 0.052	U = 0.052	U = 0.038

Grade (8")	(R-19)	(R-19)	(R-30)
Window U-Value	1.22	0.75	0.75
Window SHGC	0.25	0.25	0.25
Internal Loads			
Interior LPD	Table 9.5.1. - Office	90.1 2007 Building Area Method	10% Less 90.1
Exterior LPD	Not Analyzed	Not Analyzed	Not Analyzed
Infiltration	0.0454 CFM/sf.	0.0363 CFM/sq.ft	25% less than 90.1 2007 value
Equipment Loads	Building Average 0.75 W/sq.ft	Building Average 0.75 W/sq.ft	10% less than 90.1 2007
Occupancy	200 People/1000 sq.ft	200 People/1000 sq.ft	200 People/1000 sq.ft
Daylighting	NO	NO	YES 40 fc. 30% light, 30% Power
HVAC			
System Type	PVAV	PVAV	PVAV
Heating System	Boiler	Boiler	Boiler
Cooling System	Chiller	Chiller	Chiller
Equipment Efficiencies	90.1 2004	90.1 2007	189.1 2009
Distribution and Terminal Units	Standard VAV terminal Box	Standard VAV terminal Box	Standard VAV terminal Box

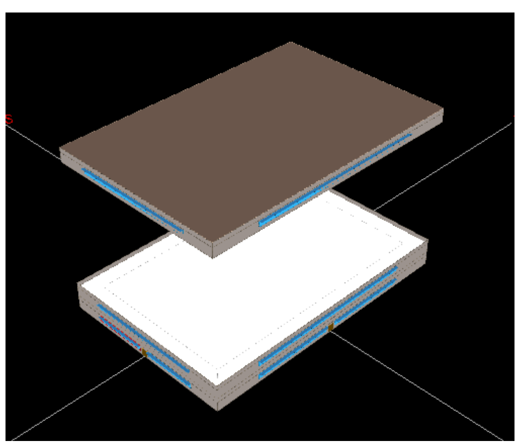

Figure 18: eQUEST Large Office- 189.1 2009

Analysis: Building Loads

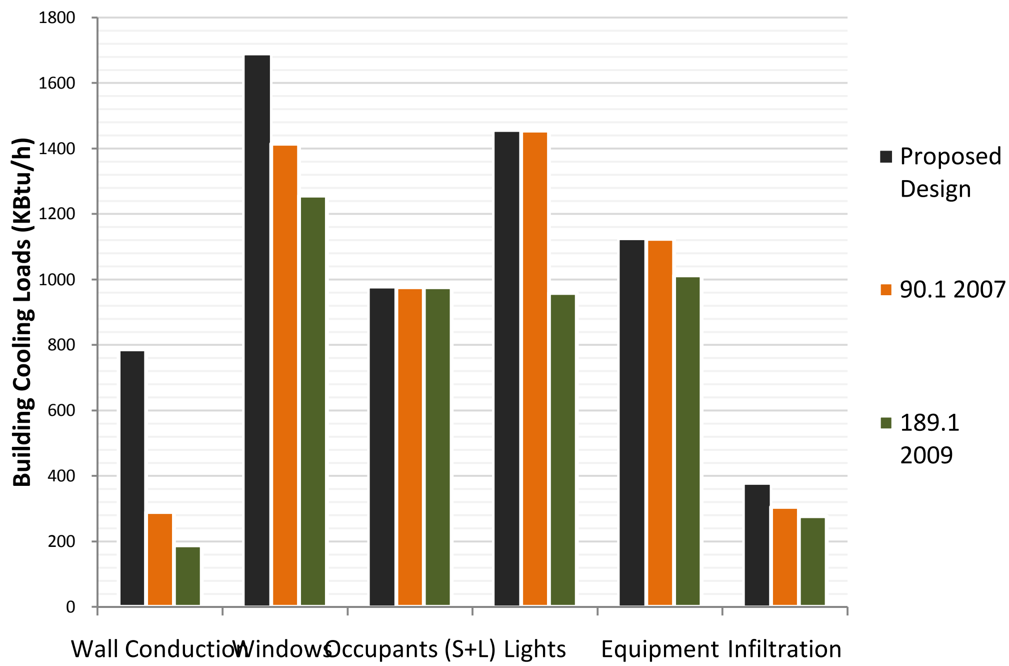

Figure 19: Large Office: Building Loads

- **Wall Conduction:** DOE reference building for large offices has mass wall construction and hence significant reduction is observed in wall conduction loads from the proposed design to 90.1. R-5 CI accounts for the reduction from 90.1 to 189.1
- All other trends are for similar reasons as observed in the medium office building.

Analysis: Building Energy. The building peakloads in a large office building, are dominated more by internal loads than envelope loads. Hence, compliance to Standard 189.1 results in an increase in heating energy, as a reduction in internal loads results in an increase in the space heating requirements. Space heating forms a negligible part of the annual energy consumption for climate zone 2B, however this might be a significant increase for heating dominated climates.

Building envelope plays a smaller role as compared to internal loads and the large extend of decrease in lighting loads and equipment loads is translated into savings in space cooling, but penalty for space heating. For Climate Zone 2B, where space heating is a small component of the total energy use, this is not too significant an increase; however this might not be the case for colder climates.

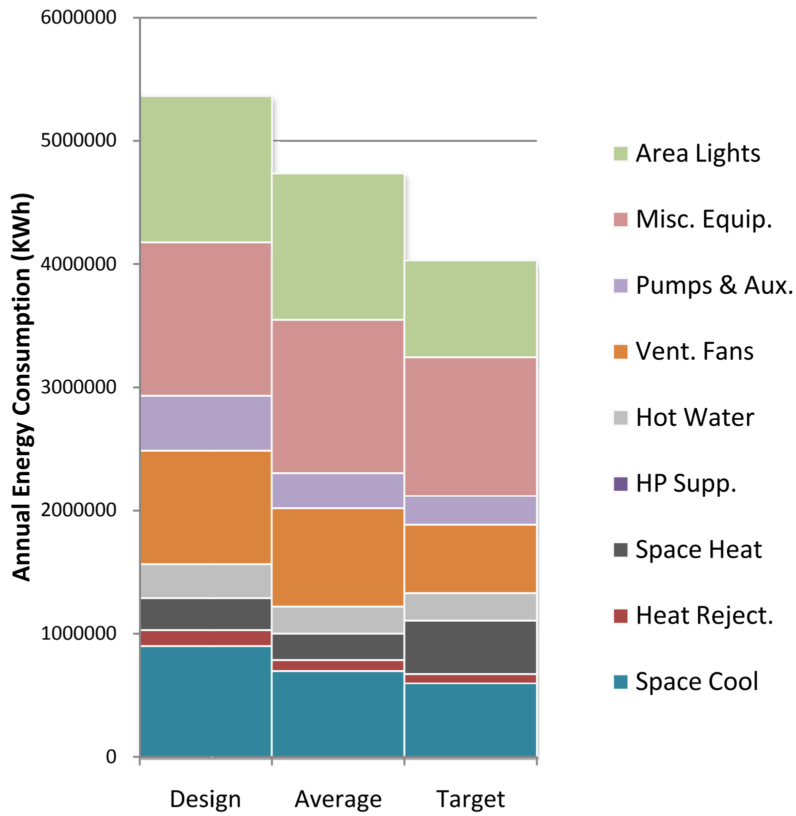

Figure 20: Large Office: Annual Energy Consumption by End-Use

The following table summarizes the Energy use Intensities (EUI) for the two prototype buildings analyzed. These are compared to the values from the NREL analysis of Standard 189.1. (Deru, et al., 2011) (Long, Bonnema, & Field, July 2010)

Table 85

Energy Use Intensities (KBTU/sq.ft) for Medium and Large Office Buildings

Energy Use Intensities (KBTU/sq.ft/Yr)						
DOE Reference Building Type	90.1 2004		90.1 2007		189.1 2009	
	NREL	ECCO	NREL	ECCO	NREL	ECCO
Medium Office	47	47.64	45	42.39	31	29.4
Large Office	37	36.71	33	32.41	23	21.97

Chapter 5

CONCLUSIONS

Code Analysis: Standard 90.1 Vs. 189.1

Standard 189.1-2009 goes much further in terms of energy savings over Standard 90.1-2007. Two third of the energy savings are from energy efficiency measures, and one third (4 KBTU/sq.ft/yr) from renewables. This is specifically true for office buildings with low energy use intensities (40-50 KBTU/sq.ft/yr).

Standard 189.1 significantly reduces building loads, through a more efficient and tighter envelope and reduced lighting and equipment loads. It is for this reason that other “process” loads become more critical to a buildings energy use.

Standard 189.1 is more focused towards heating dominated climates rather than cooling dominated climates. Savings in cooling energy are more due to reduction in building loads rather than improvements to cooling equipment efficiency requirements. However, boiler efficiency requirements have been significantly improved and hence this standard might show more savings (greater than 30%) in heating dominated climate zones.

ECCO- a Proof of Concept

This thesis provides an easier approach to code compliance in the form of a tool which can guide decision making process during design as well as code development. The intention of this thesis is not to provide a final and accurate means for energy calculations and code compliance, but a process for initial analysis and understanding of building energy use, which can be further developed for greater accuracy and functions.

If taken further, this tool would first need to be refined to minimize user intervention at all the stages. This would require excellent programming skills as well as extensive understanding of the energy simulation software. This tool can also be developed for EnergyPlus, incorporating macros for system and equipment definitions. This can then be taken further to incorporate all climate zones, energy standards and maybe even state energy codes, to provide jurisdictions with an easy to use interface applicable to their particular requiremnets.

Potential Applications

If developed further , ECCO opens up a wide array of possibilities. It can be used by jurisdictions as a preliminary tool to check for code compliance for LEED submittals. As COM*check* is used to analyze for prescriptive requirements, this tool can be used as a front end diagnostic to check for compliance with the performance requirements.

Another possible segment of users could be architects with minimal knowledge of energy simulation and engineers looking for a quick and acceptably accurate solution for code compliance and energy analysis.

This approach opens up wide possibilities of developing this for all codes and standards, climate zones and building types. With a relatively simple and easy to understand interface, the Energy Code COmpliance tool provides an appropriate solution to code compliance and design for energy efficiency.

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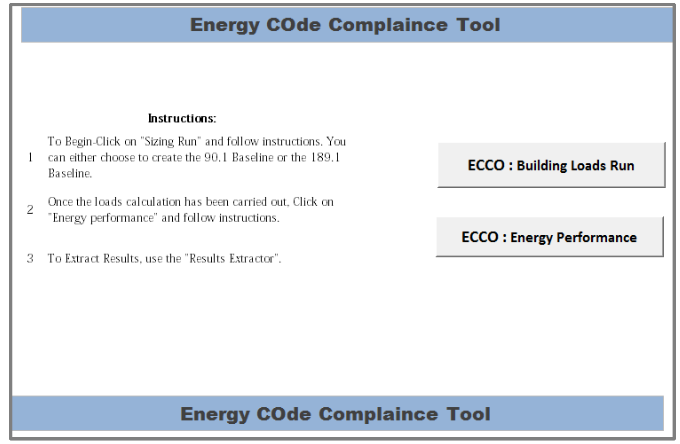
APPENDIX A

USER-FORM DETAILS

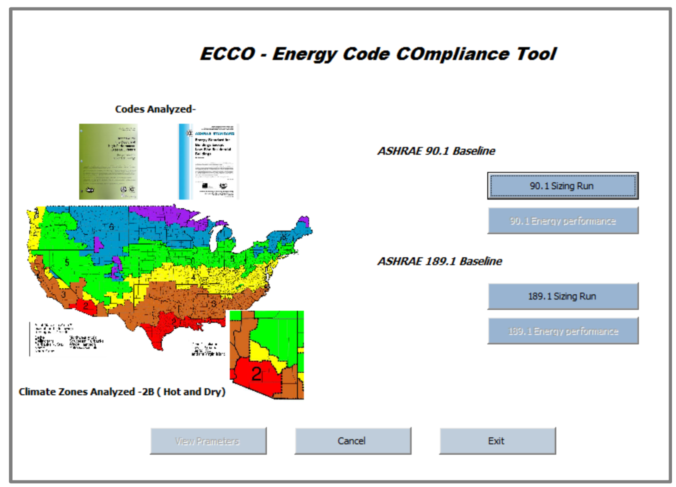
This Appendix lists the user-forms created as well as the function of each. User-forms and the corresponding global parameters have been enlisted for each of the stages discussed in the Application Process Flow.

A.1. Stage 2- Baseline Building : Loads Calculation

Form	Start Up Screen
Stage	Load Calculations
Code	90.1 and 189.1
Purpose of User-Form	General instructions on the purpose and use of tool.
User Inputs Required	Command: To begin Calculation
Values Calculated	The Standard for which Baseline building has to be generated.

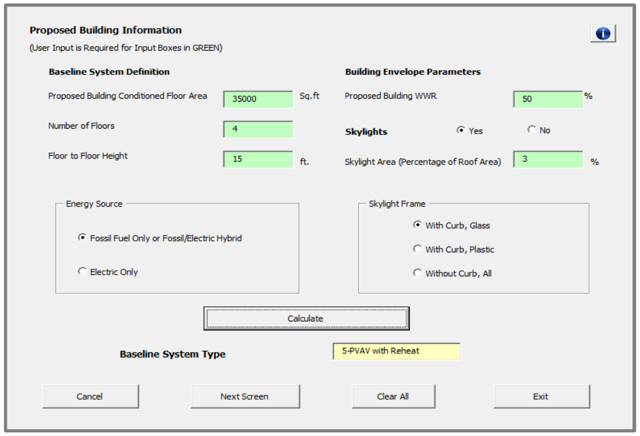


Form	Code Compliance
Stage	Load Calculations
Code	90.1 and 189.1
Purpose of User-Form	Informs user of Standards and climate zone being analyzed.
User Inputs Required	Selection of Standard for compliance Selection of Stage of Analysis: Loads Calculation/Energy Performance.
Values Calculated	Assigns values in accordance to the standard selected.



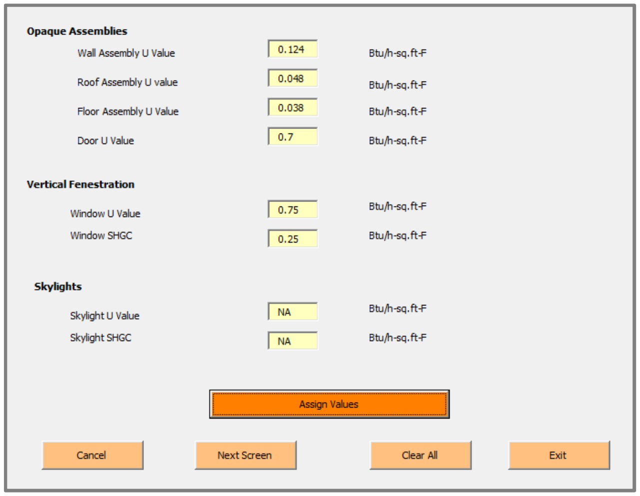
2.i. Define Baseline System Type

Form	General Building Details
Stage	Load Calculations
Code	90.1 and 189.1
Purpose of User-Form	To determine baseline system type on the basis of a few required user-inputs. To determine skylight properties if present in the proposed model.
User Inputs Required	- Proposed Design- Building Area - Proposed Design- Number of Floors - Proposed Design- Floor to Floor Height - Proposed Design- Heating Fuel Type
Values Calculated	- Baseline System Type Skylight U-Value and SHGC



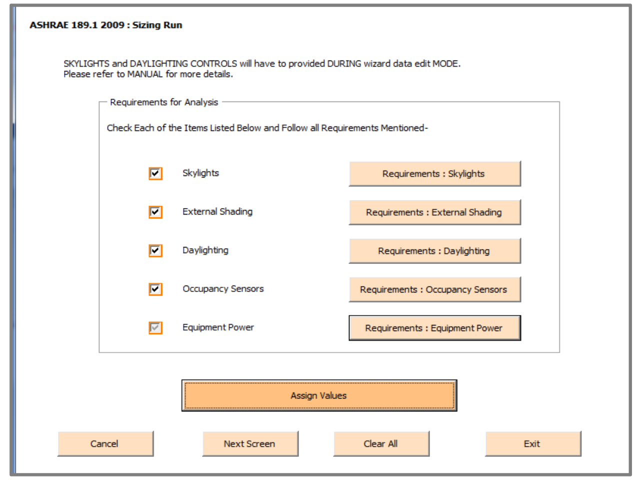
2.ii. Define Envelope Parameters

Form	Building Envelope Parameters
Stage	Load Calculations
Code	90.1 and 189.1
Purpose of User-Form	Identifies envelope parameters and code compliant values for - - Opaque Assemblies - Vertical Fenestration- Skylights
User Inputs Required	None
Values Calculated	Building Envelope Parameters Wall Window Ratios Skylight-Roof-Ratio (If Applicable

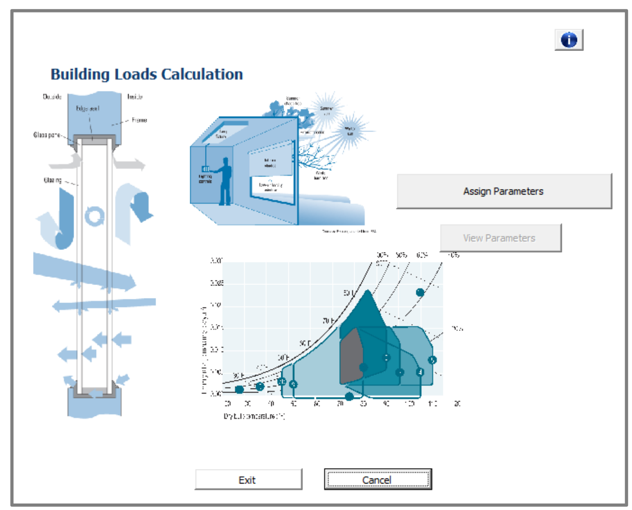


2. ii. Define Envelope and Internal Load Parameters: 189.1

Form	Envelope and Internal Loads
Stage	Load Calculations
Code	189.1
Purpose of User-Form	Identifies additional envelope parameters and code compliant values for Standard 189.1 - Skylights, External Shading, Occupancy Sensors, Daylight Sensors
User Inputs Required	None
Values Calculated	Skylight area, U Value and SHGC - Depth of Overhangs - Reduction in LPD - Presence of Daylight Sensors

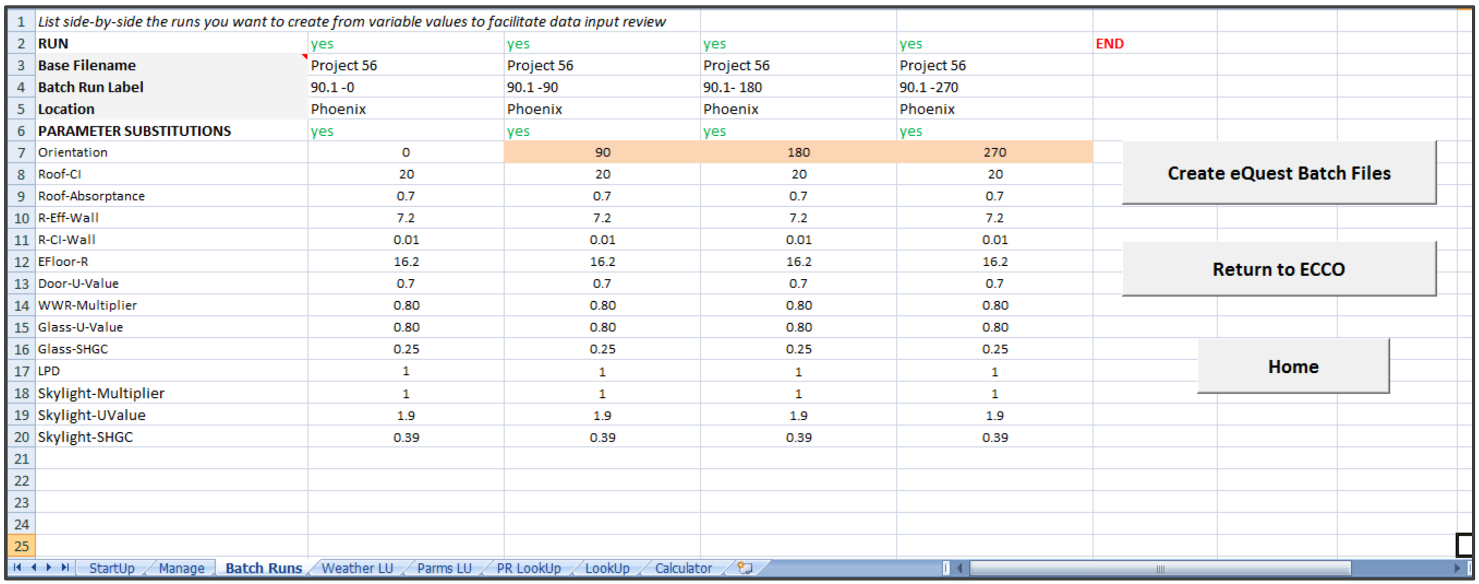


Form	Building Loads Calculation
Stage	Load Calculations
Code	90.1 and 189.1
Purpose of User-Form	View and Assign Global Parameters for Loads Calculation Modify Input file as defined by the 90.1 Loads Calculator manual/ 189.1 Loads Calculator Manual. Assign Baseline System Assign System Specific Parameters
User Inputs Required	None
Values Calculated	Global parameters to be assigned



2.iii. Assign Global Parameters (ASHRAE 90.1 2007)

1. “Assign Parameters” – Assigns values to the various global parameters as defined in the previous screens.
2. “View Parameters” – Takes the user to the “Batch Runs” tab, which contains all parameters defined for building loads calculation.
3. User is required to assign these parameters in accordance to the “ECCO Manual” as well as baseline system in accordance to table below and specify file name in “Base Filename”
4. Click on “Create eQUEST Batch Files”



List side-by-side the runs you want to create from variable values to facilitate data input review					
RUN	yes	yes	yes	yes	END
Base Filename	Project 56	Project 56	Project 56	Project 56	
Batch Run Label	90.1 -0	90.1 -90	90.1- 180	90.1 -270	
Location	Phoenix	Phoenix	Phoenix	Phoenix	
PARAMETER SUBSTITUTIONS	yes	yes	yes	yes	
Orientation	0	90	180	270	
Roof-CI	20	20	20	20	
Roof-Absorptance	0.7	0.7	0.7	0.7	
R-Eff-Wall	7.2	7.2	7.2	7.2	
R-CI-Wall	0.01	0.01	0.01	0.01	
EFloor-R	16.2	16.2	16.2	16.2	
Door-U-Value	0.7	0.7	0.7	0.7	
WWR-Multiplier	0.80	0.80	0.80	0.80	
Glass-U-Value	0.80	0.80	0.80	0.80	
Glass-SHGC	0.25	0.25	0.25	0.25	
LPD	1	1	1	1	
Skylight-Multiplier	1	1	1	1	
Skylight-UValue	1.9	1.9	1.9	1.9	
Skylight-SHGC	0.39	0.39	0.39	0.39	

Figure 21: Loads Calculation: Assign Global Parameters

2.iv. Create eQUEST Batch Files

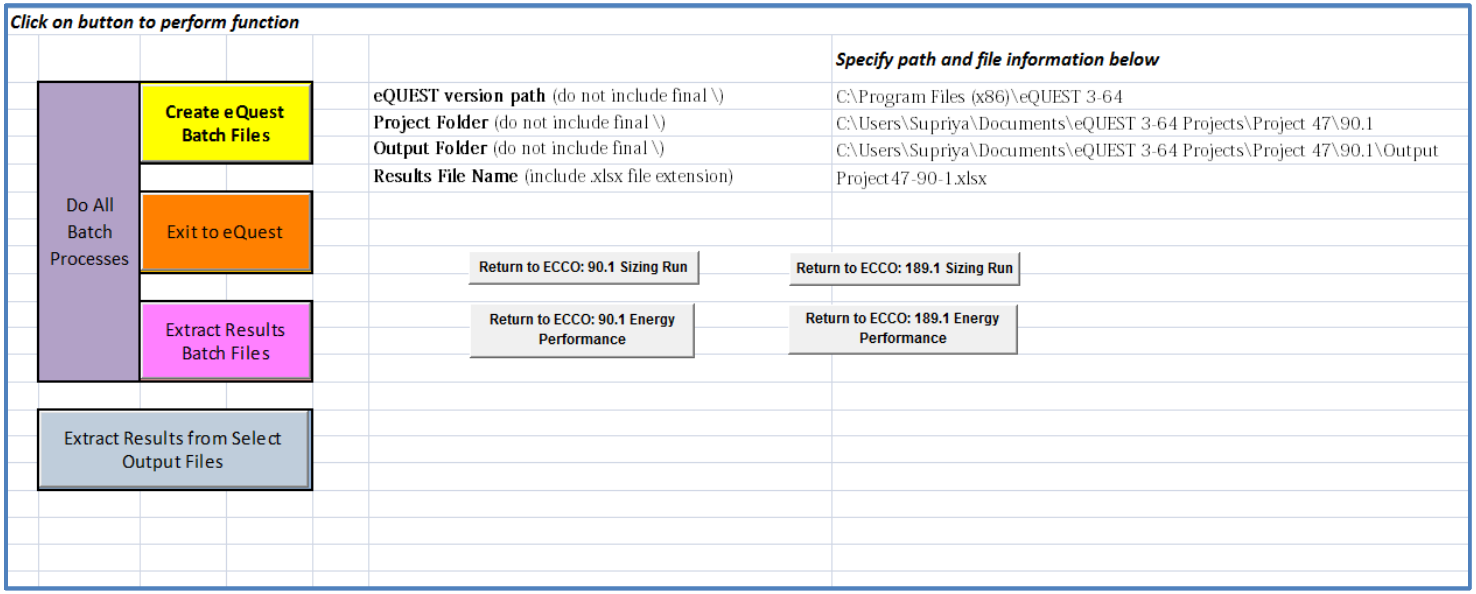


Figure 22: Loads Calculation: Create eQUEST Batch Files

User Inputs Required-

a. Enter eQUEST Version Path
b. Enter Project Folder
c. Create and Input Output folder location
d. Name Results file (.xlsx)
e. Click on “Create eQUEST Batch File

2.v. Assign Baseline System Type

a. Assign System Type as defined by ECCO

b. Refer to table below for other required values

c. Assign the required values as defined below.

Table 86:

Requirements for Baseline System Assignment

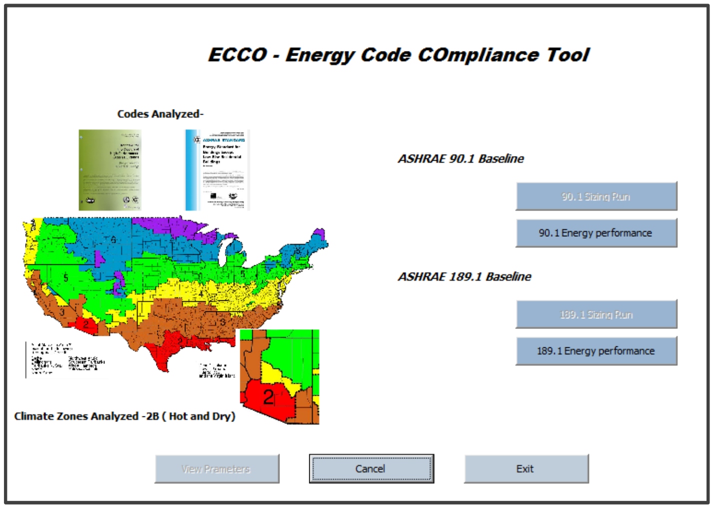
<table>
<tr><th>S.No.</th><th>Proposed</th><th>Baseline
(Fuel Type same as Proposed)</th><th>Zone Reassignments</th><th>Additional Inputs Required</th></tr>
<tr><td rowspan="12">1</td><td rowspan="12">PSZ
Electric-Cooling
Fossil Fuel - Heating</td><td>PSZ-AC (System 3)</td><td>NO</td><td>None</td></tr>
<tr><td rowspan="4">PVAV with Reheat-
Fossil Fuel
(System 5)</td><td rowspan="4">YES
(System Serves entire floor in accordance to G3.1.1)</td><td>System Type</td></tr>
<tr><td>Cool Source</td></tr>
<tr><td>Heat Source – Not Installed</td></tr>
<tr><td>System-Hot Water Loop Assignment</td></tr>
<tr><td rowspan="5">VAV with Reheat
Fossil Fuel
(System 7)</td><td rowspan="5">YES
(System Serves entire floor in accordance to G3.1.1)</td><td>System Type</td></tr>
<tr><td>Cool Source</td></tr>
<tr><td>Heat Source – Not Installed</td></tr>
<tr><td>System- CHW Loop Assignment</td></tr>
<tr><td>System-HW Loop Assignment</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3"></td></tr>
<tr><td rowspan="4">2</td><td rowspan="4">PSZ- Electric</td><td>PSZ-HP (System 4)</td><td>NO</td><td>None</td></tr>
<tr><td rowspan="3">PVAV- Electric
(System 6)</td><td rowspan="3">YES
(System Serves entire floor in accordance to</td><td>System Type</td></tr>
<tr><td>Cool Source</td></tr>
<tr><td>Heat Source – Not Installed</td></tr>
</table>

			G3.1.1)	
		VAVS - Electric (System 8)	YES (System Serves entire floor in accordance to G3.1.1)	System Type
				Cool Source
				Heat Source – Not Installed
				System- CHW Loop Assignment
3	PVAV-Fossil Fuel	PSZ-AC (System 3)	YES (System Serves each thermal block accordance to G3.1.1)	System Type
				Cool Source
				Heat Source
		PVAV - Fossil Fuel (System 5)	NO	System Type
				Cool Source
				Heat Source – Not Installed
				System-Hot Water Loop Assignment
		VAVS - Fossil Fuel(System 7)	NO	System Type
				Cool Source
				Heat Source – Not Installed
				System- CHW Loop Assignment
				System-HW Loop Assignment
4	PVAV- Electric	PSZ-HP (System 4)	YES (System Serves each thermal block accordance to G3.1.1)	System Type
				Cool Source
				Heat Source
		PVAV- Electric (System 6)	NO	System Type
				Cool Source
				Heat Source – Not Installed
		VAVS - Electric (System 8)	NO	System Type
				Cool Source

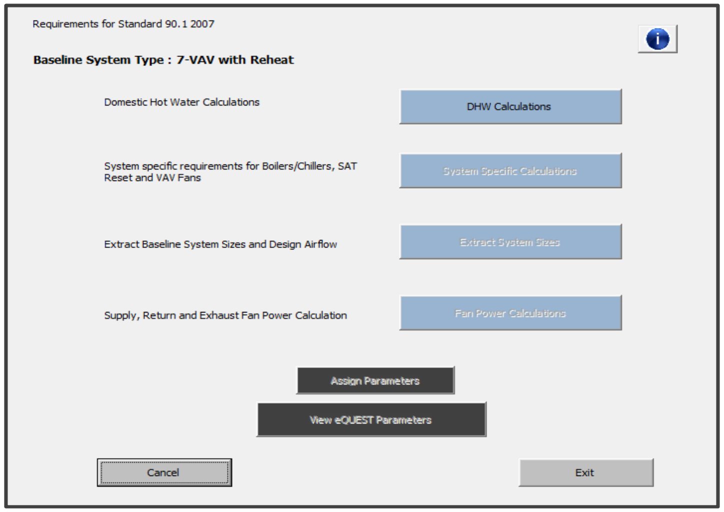
				Heat Source – Not Installed
				System- CHW Loop Assignment
5	VAV-Fossil Fuel	PSZ-AC (System 3)	YES (System Serves each thermal block accordance to G3.1.1)	System Type
				Cool Source
				Heat Source
		PVAV - Fossil Fuel (System 5)	NO	System Type
				Cool Source
				Heat Source – Not Installed
				System-Hot Water Loop Assignment
		VAVS - Fossil Fuel(System 7)	NO	System Type
				Cool Source
				Heat Source
				System- CHW Loop Assignment
				System-HW Loop Assignment
6	VAV- Electric	PSZ-HP (System 4)	YES (System Serves each thermal block accordance to G3.1.1)	System Type
				Cool Source
				Heat Source
		PVAV- Electric	NO	System Type
				Cool Source
				Heat Source – Not Installed
		VAVS - Electric	NO	System Type
				Cool Source
				Heat Source – Not Installed
				System- CHW Loop Assignment

Stage 3- Baseline Building: Sizing Run

This form displays enabled options for Standard 90.1 Energy Calculations and Standard 189.1 Energy Calculations. This helps the user define system specific requirements, calculate system efficiencies, fan control and power, domestic hot water system efficiency etc.

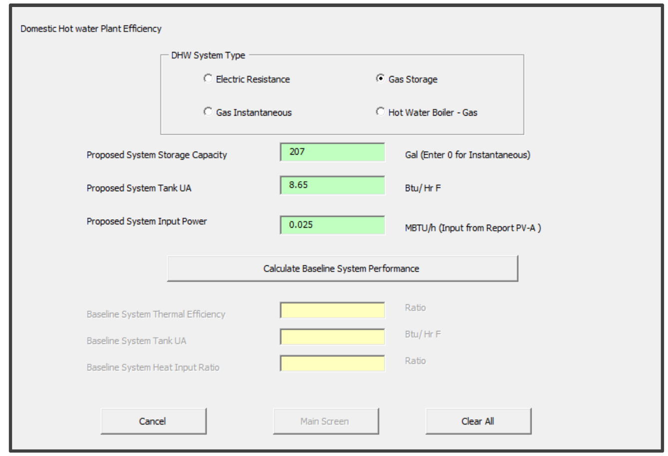


Form	90.1 Energy Calculations: Main Screen
Stage	Energy Performance
Code	90.1
Purpose of User-Form	To direct the user to the various calculations required to generate the 90.1 compliant baseline building and calculate annual energy performance of the building being analyzed.
User Inputs Required	Directs the user to- DHW Calculations System Specific Calculations Extract System Capacity for Sizing Runs Fan Power Calculations
Values Calculated	Form directs the user to Individual calculations and requirements.



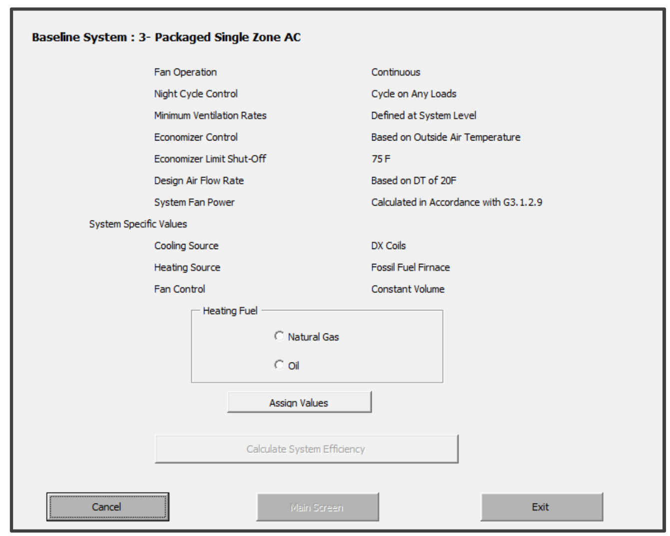
3.i. Sizing Runs: Domestic Hot Water Calculations

Form	Domestic Hot Water
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To calculate DHW system performance, Tank UA.
User Inputs Required	DHW System Type DHW Storage Capacity Tank UA, System Input Power
Values Calculated	Baseline System - Thermal Efficiency, Tank UA, HIR



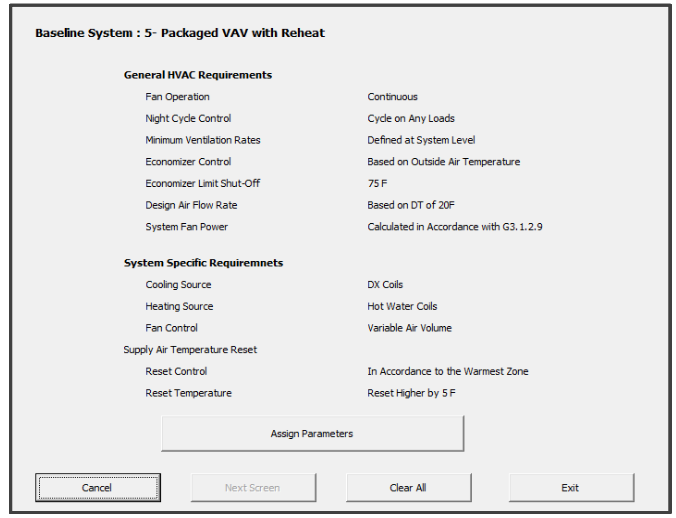
3.ii.a. Energy Performance: System 3: Specific Requirements

Form	System 3 : PSZ-AC
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To specify HVAC requirements for System 3
User Inputs Required	None
Values Calculated/ Specified	General HVAC Requirements (Economizer, Design air flow rates) Heating Source and Heating Fuel Cooling Source Fan Control



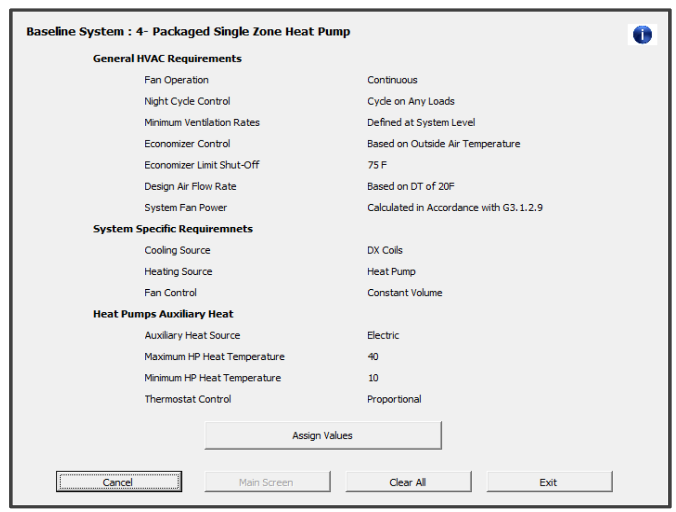
3.ii.b. Energy Performance: System 4: Specific Requirements

Form	**System 4 : PSZ-Heat Pump**
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To specify HVAC requirements for System 4
User Inputs Required	None
Values Calculated/ Specified	General HVAC Requirements Heating Source Cooling Source System Specific Values HP Auxiliary Heat Source HP Maximum and Minimum Temperature Zone throttling Range



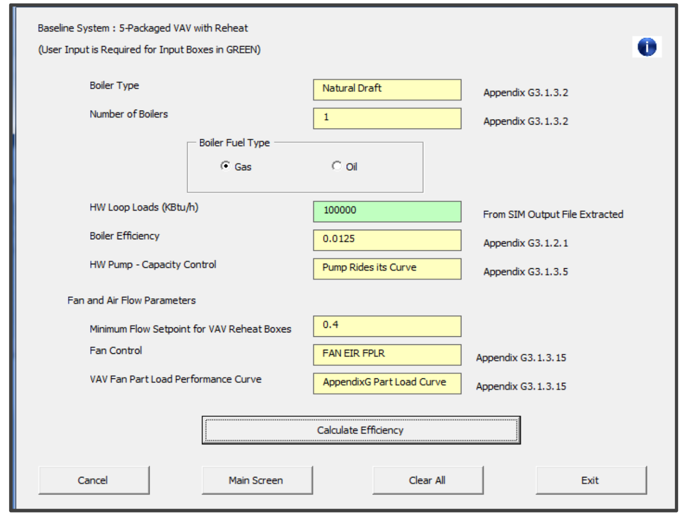
3.ii.c. Energy Performance: System 5: Specific Requirements

Form	**System 5: General Requirements**
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To define the general HVAC requirements for System 5
User Inputs Required	None
Values Calculated	Heating and Cooling Source Fan Control and Night Cycle Control Economizer Operation Supply Air Temperature Reset Controls



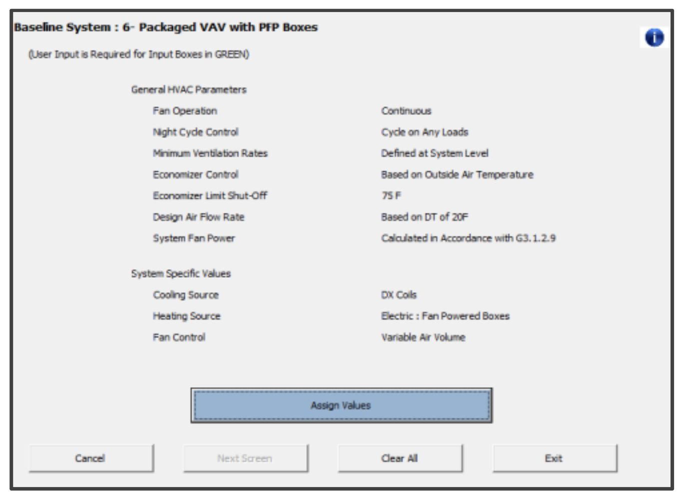
3.ii.c. Energy Performance: System 5: Specific Requirements

Form	System 5- Boiler Efficiency Calculations
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To determine boiler heat input ration (HIR) and capacity ratio for System 5 and 7.
User Inputs Required	Hot water Loop Load (Peak)
Values Calculated	Boiler Type Number of Boilers/ Boiler Capacity Ratio Boiler HIR Hot Water Pump Capacity Control



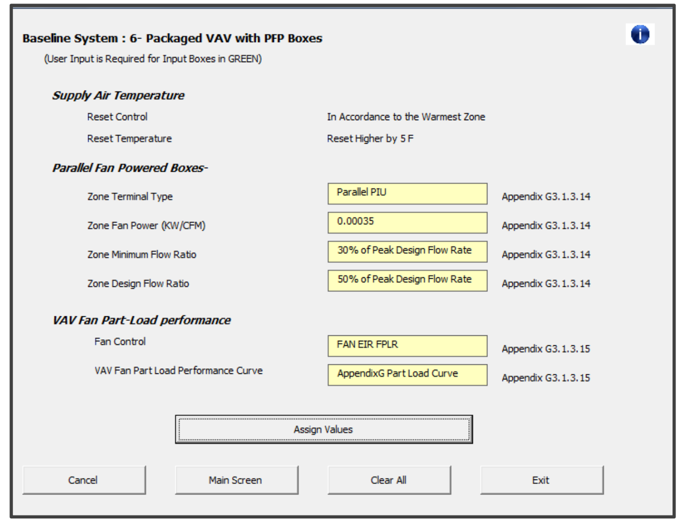
3.ii.d. Energy Performance: System 6: Specific Requirements

Form	System 6: General Requirements
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To define the general HVAC requirements for System 5
User Inputs Required	None
Values Calculated	Heating and Cooling Source Fan Control and Night Cycle Control Economizer Operation



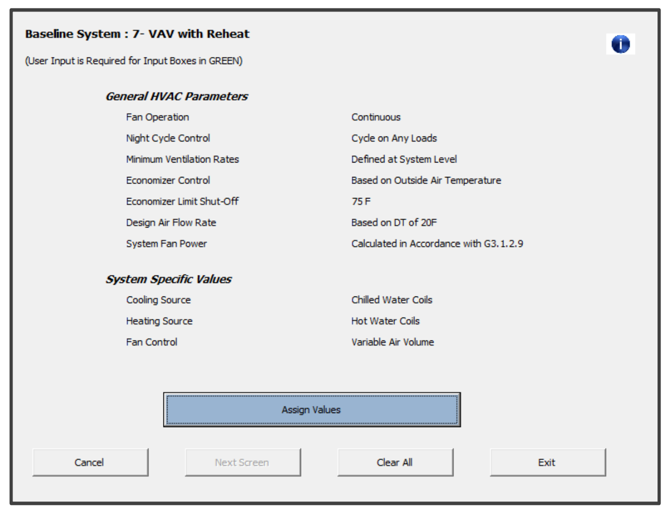
3.ii.d. Energy Performance: System 6: Specific Requirements

Form	System 6: System Specific Requirements
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To define the System Specific Requirements for System 6
User Inputs Required	None
Values Calculated	Supply Air Temperature Reset Parallel Fan Powered Boxes VAV Fan Part Load Performance



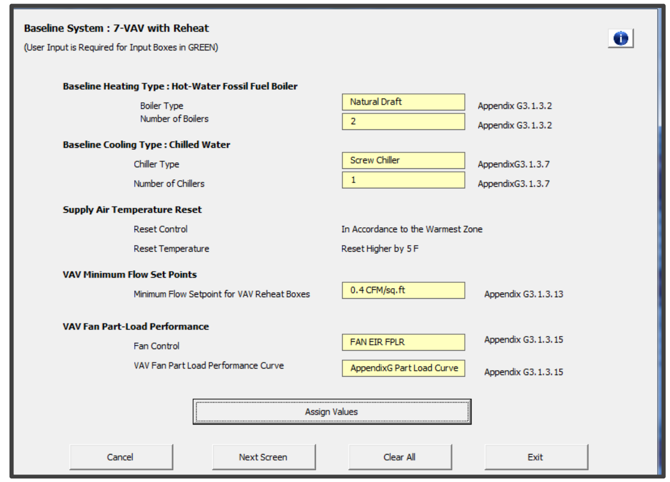
3.ii.e. Energy Performance: System 7: Specific Requirements

Form	System7: General Requirements
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To define the general HVAC requirements for System 5
User Inputs Required	None
Values Calculated	Heating and Cooling Source Fan Control and Night Cycle Control Economizer Operation



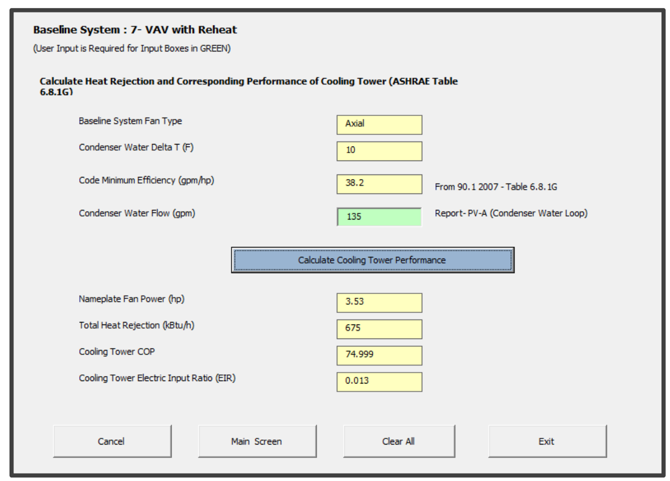
3.ii. Energy Performance: System 7: Specific Requirements

Form	System 7 - System Specific Requirements
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To define system specific requirements for System 7
User Inputs Required	None
Values Calculated	Boiler and Chiller Details Supply Air Temperature Reset Control VAV Minimum Flow Setpoints VAV Fan Part Load Performance



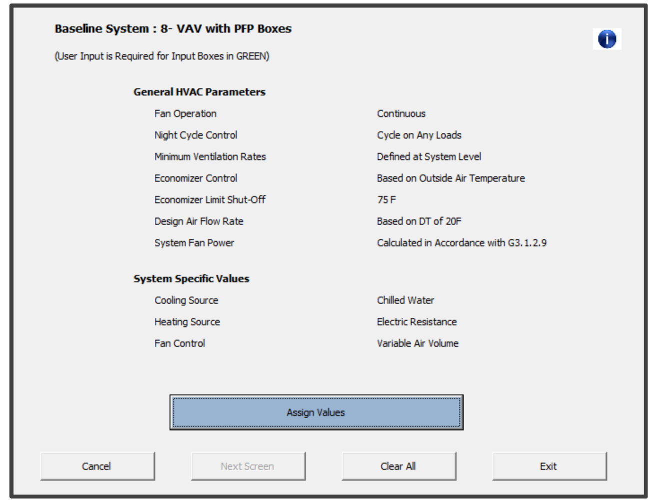
3.ii.e. Energy Performance: System 7: Specific Requirements

Form	System 7- Cooling Tower Efficiency
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To determine cooling Tower electric input ratio (EIR).
User Inputs Required	Condenser water flow (gpm)
Values Calculated	Cooling Tower EIR Cooling Tower Capacity Control



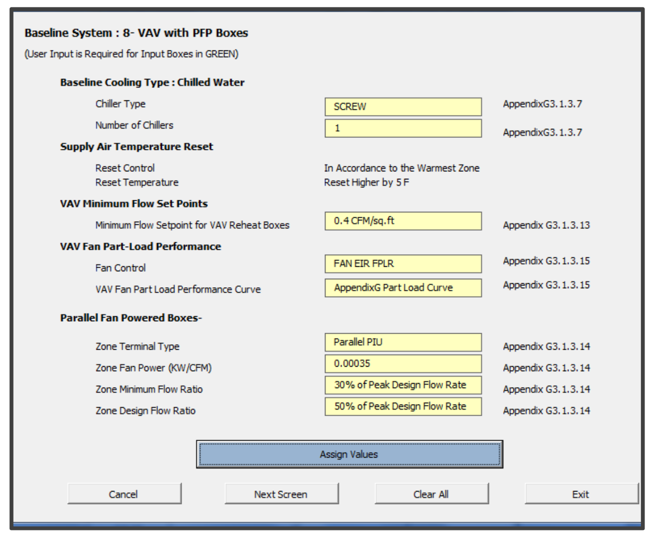
3.ii.f. Energy Performance: System 8: Specific Requirements

Form	System 8- System Specific Requirements
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To assign system specific requirements to the applicable system.
User Inputs Required	None
Values Calculated	Chiller Details Supply air temperature reset control VAV minimum flow setpoints VAV Fan Powered boxes - Fan Power VAV Fan Part Load Performance



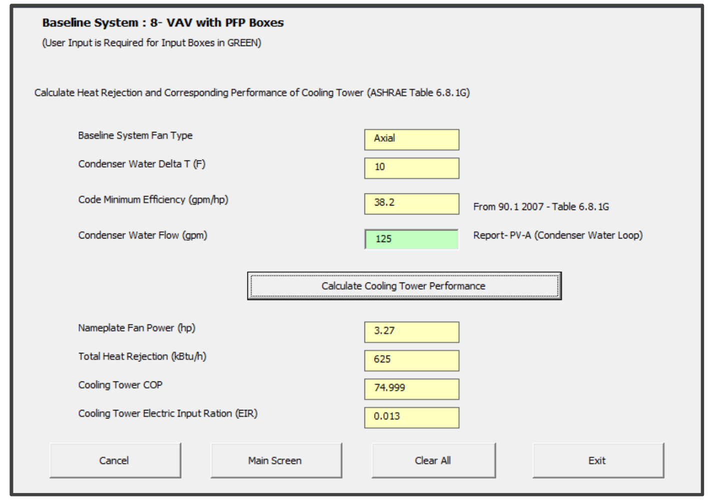
3.ii.f. Energy Performance: System 8: Specific Requirements

Form	System 8: General Requirements
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To define the general HVAC requirements for System 5
User Inputs Required	None
Values Calculated	Heating and Cooling Source Fan Control and Night Cycle Control Economizer Operation

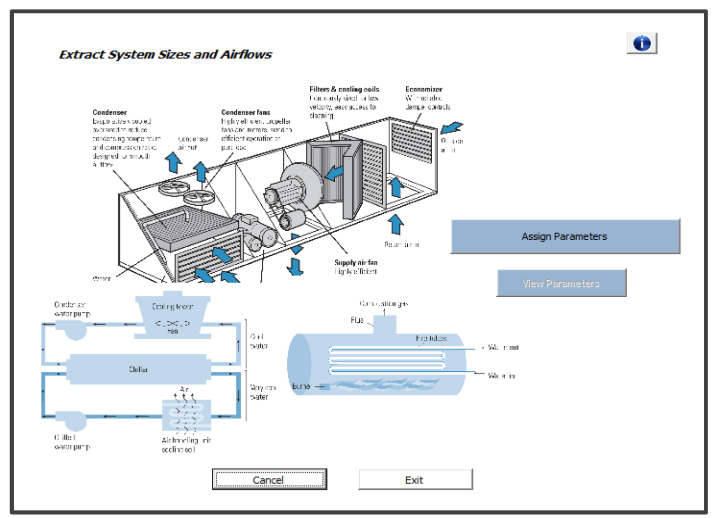


3.ii.f. Energy Performance: System 8: Specific Requirements

Form	System 8- Cooling Tower Efficiency
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To determine cooling Tower electric input ratio (EIR).
User Inputs Required	Condenser water flow (gpm)
Values Calculated	Cooling Tower EIR Cooling Tower Capacity Control



Form	Extract System Sizes and Airflows
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To direct the user to the Global parameters required to be assigned and Size Extractor.
User Inputs Required	Assign Global Parameters Run eQUEST Simulation Use "Size Extractor" for System Sizes and Airflows
Values Calculated	Global Parameters to be Assigned Creates CSV file with all requires System Sizes and Airflows



3.iii. Assign Parameters and Extract System Sizes and Airflows

Table 87

Sizing Run: Assign Parameters for System Sizing

RUN	yes	yes	yes	yes
Base Filename	Project 56	Project 56	Project 56	Project 56
Batch Run Label	90.1 -0	90.1 -90	90.1- 180	90.1 -270
Location	Phoenix	Phoenix	Phoenix	Phoenix
PARAMETER SUBSTITUTIONS	yes	yes	yes	yes
Orientation	0	90	180	270
Roof-CI	20	20	20	20
Roof-Absorptance	0.7	0.7	0.7	0.7
R-Eff-Wall	7.2	7.2	7.2	7.2
R-CI-Wall	0.01	0.01	0.01	0.01
EFloor-R	16.2	16.2	16.2	16.2
Door-U-Value	0.7	0.7	0.7	0.7
WWR-Multiplier	0.80	0.80	0.80	0.80
Glass-U-Value	0.80	0.80	0.80	0.80
Glass-SHGC	0.25	0.25	0.25	0.25
LPD	1	1	1	1
OA-Control	OA-TEMP	OA-TEMP	OA-TEMP	OA-TEMP
Econo-High-Limit	75	75	75	75
Night-Cycle-Control	CYCLE-ON-ANY	CYCLE-ON-ANY	CYCLE-ON-ANY	CYCLE-ON-ANY
DHW-HIR	1.25	1.25	1.25	1.25
Tank-UA	23.06	23.06	23.06	23.06
Min-SAT	55	55	55	55
Zone-Design-T	75	75	75	75
Zone-Heat-Source	HOT-WATER	HOT-WATER	HOT-WATER	HOT-WATER
Reheat-Delta-T	40	40	40	40

SAT-Reset	WARMEST	WARMEST	WARMEST	WARMEST
Max-Reset-Temp	60	60	60	60
Throttling-R	4	4	4	4
Boiler-HIR	0.341	0.341	0.341	0.341
Boiler-Capacity-Ratio	0.5	0.5	0.5	0.5
HW-Pump-Cap-Ctrl	ONE-SPEED-PUMP	ONE-SPEED-PUMP	ONE-SPEED-PUMP	ONE-SPEED-PUMP
VAV-Min-Flow	0.4	0.4	0.4	0.4
Fan-Curve	AppendixG Part Load Curve	AppendixG Part Load Curve	AppendixG Part Load Curve	AppendixG Part Load Curve
Fan-Control	FAN-EIR-FPLR	FAN-EIR-FPLR	FAN-EIR-FPLR	FAN-EIR-FPLR

3.iv. Create eQUEST Batch Files

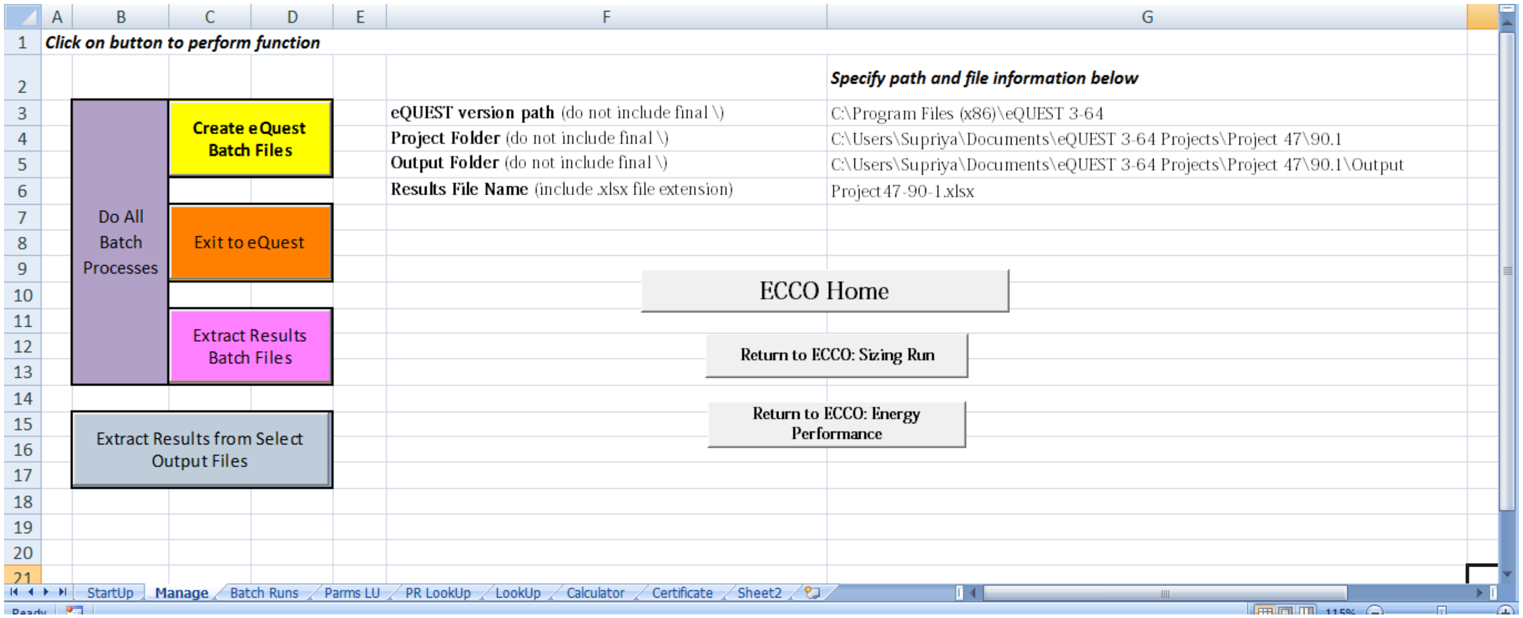


Figure 23: Loads Calculation: Create eQUEST Batch Files

User-Inputs Required

a. Enter eQUEST Version Path
b. Enter Project Folder
c. Create and Input Output folder location
d. Name Results file (.xlsx)
e. Click on “Create eQUEST Batch File”

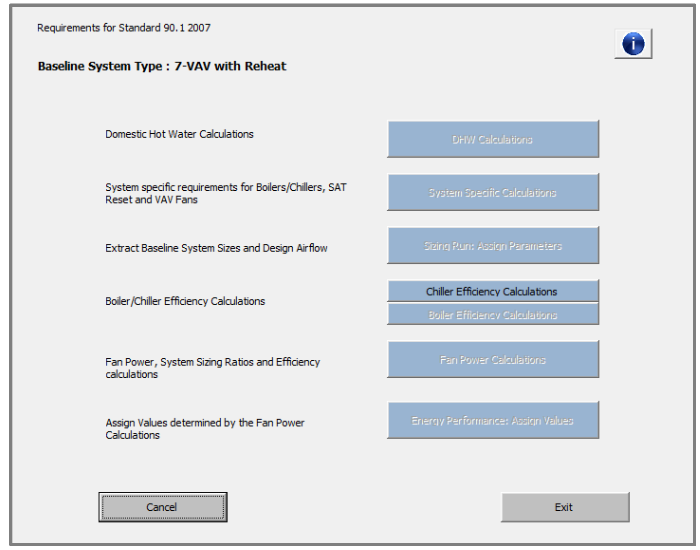
STAGE 4- BASELINE BUILDING: **Energy Performance**

4.i. Energy Performance: Calculations

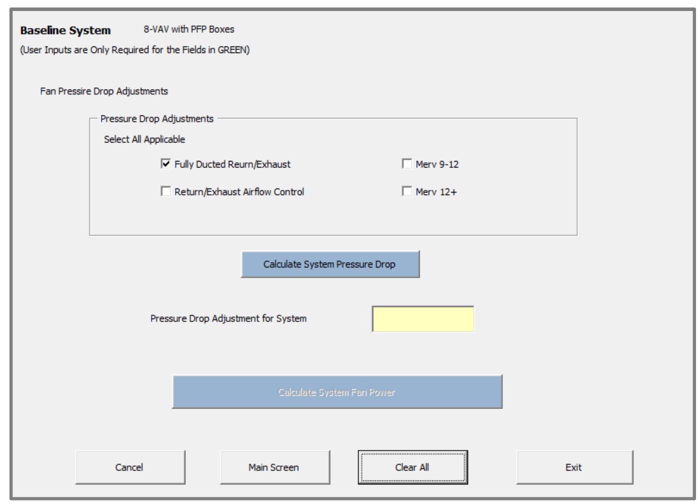
Includes calculations for-

- All systems heating and cooling efficiency calculations
- Fan power calculations
- System sizing ratios calculation
- Minimum outside air ratios calculations

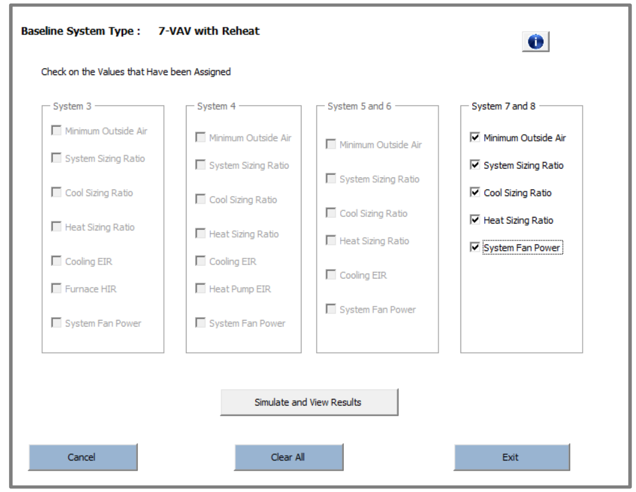
Appendix A explains in detail the calculation steps for all of these.



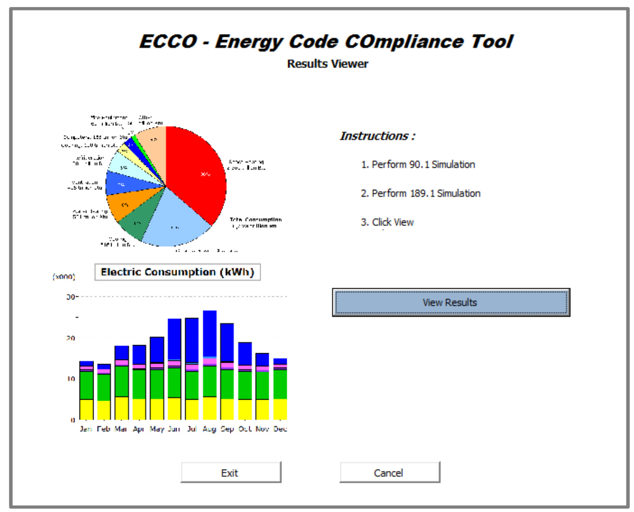
Form	Fan Power Calculations
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To calculate fan power limitation pressure drop adjustment, and guide the user to the ECCO Fan Power Calculator.
User Inputs Required	Applicable Pressure Drop Adjustment
Values Calculated	Pressure Drop Adjustment User is directed to the ECCO Fan Power Calculator



Form	Energy Performance : User Assigned Values
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To identify the values calculated during the Energy performance stage for the baseline system type.
User Inputs Required	None
Values Calculated	System Sizing Ratios System Fan Power Baseline system heating and cooling efficiencies System level minimum outside air ratios.



Form	Results: View Results
Stage	Results
Code	90.1 and 189.1
Purpose of User-Form	To direct user to the "Certificate" sheet.
User Inputs Required	Energy simulation results, which need to be copy pasted at the designated cells.
Values Calculated	Building energy performance evaluation Energy Use Intensities (KBtu/sq.ft)



4.ii. Energy Performance: Assign Defined Values

Table 88:

Energy Performance: Values to be assigned

S.No.	Description	Calculation Procedure	Command	Keyword
SYSTEM 3				
1	System: Minimum outside Air Ratio	Minimum OA Calculator	SYSTEM	MIN-OUTSIDE-AIR
2	Cooling Electric Input Ratio	Fan Power Calculator	SYSTEM	COOLING-EIR
3	Furnace Heat Input Ratio	System 3-Efficiency Calculator	SYSTEM	FURNACE-HIR
4	System Fan Power	Fan Power Calculator	SYSTEM	SUPPLY-KW/FLOW
SYSTEM 4				
1	System: Minimum outside Air Ratio	Minimum OA Calculator	SYSTEM	MIN-OUTSIDE-AIR
5	Cooling Electric Input Ratio	Fan Power Calculator	SYSTEM	COOLING-EIR
6	Heat Pump Electric Input Ratio	Fan Power Calculator	SYSTEM	HEATING-EIR
7	System Fan Power	Fan Power Calculator	SYSTEM	SUPPLY-KW/FLOW
SYSTEM 5				
1	System: Minimum Outside Air Ratio	Minimum OA Calculator	SYSTEM	MIN-OUTSIDE-AIR
2	Cooling Electric Input Ratio	Fan Power Calculator	SYSTEM	COOLING-EIR
3	System Fan Power	Fan Power Calculator	SYSTEM	SUPPLY-KW/FLOW
3	Boiler HIR	Boiler Efficiency Calculator	BOILER	HEAT-INPUT-RATIO
4	Boiler Sizing Ratio	Boiler Efficiency Calculator	CIRCULATION-LOOP	SIZING-OPTION
SYSTEM 6				
1	System: Minimum Outside Air Ratio	Minimum OA Calculator	SYSTEM	MIN-OUTSIDE-AIR
2	Cooling Electric Input Ratio	Fan Power Calculator	SYSTEM	COOLING-EIR

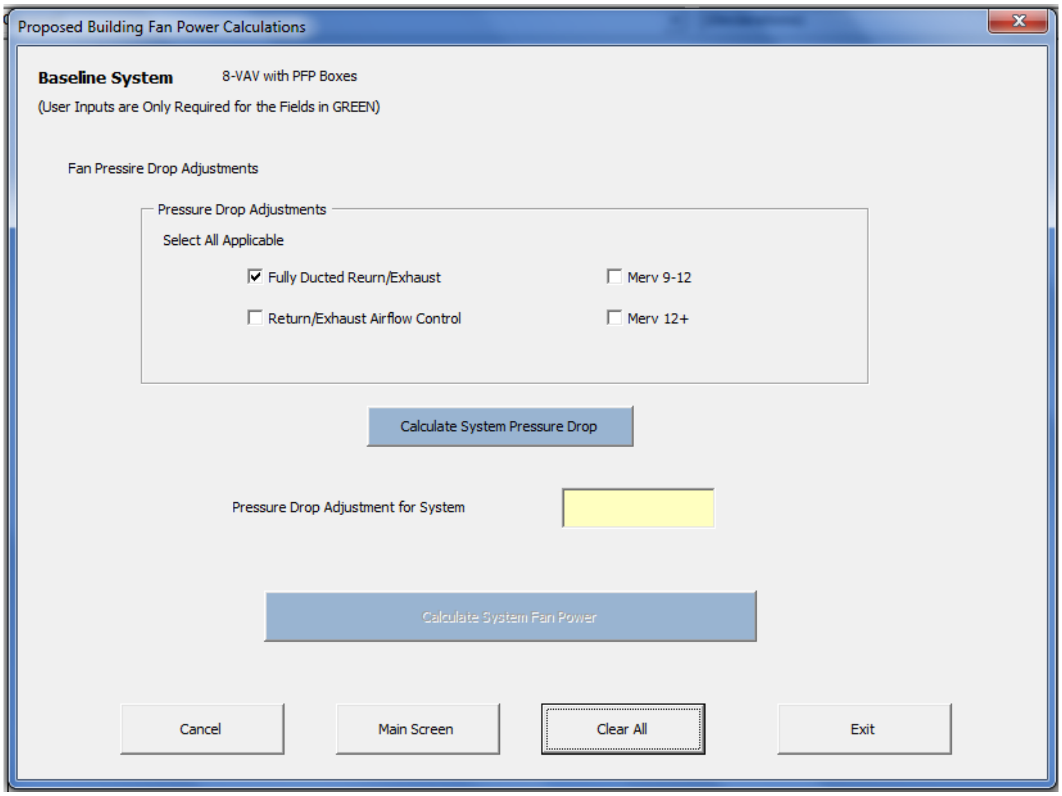
3	System Fan Power	Fan Power Calculator	SYSTEM	SUPPLY-KW/FLOW
SYSTEM 7				
1	System: Minimum Outside Air Ratio	Fan Power Calculator	SYSTEM	MIN-OUTSIDE-AIR
2	System Fan Power	Fan Power Calculator	SYSTEM	SUPPLY-KW/FLOW
3	Boiler HIR	Boiler Efficiency Calculator	BOILER	HEAT-INPUT-RATIO
4	Boiler Sizing Ratio	Boiler Efficiency Calculator	CIRCULATION-LOOP	SIZING-OPTION
5	Chiller EIR	Chiller Efficiency Calculator	CHILLER	ELEC-INPUT-RATIO
SYSTEM 8				
1	System: Minimum Outside Air Ratio	Fan Power Calculator	SYSTEM	MIN-OUTSIDE-AIR
2	System Fan Power	Fan Power Calculator	SYSTEM	SUPPLY-KW/FLOW
3	Chiller EIR	Chiller Efficiency Calculator	CHILLER	ELEC-INPUT-RATIO

APPENDIX B

CALCULATOR TOOL

B.1. Fan Power Calculation Tool

User Form: For Pressure Drop Calculations



Form	Fan Power Calculations
Stage	Energy Performance
Code	90.1 and 189.1
Purpose of User-Form	To calculate fan power limitation pressure drop adjustment, and guide the user to the ECCO Fan Power Calculator.
User Inputs Required	Applicable Pressure Drop Adjustment
Values Calculated	Pressure Drop Adjustment User is Guided to the ECCO Fan Power Calculator

Table 89

Steps Followed by ECCO Fan Power Calculator Tool

Fan Power Calculations				
(Source : Energy Model Input Translator, August 2010, Rocky Mountain Institute)				
User Input :		Baseline system maximum Design Air Flow (CFM) Fan Internal Static (From Proposed Design) For CEIR Calculations : Cooling Load		
No.	**Description**	**Systems 3-4**	**Systems 5-8**	**Explanation**
STEP 1	Baseline Fan BHP	bhp = CFM * 0.00094 + A	bhp = CFM * 0.0013 + A	90.1-Table G3.1.2.9; 189.1-Table D3.1.2.9
STEP 2	Additional Allowed BHP (A)	PD * CFM/ 4131		PD- Adjustments calculated in accordance to 90.1 Section 6.5.3.1.1 for both codes.
STEP 3	Total Allowed BHP of baseline fan motor	STEP 1 + STEP 2		Sum of baseline fan BHP and additional allowed BHP
STEP 4	Fan Motor Efficiency	Look Up Table based on Total allowed BHP (Determined in STEP 3)		Enclosed Motor, 1800 RPM. Table 10.8 for 90.1; Table C-13 for 189.1.
STEP 5	Allowed Fan KW	0.746 * Total bhp/ Motor Efficiency		90.1-AppendixG3.1.2.9; 189.1-AppendixD3.1.2.9
STEP 6	System EER	Look up table based on system cooling load		ASHRAE Tables 6.8.1A and 6.8.1B
STEP 7	External Static (SP_{ex})	The external static at rated conditions in inches of water		Look up Table- ANSI/AHRI Standard 340/360.
STEP 8	Internal Static (SP_{in})	Internal static in inches of water, same as proposed design.		Proposed Design value, else assumed 1 in w for no proposed value defined.
STEP 9	Supply Fan Ratio	1		No Return or Exhaust fans have been modeled for the purpose of this project.
STEP 10	Supply KW/CFM	Fan KW (STEP 5) * Fan Ratio (STEP 9) / CFM		Calculate Supply Fan Power
STEP 11	Cooling COP	$X= (Sp_{ex} + Sp_{in})/55.65$ 1 + X/(3.413/EER)-X		Cooling COP is calculated for all systems with DX-coil cooling. (System 3-6)
STEP 12	Cooling EIR	1/ COP		

Energy Code Compliance Tool : ASHRAE 90.1 Fan Power Calculator

INSTRUCTIONS:

User-Defined Values | eQUEST Inputs

Calculate

Home

- User inputs are required as defined.
- Please use the SIMOutput file created during the sizing run for these values.
- Click "Calculate" to calculate fan power and system efficiencies for the applicable systems.
- Click "Home" to return to the main screen.

ASHRAE 90.1 2007 FAN POWER CALCULATIONS

(System 3-8) **ASHRAE 90.1 2007**

		USER INPUT 1	A	B	USER INPUT 2	C	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5	USER INPUT 3	STEP 6	STEP 7	USER INPUT 4 STEP 8	STEP 9	STEP 10	STEP 11	STEP 12	STEP 13	ST EP 14
S.No.	Baseline System Type	Proposed System Name	Heating Type	System Type #	Supply CFM (s)	PD	BASE ALLOWED FAN BHP	Additional allowed fan BHP	Total Allowed Fan BHP	Motor Efficiency	Allowed Fan KW	Cooling Load (Btu/Hr)	Total EER	ARI Min. External Static	Internal Static	Supply Fan Ratio	Supply KW/CFM	Cooling COP	Cooling EIR	Heating COP	Heating EIR
1	5-PVAV with Reheat	System 1	Fossil	5	8000	1.00	10.40	1.94	12.34	91.00%	10.11	200000	10.80	0.35	1.3	1.00	0.00126	3.596	0.278	N/A	N/A
2	5-PVAV with Reheat	System 2	Fossil	5	10000	1.00	13.00	2.42	15.42	91.00%	12.64	240000	9.80	0.40	1.3	1.00	0.00126	3.244	0.308	N/A	N/A
3	5-PVAV with Reheat	System 3	Fossil	5	12000	1.00	15.60	2.90	18.50	91.00%	15.17	300000	9.80	0.45	1.3	1.00	0.00126	3.256	0.307	N/A	N/A
4	5-PVAV with Reheat	System 4	Fossil	5	8000	1.00	10.40	1.94	12.34	91.00%	10.11	200000	10.80	0.35	1.3	1.00	0.00126	3.596	0.278	N/A	N/A
5	5-PVAV with Reheat	System 5	Fossil	5	10000	1.00	13.00	2.42	15.42	91.00%	12.64	240000	9.80	0.40	1.3	1.00	0.00126	3.244	0.308	N/A	N/A
6	5-PVAV with Reheat	System 6	Fossil	5	12000	1.00	15.60	2.90	18.50	91.00%	15.17	300000	9.80	0.45	1.3	1.00	0.00126	3.256	0.307	N/A	N/A
7	5-PVAV with Reheat	System 7	Fossil	5	8000	1.00	10.40	1.94	12.34	91.00%	10.11	200000	10.80	0.35	1.3	1.00	0.00126	3.596	0.278	N/A	N/A
8	5-PVAV with Reheat	System 8	Fossil	5	10000	1.00	13.00	2.42	15.42	91.00%	12.64	240000	9.80	0.40	1.3	1.00	0.00126	3.244	0.308	N/A	N/A
9	5-PVAV with Reheat	System 9	Fossil	5	12000	1.00	15.60	2.90	18.50	91.00%	15.17	300000	9.80	0.45	1.3	1.00	0.00126	3.256	0.307	N/A	N/A
10	5-PVAV with Reheat	System 10	Fossil	5	12000	1.00	15.60	2.90	18.50	91.00%	15.17	200000	10.80	0.35	1.3	1.00	0.00126	3.596	0.278	N/A	N/A

B.2. Minimum Outside Air Ratio Calculator

Minimum Outside Air Ratio Calculations : Standard 90.1 and 189.1

INSTRUCTIONS:

- User inputs are required as defined.
- Please use the SIMOutput file created during the sizing run for these values.
- Click "Calculate" to calculate fan power and system efficiencies for the applicable systems. Click "Home" to return to the main screen.

User-Defined Values	eQUEST Inputs
(From SIMOutput File Created)	(To be input in Baseline File)

S.No.	System Name	Proposed Design System Design Airflow (CFM)	Proposed Design System Min. OA Ratio	Proposed Design Outside AirFlow (CFM)	Baseline Building Design Supply Airflow (CFM)	Baseline Building Outside Air Ratio
1	System 1	16621	0.226	3756.346	12829	0.293
2	System 2	19463	0.193	3756.359	18551	0.202
3	System 3	16544	0.227	3755.488	17377	0.216
4	System 4	100000	0.22	22000	15000	1.467
5	System 5	100000	0.13	13000	70000	0.186
6	System 6	100000	0.15	15000	90000	0.167

B.3. System 3: Efficiency Calculations

Energy Code Compliance Tool : System 3 Heating Efficiency Calculator

ASHRAE 90.1 2007 HEATING SYSTEM EFFICIENCY CALCULATIONS

System 3

S.No.	Baseline System Type	Proposed System Name	Heating Fuel (Gas or Oil)	Heating Capacity (Btu/h))	AFUE/ E_t	Thermal Efficiency
1	3-PSZ-AC	System 1	Oil	100000	0.8	1.25
2	3-PSZ-AC	System 2	Oil	100000	0.8	1.25
3	3-PSZ-AC	System 3	Oil	300000	0.81	1.235
4	3-PSZ-AC	System 4	Oil	100000	0.8	1.25
5	3-PSZ-AC	System 5	Oil	100000	0.8	1.25
6	3-PSZ-AC	System 6	Oil	100000	0.8	1.25

90.1 Fan Power Calculations

Minimum Outside Air Calculations

Return to ECCO

Calculate

User-Inputs (From SIMOutput File)

Values to be Input in eQUEST

Provide the required information from the SIMOutput file created during the Sizing Run. Click "Calculate" to calculate Furnace Efficiency. Input the Calculated Values into the eQUEST File

APPENDIX C

SYSTEM INPUT TEMPLATES

C1. System 3: PSZ-AC
$System Input Template

```
"Sys1 (PSZ) (G.S1)"           = SYSTEM
  TYPE                        = PSZ
  HEAT-SOURCE                 = FURNACE
  ZONE-HEAT-SOURCE            = NONE
  BASEBOARD-SOURCE            = NONE
  SIZING-RATIO                = {#pa("System-Sizing-Ratio")}
  HEAT-SIZING-RATI            = {#pa("Heat-Sizing-Ratio")}
  COOL-SIZING-RATI            = {#pa("Cool-Sizing-Ratio")}
  MAX-SUPPLY-T                = 120
  MIN-SUPPLY-T                = 55
  ECONO-LIMIT-T               = {#pa("Econo-High-Limit")}
  ECONO-LOCKOUT               = YES
  OA-CONTROL                   = {#si(#pa("OA-Control"), "SYSTEM" , "OA-
CONTROL")}
  FAN-SCHEDULE                = "Sys1 (PSZ) Fan Sch"
  FAN-CONTROL                 = {#si (#pa("Fan-Control") , "SYSTEM", "FAN-
CONTROL")}
  SUPPLY-EFF                  = 0.53
  SUPPLY-KW/FLOW              = 0.00068
  RETURN-EFF                  = 0.53
  RETURN-KW/FLOW              = 0.00023
  NIGHT-CYCLE-CTRL            =  {#SI(#PA("Night-Cycle-Control") , "SYSTEM" ,
                              "NIGHT- CYCLE-CTRL")}
  INDOOR-FAN-MODE               = {#SI(#pa("Fan-Operation"), "SYSTEM" , "INDOOR-
                                FAN-MODE")}
  COOLING-EIR                 = 0.330
  FURNACE-AUX                 = 0
  FURNACE-HIR                 = 1.25
  CONTROL-ZONE                = "South Perim Zn (G.S1)"
```

C2. System 4: PZS-HP
$SYSTEM Input Template

```
"Sys1 (PSZ) (G.S1)"           = SYSTEM
  TYPE                        = PSZ
  HEAT-SOURCE                 = HEAT-PUMP
  ZONE-HEAT-SOURCE            = NONE
  BASEBOARD-SOURCE            = NONE
  SIZING-RATIO                = {#pa("Syztem-Sizing-Ratio")}
  HEAT-SIZING-RATI            = {#pa("Heat-Sizing-Ratio")}
  COOL-SIZING-RATI            = {#pa("Cool-Sizing-Ratio")}
  MAX-SUPPLY-T                = 90
  MIN-SUPPLY-T                = {#pa("Min-SAT")}
  ECONO-LIMIT-T               = {#pa("Econo-High-Limit")}
  ECONO-LOCKOUT               = YES
  OA-CONTROL                  = {#si(#pa("OA-Control"), "SYSTEM" , "OA-CONTROL")}
  FAN-SCHEDULE                = "Sys1 (PSZ) Fan Sch"
```

```
  FAN-CONTROL                = {#si (#pa("Fan-Control") , "SYSTEM", "FAN-
CONTROL")}
  SUPPLY-STATIC              = 1
  SUPPLY-EFF                 = 0.53
  SUPPLY-KW/FLOW             = 0.00068
  RETURN-EFF                 = 0.53
  RETURN-KW/FLOW             = 0.00023
  NIGHT-CYCLE-CTRL           = {#SI(#PA("Night-Cycle-Control") , "SYSTEM" ,
                        "NIGHT-CYCLE-CTRL")}
  INDOOR-FAN-MODE            = {#SI(#pa("Fan-Operation"), "SYSTEM" , "INDOOR-
                        FAN-MODE")}
  COOLING-EIR                = 0.34565
  COOL-CTRL-RANGE            = {#pa("Throttling-Range")}
  HEATING-EIR                = 0.316442
  HP-SUPP-SOURCE             = {#si(#pa("Elec-Aux-Heat"), "SYSTEM" , "HP-SUPP-
                               SOURCE")}
  MIN-HP-T                   = {#pa("Min-HP-T")}
  MAX-HP-SUPP-T              = {#pa("Max-HP-T")}
  CONTROL-ZONE               = "South Perim Zn (G.S1)"
  ..
```

$ZONE Level Inputs

```
"South Perim Zn (G.S1)"      = ZONE
  TYPE                       = CONDITIONED
  FLOW/AREA                  = 0.5
  OA-FLOW/PER                = 15
  DESIGN-HEAT-T              = 72
  HEAT-TEMP-SCH              = "GndCor Sys1 Heat Sch"
  DESIGN-COOL-T              = {#pa("Zone-Design-T")}
  COOL-TEMP-SCH              = "GndCor Sys1 Cool Sch"
  THERMOSTAT-TYPE            = {#si(#pa("Therm-Ctrl"), "ZONE" , "THERMOSTAT-
TYPE")
}
  SIZING-OPTION              = ADJUST-LOADS
  SPACE                      = "South Perim Spc (G.S1)"
  ..
```

C3. System 5: PVAV with Reheat

$SYSTEM Input Template

```
"Sys1 (PMZS) (G)"            = SYSTEM
  TYPE                       = PVAVS
  HEAT-SOURCE                = NONE
  ZONE-HEAT-SOURCE           = {#si(#pa("Zone-Heat-Source"), "SYSTEM" , "ZONE-
                               HEAT-SOURCE")}
  BASEBOARD-SOURCE           = NONE
  SIZING-RATIO                     = 1
  COOL-SIZING-RATI           = 1.15
  MAX-SUPPLY-T               = 95
  MIN-SUPPLY-T               = {#pa("Min-SAT")}
  COOL-RESET-SCH             = "Sys1 (PMZS) (G) CRS"
```

```
  COOL-CONTROL               = {#si(#pa("SAT-Reset"), "SYSTEM" , "COOL-
CONTROL")}
  ECONO-LIMIT-T              = {#PA("Econo-High-Limit")}
  ECONO-LOCKOUT              = NO
  COOL-MAX-RESET-T           = {#PA("Max-Reset-Temp")}
  MIN-OUTSIDE-AIR            = 0.293
  OA-CONTROL                 = {#si(#pa("OA-Control"), "SYSTEM" , "OA-CONTROL")}
  FAN-SCHEDULE               = "Sys1 (PMZS) Fan Sch"
  FAN-CONTROL                = {#si(#pa("Fan-Control"), "SYSTEM", "FAN-
CONTROL")}
  SUPPLY-KW/FLOW             = 0.00093
  RETURN-KW/FLOW             = 0.00031
  NIGHT-CYCLE-CTRL           =
                         {#si(#pa("Night-Cycle-Control"), "SYSTEM" , "NIGHT-CYCLE-
                         CTRL" )}
  FAN-EIR-FPLR               = {#si(#PA("Fan-Curve"), "SYSTEM" , "FAN-EIR-
FPLR")}
  REHEAT-DELTA-T             = {#PA("Reheat-Delta-T")}
  MIN-FLOW-RATIO             = {#PA("VAV-Min-Flow")}
  HW-LOOP                    = "ASHRAE-HW-Loop"
  COOLING-EIR                = 0.33
  COOL-CTRL-RANGE            = {#pa("Throttling-R")}
  FURNACE-AUX                = 0
```

$Zone Input Template

```
"South Perim Zn (G.S1)"      = ZONE
  TYPE                       = CONDITIONED
  FLOW/AREA                  = 0.5
  OA-FLOW/PER                = 20
  DESIGN-HEAT-T              = 72
  HEAT-TEMP-SCH              = "GndCor Sys1 Heat Sch"
  DESIGN-COOL-T              = {#pa("Zone-Design-T")}
  COOL-TEMP-SCH              = "GndCor Sys1 Cool Sch"
  SIZING-OPTION              = ADJUST-LOADS
  SPACE                      = "South Perim Spc (G.S1)"
```

C4. System 6- pvav with pfp boxes

$SYSTEM Input Template

```
"Sys1 (PIU) (G.S1)"          = SYSTEM
  TYPE                       = PIU
  HEAT-SOURCE                = ELECTRIC
  ZONE-HEAT-SOURCE           = {#si(#pa("Zone-Heat-Source"), "SYSTEM" , "ZONE-
                               HEAT-SOURCE")}
  BASEBOARD-SOURCE           = NONE
  SIZING-RATIO               = {#pa("System-Sizing-Ratio")}
  HEAT-SIZING-RATI           = {#pa("Heat-Sizing-Ratio")}
  COOL-SIZING-RATI           = {#pa("Cool-Sizing-Ratio")}
```

```
  COOL-SOURCE              = ELEC-DX
  MAX-SUPPLY-T             = {#pa("Heat-Set-T")}
  MIN-SUPPLY-T             = {#pa("Min-SAT")}
  COOL-CONTROL             = {#si(#pa("SAT-Reset"), "SYSTEM" , "COOL-
CONTROL")}
  ECONO-LIMIT-T            = {#PA("Econo-High-Limit")}
  ECONO-LOCKOUT            = YES
  COOL-MAX-RESET-T         = {#PA("Max-Reset-Temp")}
  OA-CONTROL               = {#si(#pa("OA-Control"), "SYSTEM" , "OA-CONTROL")}
  FAN-SCHEDULE             = "Sys1 (PSZ) Fan Sch"
  FAN-CONTROL              = {#si (#pa("Fan-Control") , "SYSTEM", "FAN-
CONTROL")}
  SUPPLY-EFF               = 0.53
  SUPPLY-KW/FLOW           = 0.00076
  RETURN-EFF               = 0.53
  RETURN-KW/FLOW           = 0.00023
  NIGHT-CYCLE-CTRL         = {#SI(#PA("Night-Cycle-Control") , "SYSTEM" ,
                           "NIGHT-CYCLE-CTRL")}
  FAN-EIR-FPLR             = "DX-Cool-EIR-fPLR"
  REHEAT-DELTA-T           = {#pa("Reheat-Delta-T")}
  COOLING-EIR              = 0.34565
  ..
$ZONE Input Template
"South Perim Zn (G.S1)"    = ZONE
  TYPE                     = CONDITIONED
  MIN-FLOW-RATIO           = {#pa("Zone-Min-Flow-Ratio")}
  FLOW/AREA                = 0.5
  OA-FLOW/PER              = 15
  DESIGN-HEAT-T            = 72
  HEAT-TEMP-SCH            = "GndCor Sys1 Heat Sch"
  DESIGN-COOL-T            = {#pa("Zone-Design-T")}
  COOL-TEMP-SCH            = "GndCor Sys1 Cool Sch"
  ZONE-FAN-KW/FLOW         = {#pa("Zone-Fan-Power")}
  ZONE-FAN-T-SCH           = "GndCor Sys1 Cool Sch"
  ZONE-FAN-RATIO           = {#pa("Zone-Fan-Ratio")}
  SIZING-OPTION            = ADJUST-LOADS
  TERMINAL-TYPE            = {#si(#pa("Zone-Terminal-Type"), "ZONE",
                           "TERMINAL-TYPE")}
  SPACE                    = "South Perim Spc (G.S1)"
  ..
```

C.5. System 7- VAV WITH REHEAT

```
"Sys1 (VAVS) (G)"          = SYSTEM
  TYPE                     = VAVS
  HEAT-SOURCE              = NONE
  ZONE-HEAT-SOURCE         = {#si(#pa("Zone-Heat-Source"), "SYSTEM" , "ZONE-
                           HEAT-SOURCE")}
  BASEBOARD-SOURCE         = NONE
  SIZING-RATIO             = {#pa("System-Sizing-Ratio")}
```

```
  COOL-SIZING-RATI          = {#PA("Cool-Sizing-Ratio")}
  MAX-SUPPLY-T              = 95
  MIN-SUPPLY-T              = {#pa("Min-SAT")}
  COOL-RESET-SCH            = "Sys1 (VAVS) (G) CRS"
  COOL-CONTROL              = {#si(#pa("SAT-Reset") , "SYSTEM" , "COOL-
CONTROL")}
  ECONO-LIMIT-T             = {#PA("Econo-High-Limit")}
  COOL-MAX-RESET-T          = {#PA("Max-Reset-Temp")}
  MIN-OUTSIDE-AIR           = 0.134
  OA-CONTROL                = {#si(#pa("OA-Control"), "SYSTEM" , "OA-CONTROL")}
  FAN-SCHEDULE              = "Sys1 (VAVS) Fan Sch"
  FAN-CONTROL               = {#SI(#PA("Fan-Control"), "SYSTEM" , "FAN-
CONTROL")}
  RETURN-KW/FLOW            = 0.0003
  NIGHT-CYCLE-CTRL          = {#si(#pa("Night-Cycle-Control"), "SYSTEM" , "NIGHT-
                            CYCLE-CTRL")}
  FAN-EIR-FPLR              = {#si(#pa("Fan-Curve"), "SYSTEM" , "FAN-EIR-FPLR")}
  RETURN-FAN-CONTR          = {#SI(#PA("Fan-Control"), "SYSTEM" , "FAN-
CONTROL")}
  RETURN-EIR-FPLR           = {#si(#pa("Fan-Curve"), "SYSTEM" , "FAN-EIR-FPLR")}
  REHEAT-DELTA-T            = {#PA("Reheat-Delta-T")}
  MIN-FLOW/AREA             = {#PA("VAV-Min-Flow")}
  HW-VALVE-TYPE             ={#si(#pa("HW-Valve-Type") , "SYSTEM" , "HW-VALVE-
TYPE")}
  CHW-VALVE-TYPE            = {#si(#pa("CHW-Valve-Type") , "SYSTEM" , "CHW-
                            VALVE TYPE")}
  CHW-LOOP                  = "ASHRAE-CHW-Loop"
  COOL-CTRL-RANGE           = {#pa("Throttling-R")}
  ZONE-HW-LOOP              = "ASHRAE-HW-Loop"
  ..
```

$Zone Input Template

```
"South Perim Zn (G.S1)"      = ZONE
  TYPE                      = CONDITIONED
  FLOW/AREA                 = {#pa(“VAV-Min-Flow”)}
  OA-FLOW/PER               = 15
  DESIGN-HEAT-T             = 72
  HEAT-TEMP-SCH             = "GndCor Sys1 Heat Sch"
  DESIGN-COOL-T             = {#pa("Zone-Design-T")}
  COOL-TEMP-SCH             = "GndCor Sys1 Cool Sch"
  SIZING-OPTION             = ADJUST-LOADS
  TERMINAL-TYPE             = SVAV
  SPACE                     = "South Perim Spc (G.S1)"
  ..
```

C.6. System 8- VAV WITH PFP BOXES

$SYSTEM Input Template

```
"Sys1 (PIU) (G)"            = SYSTEM
  TYPE                      = PIU
  HEAT-SOURCE               = ELECTRIC
```

```
  BASEBOARD-SOURCE         = NONE
  SIZING-RATIO             = {#pa("System-Sizing-Ratio")}
  COOL-SIZING-RATI         = {#PA("Cool-Sizing-Ratio")}
  COOL-SOURCE              = ELEC-DX
  MAX-SUPPLY-T             = {#PA("Heat-Set-T")}
  MIN-SUPPLY-T             = {#pa("Min-SAT")}
  COOL-RESET-SCH           = "Sys1 (PIU) (G) CRS"
  COOL-CONTROL             = {#si(#pa("SAT-Reset") , "SYSTEM" , "COOL-
CONTROL")}
  ECONO-LIMIT-T            = {#PA("Econo-High-Limit")}
  COOL-MAX-RESET-T         = {#PA("Max-Reset-Temp")}
  MIN-OUTSIDE-AIR          = 0.134
  OA-CONTROL               = {#si(#pa("OA-Control"), "SYSTEM" , "OA-CONTROL")}
  FAN-SCHEDULE             = "Sys1 (VAVS) Fan Sch"
  FAN-CONTROL              = {#SI(#PA("Fan-Control"), "SYSTEM" , "FAN-
CONTROL")}
  RETURN-KW/FLOW           = 0.0003
  NIGHT-CYCLE-CTRL         = {#si(#pa("Night-Cycle-Control"), "SYSTEM" , "NIGHT-
                           CYCLE-CTRL")}
  FAN-EIR-FPLR             = {#si(#pa("Fan-Curve"), "SYSTEM" , "FAN-EIR-FPLR")}
  RETURN-FAN-CONTR         = {#SI(#PA("Fan-Control"), "SYSTEM" , "FAN-
CONTROL")}
  RETURN-EIR-FPLR          = {#si(#pa("Fan-Curve"), "SYSTEM" , "FAN-EIR-FPLR")}
  REHEAT-DELTA-T           = {#PA("Reheat-Delta-T")}
  MIN-FLOW/AREA            = {#PA("VAV-Min-Flow")}
  COOL-CTRL-RANGE          = {#pa("Throttling-R")}
  ..
$ZONE Level Inputs
"South Perim Zn (G.S1)"    = ZONE
  TYPE                     = CONDITIONED
  MIN-FLOW-RATIO           = {#pa("Zone-Min-Flow-Ratio")}
  FLOW/AREA                = {#pa("VAV-Min-Flow")}
  OA-FLOW/PER              = 15
  DESIGN-HEAT-T            = 72
  HEAT-TEMP-SCH            = "GndCor Sys1 Heat Sch"
  DESIGN-COOL-T            = {#pa("Zone-Design-T")}
  COOL-TEMP-SCH            = "GndCor Sys1 Cool Sch"
  ZONE-FAN-KW/FLOW         = {#pa("Zone-Fan-Power")}
  ZONE-FAN-T-SCH           = "GndCor Sys1 Cool Sch"
  ZONE-FAN-RATIO           = {#pa("Zone-Fan-Ratio")}
  SIZING-OPTION            = ADJUST-LOADS
  TERMINAL-TYPE            = {#si(#pa("Zone-Terminal-Type"), "ZONE",
                           "TERMINAL-TYPE")}
  SPACE                    = "South Perim Spc (G.S1)"
  ..
```

APPENDIX D

GLOBAL PARAMETERS DEFINED

Appendix D lists out the global parameters for all requirements for Appendix G&D. The ECCO procedure (Calculated by ECCO or pre-defined in accordance to requirements) is specified, along with the parameter type. (String or numeric).

Table 90

Global Parameters for Standard 90.1 and 189.1 Performance Rating Method

IMPLEMENTATION IN ECCO							
	Description	Calculated/ Pre-Defined	Parameter Name	P-Type	P-Type	ASHRAE 90.1 - 2007	ASHRAE -189.1
	PROPOSED BUILDING PARAMETERS (For 189.1 Analysis)						
1	Skylight Multiplier (5% Area - Defined in proposed)	Calculated	Skylight-Multiplier	Numeric	Float	0.9	0.9
2	Daylighting Controls (One sensor, 40fc)	Pre-Defined	Daylight-Sensor	Symbolic	String	NO	YES
	GENERAL PARAMETERS : BUILDING ENVELOPE						
1	Orientation (All 4 for Baseline)	Pre-Defined	Orientation	Numeric	Float	0	0
2	Roof Continuous Insulation	Pre-Defined	Roof-CI	Numeric	Float	20	25
3	Roof Absorptance value	Pre-Defined	Roof-Absorptance	Numeric	Float	0.7	0.55
4	Above Grade Walls, Effective R value for Cavity Insulation	Pre-Defined	R-Eff-Wall	Numeric	Float	8.1	8.1
5	Above Grade Walls - Continuous Insulation	Pre-Defined	R-CI-Wall	Numeric	Float	0.01	6.5
6	Floor Perimeter Insulation	Pre-Defined	EFloor-R	Numeric	Float	16.2	26.2
7	Opaque Door U Value	Pre-Defined	Door-U-Value	Numeric	Float	0.7	0.6
8	WWR Multiplier- have to assure that area of window not less than area of frame	Calculated	WWR-Multiplier	Numeric	Float	0.40	0.40
9	Glass U Value	Pre-Defined	Glass-U-Value	Numeric	Float	0.75	0.75
10	Glass SHGC	Pre-Defined	Glass-SHGC	Numeric	Float	0.25	0.25

11	Glass Visible Transmittance	Pre-Defined	Glass-T-Vis	Numeric	Float	0.9	0.9
	Project Specific Input (Determined by ECCO)						
1	Skylight Multiplier	Calculated	Skylight-Multiplier	Numeric	Float	0.9	0.9
2	Skylights-U Value.	Calculated	Skylight-U-Value	Numeric	Float	1.98	1.19
3	Skylights- SHGC	Calculated	Skylight-SHGC	Numeric	Float	0.36	0.19
	189.1 Specific Requirements						
1	Overhang Depth Multiplier	Pre-Defined	PF	Numeric	Float	0.00	0.50
	GENERAL PARAMETERS: INTERNAL LOADS						
1	LPD	Pre-Defined	LPD	Numeric	Float	1	0.9
	189.1 Specific Requirements						
1	Equipment Power Density - Reduction	Pre-Defined	EPD	Numeric	Float	0.01	0.10
2	Occupancy Sensors	Pre-Defined	Occ-Sensor	Numeric	Float	0.01	0.10
3	Daylighting Controls	Pre-Defined	Daylight-Sensor	Symbolic	String	NO	YES
4	Infiltration (CFM/SQ.FT)	Pre-Defined	Infil-Reduction	Numveric	Float	0.05	0.0468 - (0.0468* 0.25)
	ECONOMIZER AND OUTSIDE AIR						
1	OA Control for Air Side Economiser Cycle	Pre-Defined	OA-Control	Symbolic	String	OA-TEMP	DUAL-TEMP
2	"Econo-High-Limit"=75	Pre-Defined	Econo-High-Limit	Numeric	Float	75	75
	FANS						
1	Night Cycle Control	Pre-Defined	Night-Cycle-Control	Symbolic	String	CYCLE-ON-ANY	CYCLE-ON-ANY
	DOMESTIC HOT WATER						
1	DHW Heat Input Ratio	Calculated	DHW-HIR	Numeric	Float	1.25	1.24
2	Tank-UA	Calculated	Tank-UA	Numeric	Float	11.18	11.18
	189.1 Specific Requirements						

3	Tank Storage Capacity	Calculated	Tank-Storage	Numeric	Float	NA	10% less than Proposed
	System Specific Requirements- System 3						
	Stage I - Building Loads						
1	System Type	NR	NR	NR	NR	PSZ	PSZ
2	Cool Source	NR	NR	NR	NR	Need Not be Assigned: Default - Electric	
3	Heat Source	NR	NR	NR	NR	FURNACE	FURNACE
	Stage II - Energy Performance						
1	Fan System Operation (G3.1.2.4)	Pre-Defined	Fan-Operation	Symbolic	String	CONTINUOUS	CONTINUOUS
2	Fan Control	Calculated	Fan-Control	Symbolic	String	CONSTANT-VOLUME	CONSTANT-VOLUME
3	Cooling Sizing Ratio	Pre-Defined	Cool-Sizing-Ratio	Numeric	Float	1.15	1.15
4	Heating Sizing Ratio	Pre-Defined	Heat-Sizing-Ratio	Numeric	Float	1.25	1.25
	Stage III- Energy Performance						
1	Minimum Outside Air	NR	NR	Is calculated by ECCO and assigned by the user.			
2	Cooling Electric Input Ratio	NR	NR	Is calculated by ECCO and assigned by the user.			
3	Furnace Heat Input Ratio	NR	NR	Is calculated by ECCO and assigned by the user.			
4	System Fan Power	NR	NR	Is calculated for individual systems using Fan-Power-Calculator, and is assigned by the user.			

	System Specific Requirements- System 4						
	Stage I - Building Loads						
1	System Type	NR	NR	NR	NR	PSZ	PSZ
2	Cool Source	NR	NR	NR	NR	Need Not be Assigned : Default - Electric	
3	Heat Source	NR	NR	NR	NR	HEAT-PUMP	HEAT-PUMP
	Stage II - Sizing Runs						
1	Cooling Sizing Ratio	Pre-Defined	Cool-Sizing-Ratio	Numeric	Float	1.15	1.15
2	Heating Sizing Ratio	Pre-Defined	Heat-Sizing-Ratio	Numeric	Float	1.25	1.25
3	Fan System Operation (G3.1.2.4)	Pre-Defined	Fan-Operation	Symbolic	String	CONTINUOUS	CONTINUOUS
4	Minimum Supply Air Temperature	Pre-Defined	Min-SAT	Numeric	Float	55	55
5	Zone Design Temperature - Cooling	Pre-Defined	Zone-Design-T	Numeric	Float	75	75
6	Auxiliary Heat Source	Calculated	Elec-Aux-Heat	Symbolic	String	ELECTRIC	ELECTRIC
7	Reheat Delta T	Pre-Defined	Reheat-Delta-T	Numeric	Float	40	40
8	Maximum Supp-HP Supply Temperature	Pre-Defined	Max-HP-T	Numeric	Float	40	40
9	Minimum Supp-HP Supply Temperature	Pre-Defined	Min-HP-T	Numeric	Float	10	10
10	Thermostat Control	Pre-Defined	Therm-Ctrl	Symbolic	String	PROPORTIONAL	PROPORTIONAL
11	Fan Control	Calculated	Fan-Control	Symbolic	String	CONSTANT-VOLUME	CONSTANT-VOLUME
12	Throttling Rnage or cool control range	Pre-Dedined	Throttling-Range	Numeric	Float	2	2

	Stage III- Energy Performance						
1	Minimum Outside Air	NR	NR	Is calculated by ECCO and assigned by the user.			
5	Cooling Electric Input Ratio	NR	NR	Is calculated by ECCO and assigned by the user.			
6	Heat Pump Electric Input Ratio			Is calculated by ECCO and assigned by the user.			
7	System Fan Power	NR	NR	Is calculated for individual systems using Fan-Power-Calculator, and is assigned by the user.			
	System Specific Requirements- System 5						
	Stage I - Building Loads						
1	System Type	NR	NR	NR	NR	PVAV	PVAV
2	Cool Source	NR	NR	NR	NR	Need Not be Assigned : Default - Electric	
3	Heat Source	NR	NR	NR	NR	HOT-WATER	HOT-WATER
4	System-Hot Water Loop Assignment	NR	NR	NR	NR	ASHRAE-HW-Loop	ASHRAE-HW-Loop
	Stage II - Sizing Runs						
1	Cooling Sizing Ratio	Pre-Defined	Cool-Sizing-Ratio	Numeric	Float	1.15	1.15
2	Minimum Supply Air Temperature	Pre-Defined	Min-SAT	Numeric	Float	55	55
3	Zone Design Temperature - Cooling	Pre-Defined	Zone-Design-T	Numeric	Float	75	75
4	Zone Heat Source	Pre-Defined	Zone-Heat-Source	Symbolic	String	HOT-WATER	HOT-WATER
5	Reheat Delta T	Pre-Defined	Reheat-Delta-T	Numeric	Float	40	40
6	Zone Entering Maximum Supply	Pre-Defined	Heat-Set-T	Numeric	Float	95	95

	Temperature						
7	SAT Reset- Cool-Control - Warmest	Pre-Defined	SAT-Reset	Symbolic	String	WARMEST	WARMEST
8	Reset by 5F (Minimum 55F, Max 60F)	Pre-Defined	Max-Reset-Temp	Symbolic	String	60	60
9	Throttling Range	Pre-Defined	Throttling-R	Numeric	Float	4	4
A	**Boiler**						
1	Boiler Capacity Ratio	Calculated	Boiler-Capacity-Ratio	Numeric	Float	0.5	0.5
B	**Pump Definition**						
1	HW Pump - Speed Control CFA<120,000 sq.ft - 1 speed. Else Var-Speed	Calculated	HW-Pump-Cap-Ctrl	Symbolic	String	ONE-SPEED-PUMP	ONE-SPEED-PUMP
C	**Fans**						
1	VAV Minimum Flow Setpoints	Calculated	VAV-Min-Flow	Numeric	Float	0.4	0.4
2	VAV Fan Part Load Performance	Pre-Defined	Fan-Curve	Symbolic	String	Appendix G Part Load Curve	Appendix G Part Load Curve
3	Fan Control	Calculated	Fan-Control	Symbolic	String	FAN-EIR-FPLR	FAN-EIR-FPLR
	Stage III- Energy Performance						
1	Minimum Outside Air	NR	NR	Is calculated by ECCO and assigned by the user.			
2	Cooling Electric Input Ratio	NR	NR	Is calculated by ECCO and assigned by the user.			
3	System Fan Power	NR	NR	Is calculated for individual systems using Fan-Power-Calculator, and is assigned by the user.			

4	Boiler Efficiency	NR	NR	Is calculated by ECCO and assigned by the user.			
5	Heat Sizing Ratio	NR	NR	Is calculated by ECCO and assigned by the user.			
	System Specific Requirements- System 6						
	Stage I - Building Loads						
1	System Type	NR	NR	NR	NR	PIU	PIU
2	Cool Source	NR	NR	NR	NR	ELEC-DX	ELEC-DX
3	Heat Source	NR	NR	NR	NR	ELECTRIC	ELECTRIC
	Stage II - Sizing Runs						
1	Cooling Sizing Ratio	Pre-Defined	Cool-Sizing-Ratio	Numeric	Float	1.15	1.15
2	Heating Sizing Ratio	Pre-Defined	Heat-Sizing-Ratio	Numeric	Float	1.25	1.25
3	Minimum Supply Air Temperature	Pre-Defined	Min-SAT	Numeric	Float	55	55
4	Zone Design Temperature - Cooling	Pre-Defined	Zone-Design-T	Numeric	Float	75	75
5	Zone Heat Source	Pre-Defined	Zone-Heat-Source	Symbolic	String	ELECTRIC	ELECTRIC
6	Reheat Delta T	Pre-Defined	Reheat-Delta-T	Numeric	Float	40	40
7	Heat-Set-T	Pre-Defined	Heat-Set-T	Numeric	Float	80	80
8	SAT Reset- Cool-Control - Warmest	Pre-Defined	SAT-Reset	Symbolic	String	WARMEST	WARMEST
9	Reset by 5F (Minimum 55F, Max 60F)	Pre-Defined	Max-Reset-Temp	Symbolic	String	60	60
	Fans						
1	VAV Fan Part Load Performance	Pre-Defined	Fan-Curve	Symbolic	String	Appendix G Part Load Curve	Appendix G Part Load Curve
2	Fan Control	Calculated	Fan-Control	Symbolic	String	FAN-	FAN-

						EIR-FPLR	EIR-FPLR
3	Zone Design Flow Ration	Pre-Defined	Zone-Fan-Ratio	Numeric	Float	0.5	0.5
4	Zone Fan Power	Pre-Defined	Zone-Fan-Power	Numeric	Float	0.00035	0.00035
5	Zone Minimum Flow	Pre-Defined	Zone-Min-Flow-Ratio	Numeric	Float	0.3	0.3
6	Terminal Type	Pre-Defined	Zone-Terminal-Type	Symbolic	String	PARALLEL-PIU	PARALLEL-PIU
	Stage III- Energy Performance						
1	Minimum Outside Air	NR	NR	Is calculated by ECCO and assigned by the user.			
5	Cooling Electric Input Ratio	NR	NR	Is calculated by ECCO and assigned by the user.			
6	System Fan Power	NR	NR	Is calculated for individual systems using Fan-Power-Calculator, and is assigned by the user.			
	System Specific Requirements- System 7						
	Stage I - Building Loads						
1	System Type	NR	NR	NR	NR	VAVS	VAVS
2	Cool Source	NR	NR	NR	NR	CHILLED-WATER	CHILLED-WATER
3	Heat Source	NR	NR	NR	NR	HOT-WATER	HOT-WATER
4	System- CHW Loop Assignment	Pre-Defined	System-CHW-Loop	Symbolic	String	ASHRAE-CHW-Loop	ASHRAE-CHW-Loop
5	System-HW Loop Assignment	Pre-Defined	System-HW-Loop	Symbolic	String	ASHRAE-HW-Loop	ASHRAE-HW-Loop

	Stage II - Sizing Runs						
1	Cooling Sizing Ratio	Pre-Defined	Cool-Sizing-Ratio	Numeric	Float	1.15	1.15
2	Minimum Supply Air Temperature	Pre-Defined	Min-SAT	Numeric	Float	55	55
3	Zone Design Temperature - Cooling	Pre-Defined	Zone-Design-T	Numeric	Float	75	75
4	Zone Heat Source	Pre-Defined	Zone-Heat-Source	Symbolic	String	HOT-WATER	HOT-WATER
5	Reheat Delta T	Pre-Defined	Reheat-Delta-T	Numeric	Float	40	40
6	Zone Entering Maximum Supply Temperature	Pre-Defined	Heat-Set-T	Numeric	Float	95	95
7	SAT Reset- Cool-Control - Warmest	Pre-Defined	SAT-Reset	Symbolic	String	WARMEST	WARMEST
8	Reset by 5F (Minimum 55F, Max 60F)	Pre-Defined	Max-Reset-Temp	Symbolic	String	60	60
9	Valve (For Chilled Water System)	Pre-Defined	CHW-Valve-Type	Symbolic	String	TWO-WAY	TWO-WAY
A	**Schedule Definition**						
	HW-Reset-ASHRAE-Sch	INP File					
	CHW-Reset-ASHRAE-Sch	INP File					
	Process-Load-Annual	INP File					
B	**Pump Definition**						
	ASHRAE-CHW-Loop-Pump	INP File					
	ASHRAE-HW-Loop-Pump	INP File					
	ASHRAE-CW-Loop-Pump	INP File					
C	**Circulation Loops Definition**						
	ASHRAE-HW-Loop	INP File					
	ASHRAE-CHW-Loop	INP File					
	ASHRAE-CHW-Sec-Loop	INP File					
	ASHRAE-CW-Loop	INP File					
D	**Boilers**						

1	Boiler Capacity Ratio	Calculated	Boiler-Capacity-Ratio	Numeric	Float	0.5	0.5
E	**Chiller**						
1	Type of Chiller. Depends on Cooling Load.	Calculated	Chiller-Type	Symbolic	String	ELEC-SCREW	ELEC-SCREW
2	Number of Chillers/ Chiller Capacity Ratio	Calculated	Chiller-Capacity-Ratio	Numeric	Float	0.5	0.5
A	**Pumps**						
1	HW Pump - Speed Control	Calculated	HW-Pump-Cap-Ctrl	Symbolic	String	ONE-SPEED-PUMP	ONE-SPEED-PUMP
2	CHW Pump Speed Control	Calculated	Sec-Pump-Cap-Ctrl	Symbolic	String	VAR-SPEED-PUMP	ONE-SPEED-PUMP
B	**Heat Rejection**						
1	HR-Fan-Control	Pre-Defined	HR-Fan-Control	Symbolic	String	TWO-SPEED-FAN	TWO-SPEED-FAN
2	Cooling Tower EIR	Calculated	Cooling-Tower-EIR	Numeric	Float	0.013	0.013
3	Number of Cells	Calculated	Cells-Number	Numeric	Float	2	2
C	**Fans**						
1	Fan Control (According to System Type - CV (3,4) or VAV - 5-8)	Calculated	Fan-Control	Symbolic	String	FAN-EIR-FPLR	FAN-EIR-FPLR
2	VAV Minimum Flow Setpoints	Calculated	VAV-Min-Flow	Numeric	Float	0.4	0.4
3	VAV Fan Part Load Performance	Pre-Defined	Fan-Curve	Symbolic	String	Appendix G Part Load	Appendix G Part Load

						Curve	Curve
	Stage III- Energy Performance						
1	Minimum Outside Air	NR	NR	Is calculated for individual systems, and is assigned by the user.			
2	System Fan Power	NR	NR	Is calculated for individual systems using Fan-Power-Calculator, and is assigned by the user.			
3	Chiller EIR	NR	NR	Is calculated by ECCO and assigned by the user.			
4	Boiler HIR	NR	NR	Is calculated by ECCO and assigned by the user.			
5	Boiler Sizing Ratio	NR	NR	Is calculated and assigned to the circulation loop.			
	System Specific Requirements- System 8						
	Stage I - Building Loads						
1	System Type	NR	NR	NR	NR	PIU	PIU
2	Cool Source	NR	NR	NR	NR	CHILLED -WATER	CHILLED -WATER
3	Heat Source	NR	NR	NR	NR	ELECTRI C	ELECTRI C
4	System- CHW Loop Assignment	Pre-Defined	System-CHW-Loop	Symbolic	String	ASHRAE -CHW-Loop	ASHRAE -CHW-Loop
	Stage II - Sizing Runs						
1	Cooling Sizing Ratio	Pre-Defined	Cool-Sizing-Ratio	Numeric	Float	1.15	1.15
2	Heating Sizing Ratio	Pre-Defined	Heat-Sizing-Ratio	Numeric	Float	1.25	1.25
3	Minimum Supply Air Temperature	Pre-Defined	Min-SAT	Numeric	Float	55	55
4	Zone Design Temperature - Cooling	Pre-Defined	Zone-Design-T	Numeric	Float	75	75
5	Zone Heat Source	Pre-Defined	Zone-Heat-	Symbolic	String	ELECTRI	ELECTRI

			Source			C	C
6	Reheat Delta T	Pre-Defined	Reheat-Delta-T	Numeric	Float	30	30
7	Zone maximum supply temperature	Pre-Defined	Heat-Set-T	Numeric	Float	95	95
8	SAT Reset- Cool-Control - Warmest	Pre-Defined	SAT-Reset	Symbolic	String	WARMEST	WARMEST
9	Reset by 5F (Minimum 55F, Max 60F)	Pre-Defined	Max-Reset-Temp	Symbolic	String	60	60
10	Valve (For Chilled Water System)	Pre-Defined	CHW-Valve-Type	Symbolic	String	TWO-WAY	TWO-WAY
A	**Schedule Definition**						
	CHW-Reset-ASHRAE-Sch	INP File					
	Process-Load-Annual	INP File					
B	**Pump Definition**						
	ASHRAE-CHW-Loop-Pump	INP File					
	ASHRAE-CHW-Sec-Loop-Pump	INP File					
	ASHRAE-CW-Loop-Pump	INP File					
C	**Circulation Loops Definition**						
	ASHRAE-CHW-Loop	INP File					
	ASHRAE-CHW-Sec-Loop	INP File					
	ASHRAE-CW-Loop	INP File					
D	**Pumps**						
1	Zone Fan Power	Pre-Defined	Zone-Fan-Power	Numeric	Float	0.00035	0.00035
2	Zone Minimum design flow ratio	Pre-Defined	Zone-Min-Flow-Ratio	Numeric	Float	0.3	0.3
3	Terminal Type	Pre-Defined	Zone-Terminal-Type	Symbolic	String	PARALLEL-PIU	PARALLEL-PIU
E	**Chillers**						
1	Number of Chillers/ Chiller Capacity Ratio	Calculated	Chiller-Capacity-Ratio	Numeric	Float	0.65	0.65

2	Type of Chiller	Calculated	Chiller-Type	Symbolic	String	ELEC-SCREW	ELEC-SCREW
	Heat Rejection						
1	HR-Fan-Control	Pre-Defined	HR-Fan-Control	Symbolic	String	TWO-SPEED-FAN	TWO-SPEED-FAN
2	Cooling Tower EIR	Calculated	Cooling-Tower-EIR	Numeric	Float	0.013	0.013
3	Number of Cells	Calculated	Cells-Number	Numeric	Float	2	2
F	**Fans**						
1	VAV Fan Part Load Performance	Pre-Defined	Fan-Curve	Symbolic	String	Appendix G Part Load Curve	Appendix G Part Load Curve
2	Fan Control (According to System Type - CV (3,4) or VAV - 5-8)	Calculated	Fan-Control	Symbolic	String	FAN-EIR-FPLR	FAN-EIR-FPLR
3	VAV Minimum Flow Setpoints	Calculated	VAV-Min-Flow	Numeric	Float	0.4	0.4
4	Zone Fan Ratio	Pre-Defined	Zone-Fan-Ratio	Numeric	Float	0.5	0.5
5	Zone Fan Power	Pre-Defined	Zone-Fan-Power	Numeric	Float	0.00035	0.00035
6	Zone Minimum design flow ratio	Pre-Defined	Zone-Min-Flow-Ratio	Numeric	Float	0.3	0.3
7	Terminal Type	Pre-Defined	Zone-Terminal-Type	Symbolic	String	PARALLEL-PIU	PARALLEL-PIU
	Stage III- Energy Performance						
1	Minimum Outside Air	NR	NR	Is calculated by ECCO and assigned by the user.			
2	System Fan Power	NR	NR	Is calculated for individual systems using Fan-Power-Calculator, and is assigned by			

				the user.
3	Chiller EIR	NR	NR	Is calculated by ECCO and assigned by the user.

APPENDIX E

SPREADSHEET TOOL

Consult Attached File for the ECCO Tool