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DEVELOPMENT OF A WEB-BASED, CODE-COMPLIANT ASHRAE 90.1-1999 COMMERCIAL SIMULATION FOR TEXAS

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ABSTRACT

This paper describes the development of a web-based, code-compliant ASHRAE Standard 90.1-1999 commercial simulation for Texas. Included in the paper is a description of the software and database platform used in the web application and how this software is attached to the DOE-2 legacy software running on a cluster of servers. This tool will be used by commercial builders in Texas to check code compliance of new commercial construction for specific building types.

BACKGROUND

In 2001, as part of the Texas Emissions Reduction Plan (TERP), the Texas State Legislature adopted the 2000 International Energy Conservation Code (IECC), as amended by the 2001 Supplement (IECC, 2000; 2001), which remains as the state building code for those counties determined by the U.S.E.P.A. to be non-attainment and affected counties[1]. In 2001, thirty-eight counties in Texas were designated by the EPA as either non-attainment or affected areas. In 2003, three additional counties were classified as affected counties, bringing the total to forty-one counties (sixteen non-attainment and twenty-five affected counties).

In Chapter 7 of the 2001 IECC ASHRAE Standard 90.1-1999 is referenced as an equivalent standard to the commercial code contained in Chapter 8 of the IECC. This paper provides a detailed discussion of the procedures and simulation tools that have been developed to calculate ASHRAE Standard 90.1-1999 code-compliant commercial construction for an office building, as well as Standard 90.1-1989 as a base-case model. To accomplish this, a flexible simulation procedure was created for a general commercial office building configuration, which could be used both for office and retail end-uses. The simulation models were then modified to accommodate the different scenarios of construction and HVAC equipment typically used in the commercial sector. The simulation models, created with the DOE-2.1e simulation program (LBNL, 1993a; 1993b), were then linked to a web-based graphic user interface and the U.S.E.P.A.'s eGRID[2] to convert the energy savings to NOx emissions reduction.

In the original development of this web-based program (Ahmad et al., 2005), the code-compliant simulations were used to calculate air pollution savings. To accomplish this, three simulations were used for the assessment since the EPA only allows the Texas Commission on Environmental Quality (TCEQ) to claim NOx emissions reductions credits from those measures that were implemented after the September 2001 start date for the TERP. For commercial buildings, office or retail, a complete set of comparisons includes three simulation runs: 1) a Pre-code run based on the construction characteristics required by ASHRAE Standard 90.1-1989 (ASHRAE, 1989), 2) a Code run based on the minimum construction requirement of ASHRAE 90.1-1999 (ASHRAE, 1999), and 3) the user input.

The code characteristics for the office and retail are based on the minimum requirements according to climate zone. The HVAC requirements are selected according to the end use, building size and building loads. Without simplification, in order to run a complete code and pre-code simulation, at least seven DOE-2 runs are required -- four for the code run and three for the pre-code run, respectively. Additional runs were then used for the user's analysis.

The code and pre-code envelope and glazing characteristics[3] were assigned according to the county

[1] The exception to this are Texas state agencies and, beginning in September 2008, Independent School Districts, which must comply with ASHRAE Standard 90.1 – latest edition, where the latest edition is interpreted to be the latest published full edition of ASHRAE Standard 90.1, which is currently ASHRAE Standard 90.1-2007.

[2] eGRID, is the EPA's Emissions and Generation Resource Integrated Database (Version 2). This publicly available database can be found at www.epa.gov/airmarkets/egrid/. The information in this table is from a special edition of the eGRID database, provided by Art Diem at the USEPA for the TCEQ for use with Senate Bill 5.

[3] To calculate the compliance for a building in a specific county, the calculator has to assume certain characteristics about the building that are compliant with 90.1-1989 and 90.1-1999. These

chosen by the user. In Table 1 (i.e., Harris County), it can be seen that the pre-code glazing U-factor is more stringent than the code requirements; therefore, no savings were attributed to this characteristic since the pre-code value would be used in both the code and pre-code simulation.

The original implementation of the web-based emissions calculator used measured weather data for 1999 from the National Oceanic and Atmospheric Administration (NOAA 1993), National Weather Service (NWS), packed into the TRY weather format for nine stations in Texas, to perform the energy simulations for the 41 non-attainment and affected counties. Weather files were assigned according to the counties chosen by the user according to the nearest weather station. For Harris County, measured weather data from Houston's Bush Intercontinental Airport was used.

The three sets of inputs were then processed through the DOE-2 simulation program to determine the varying levels of energy consumption of the building. The values of interest from the DOE-2 output were the annual and peak day electricity and gas consumption in kWh and Therms, respectively. These values from the user input were then compared with the output from the pre-code and code runs to determine the annual and peak day energy consumption savings. The electricity saving values were then processed through the EPA's eGRID to calculate the annual and peak day NOx emissions reduction number in pounds and tons. Natural gas savings were converted into NOx emissions using the EPA's emissions factors[4].

Office/Retail Input File

Tables in Ahmed et al. (2005) describe all the DOE-2 parameters that were required to generate the office simulation model in this analysis[5]. The parameters were divided into three major categories; LOADS, SYSTEMS, and PLANT[6]. The loads were then further divided into building, construction, space and shading parameters. The building parameters were used to define the location, orientation and the basic dimensions and layout of the building. The simulation model has the provision of only creating a four-sided building model with up to one-hundred stories with or without a basement. This portion of the input file also has the "building type" parameter which switches between the office and retail version of the inputs.

If a retail building is selected, then four additional parameters are activated that allow the retail store to be placed within a larger conditioned space. The switch between quick and thermal mass mode is fixed at quick construction for the current version[7]. This means that the current DOE-2 simulation is using ASHRAE pre-calculated weighting factors for the calculation of a code-complaint building[8].

The construction parameters include the material properties and U-values for the different components including the glazing properties and the window-to-wall area ratio. The user has the provision of entering different window areas for the different orientations. The upper limit on the window-to-wall ratio depends on the plenum height, i.e., the plenum height is added to the building section to calculate the maximum window-to-wall area ratio for that building. The maximum upper limit is 90%.

Table 1
Code & Pre-code Buildings for Harris County

Harris County	Fenestration Properties			Envelope Properties	
	U-Factor	SHGC	Window to Wall ratio (%)	Wall U-value	Roof U-value
ASHRAE 90.1 1989 ACP Table 8A - 10 (Requires Internal Load Density ILD)	1.15 Btu/hr-sq ft-F 6.53 W/(m^2. K)	0.61	23 (for ILD < 1.5) 18 (for 1.51 < ILD < 3) 15 (for ILD > 3)	0.15 Btu/hr-sq ft-F 0.85 W/(m^2. K) (Light weight)	0.066 Btu/hr-sq ft-F 0.37 W/(m^2. K)
ASHRAE 90.1 -1999 Table B-5 (Requires Window to Wall ratio %)	1.22 Btu/hr-sq ft-F 6.93 W/(m^2. K)	0.25	< 40%	0.124 Btu/hr-sq ft-F 0.70 W/(m^2. K) (Steel framed)	0.063 Btu/hr-sq ft-F 0.36 W/(m^2. K)
	1.22 Btu/hr-sq ft-F 6.93 W/(m^2. K)	0.17	> 40%	0.089Btu/hr-sq ft-F 0.51 W/(m^2. K) (wood framed)	

With regards to internal load, Table 6.5, 13.2 and 13.4 of ASHRAE Standard 90.1-1989 describes the requirements for lighting, occupancy and receptacles according to the square footage and end-use. ASHRAE Standard 90.1-1999 does not give requirements for occupancy and receptacles, but defines the lighting power density (LPD) requirements for different building types in Table 9.3.1.1. For example, Standard 90.1-1989 allows a LPD of 1.3 W/ft^2 (14 W/m^2) and 1.9 W/ft^2 (20.5 W/m^2) for office and retail, respectively.

characteristics include the budget building assumptions for the performance modeling and the prescriptive requirements for each county/climate zone.

4 EPA AP42 Project, published in 2003, www.epa.gov/ttn/chief/ap42/ap42supp.html.

5 Electronic copies of this paper can be obtained from the Energy System Laboratory, www.esl.tamu.edu, under the publications tab.

6 These categories were chosen to align the input with the DOE-2 BDL, which divides a building's description into LOADS, SYSTEMS and PLANT input files.

7 The "quick" and "thermal mass" modes are used to denote the use of pre-calculated ASHRAE weighting factors (quick), or Custom Weighting Factors (thermal mass). Future versions of the calculator are being developed to utilize the thermal mass mode, which requires layered walls and roof, as well as other factors.

8 The use of pre-calculated weighting factors has been shown to be problematic because of the impact of the thermal mass on the cooling and heating loads. For more information see the ESL's 2004 report to the TCEQ (Haberl et al., 2004).

The system parameters include the type of systems, the system capacity and the efficiencies of the system selected. In the original version, the user could choose from three kinds of systems: 1) a Variable Air Volume (VAV) system with a central HVAC plant, 2) a Packaged Variable Air Volume (PVAV) system, and 3) a Packaged Single Zone (PSZ) system with either gas or electric heating. The DHW heater can be either gas or electric. If the DHW heater is gas, then one pilot light is assumed at a fixed load of 500 Btu/hr (147 W).

System Simulation according to ASHRAE 90.1-1989

As previously mentioned, for the code and pre-code runs, several simulations needed to be performed in order to select the correct size and number of the HVAC equipment for both ASHRAE 90.1-1989 and 1999. Figure 1 shows the complete flow diagram of all the processes required to run an ASHRAE Standard 90.1-1989 performance-based simulation. Standard 90.1-1989 defines seven system types according to the type of building and conditioned floor area (ASHRAE 90.1-1989, Table 13-5). For office and retail, the system requirements were chosen according to the square footage (Table 2). Table 13-6 of ASHRAE Standard 90.1-1989 provides the requirements of the different system components.

For buildings with a central plant, the number and size of the chillers and boilers was determined by the simulated cooling and heating loads for the building (ASHRAE 90.1-1989, Table 13-6, Note 11). Equipment efficiencies were determined by the final size of each plant component. Therefore, in order to analyze an ASHRAE Standard 90.1-1989 code-compliant building with the DOE-2 simulation program, three simulations are run: 1) after choosing the system type from the building's conditioned area, the first simulation provides the peak heating and cooling load to allow for the number of chillers selected; 2) after the type and size of chiller is chosen, a second simulation is performed to choose the efficiency of the chiller; and 3) a third and final simulation is performed with the chosen chiller, boiler and domestic water heater.

The following example illustrates the procedures used to calculate the pre-code run (i.e., a building that is compliant with ASHRAE Standard 90.1-1989)[9]. In this analysis, an office building 122 ft x 122 ft (37 m x 37 m), 6-stories in height located in Houston, Texas, was used. To simulate a building that is compliant with ASHRAE Standard 90.1-1989, the building aspect ratio is first fixed at 2.5 to 1, with the longer side oriented with an east-west axis, yielding an equivalent footprint of 193 ft by 77 ft (59 m x 24 m). The envelope details for the building comply with the prescriptive requirements of Standard 90.1-1989 for Harris County (Table 1).

In Standard 90.1-1989, the specific values in Table 2 were chosen according to the Internal Load Density (ILD) which includes the occupancy, lighting and receptacle loads. For this building, the ILD due to occupancy, lighting and receptacles was obtained from Table 13-2, Section 6 and Table 13-4 of Standard 90.1-1989, yielding an occupancy density of 275 ft^2/person (26 m^2/person), the Lighting Power Density (LPD) was 1.57 W/ft^2 (17 W/m^2) and receptacle loads were 0.75 W/ft^2 (8 W/m^2). The resultant ILD density was then used to determine the window-to-wall area ratio (WWR) for the standard building that was used for the simulation. For this example, an 18% window-to-wall area was calculated for the building.

Since the total square footage was more than 75,000 ft^2 (6968 m^2), and the number of floors exceeded three, as shown in Table 2, the system should be a built-up VAV system with perimeter reheat. The remaining characteristics of the system, including fan control, static pressure and fan efficiencies, were taken from Table 13-6 of Standard 90.1-1989, where the values for supply and return static are 4.0 in. of WC (995 Pa) and 1.0 in. of WC (249 Pa), respectively. The required supply and return fan efficiencies were set at 61% and 32%, respectively, which are the combined efficiencies for the motor and the fan including the variable frequency drives.

For the first run, the system was auto-sized by the DOE-2 simulation to meet the peak heating and cooling load requirements for the whole-building, including the envelope characteristics and interior loads defined by Standard 90.1-1989. From DOE-2's verification report (PV-A), from the plant portion of the DOE-2 simulation output, the number and type of chillers were determined. For this example, the chiller size was 1.806 MMBtu/hr, which corresponds to 150.5 tons (529 kW). According to ASHRAE Standard 90.1-1989 (Table 13-6, Note 11), for cooling loads less than 175 tons (615 kW), a single reciprocating chiller should be used. Therefore, for the second simulation run, one reciprocating chiller was used and the simulation was run again to determine a more exact size of the one chiller.

The results of the second run were then used to determine the efficiency of the chiller, size and efficiency of the boiler and DHW heater. For a

[9] The user can also perform parametrics, for example, varying the width and length of the building to see if there is a difference in energy use. Additional details about this example can be found in Ahmed et al. (2005).

reciprocating chiller between 150 and 300 tons (528 and 1055 kW), Standard 90.1-1989 requires that the COP is 4.2 (Table 10-7). The boiler size from the second run was 1,241,000 Btu/hr (364 kW), which corresponds to an efficiency of 80% for boiler sizes > 300,000 Btu/hr (88 kW) (Table 10-8). For the gas-fired domestic water heater, if the rating is less than 75,000 Btu/hr (22 kW), the energy factor is determined from the NAECA requirement (NAECA, 1987): Energy Factor = 0.62 - 0.0019 x V, where V = storage capacity of the tank in gallons. For this example, the storage capacity of the domestic water heater was taken as 75 gallons[10] (284 L), which yielded an energy factor of 0.4775.

Table 2
System requirements according to the total conditioned floor area for ASHRAE-90.1 1989

Building Type	System
Office	
a) ≤ 20,000 ft^2 (1,858 m^2)	Packaged roof top single zone system
b) ≥ 20,000 ft^2 (1,858 m^2) and either ≤ 3 floors or ≤ 75,000 ft^2 (6,968 m^2)	Packaged roof top VAV with perimeter reheat
c) > 3 floors or > 75,000 ft^2 (6,968 m^2)	Built up central VAV with perimeter reheat
Retail	
a) ≤ 50,000 ft^2 (4,645 m^2)	Packaged roof top single zone or air-handler per zone with central plant
b) > 50,000 ft^2 (4,645 m^2)	Packaged roof top VAV with perimeter reheat or built up central VAV with perimeter reheat

The efficiencies of the chiller, boiler and domestic water heater were entered into the DOE-2 simulation using the DOE-2 keywords: ELEC-INPUT-RATIO, HW-BOILER-HIR and DHW-HIR[11]. These values were then updated in the input file to complete the system selection process according to ASHRAE 90.1-1989. The annual energy consumption from this third run, which included the correctly-sized systems according to ASHRAE Standard 90.1-1989, was then used to determine the pre-code energy use of the building.

The variations from the first to third simulations of the Standard 90.1-1989 simulation, which included the change in the system sizing, type of equipment and equipment efficiency, reduced the cooling consumption by approximately 25% compared to the first run[12]. This reduction is from the change in the chiller type from centrifugal to reciprocating, and reflects the difference in efficiency factors. The third run showed an increase in cooling energy use of about 15% compared to the second run, which reflected a change in the default COP of 5 that was reset to the required COP of 4.2 for the chosen chiller. Heating equipment efficiency was changed in the third simulation to match the requirements of Standard 90.1-1989, which resulted in the decreased heating consumption of approximately 10%. In the third run, the domestic hot water consumption increased by 20%. This was caused by the change in the domestic water heating efficiency, which was reset to the required 47.75% from the default of 75%.

System Simulation According to ASHRAE 90.1-1999

As expected, the requirements for ASHRAE Standard 90.1-1999 are almost completely different from ASHRAE Standard 90.1-1989. The complete process flow for simulating Standard 90.1-1999 is shown in Figure 2. In difference to the Standard 90.1-1989, Standard 90.1-1999 does not specify the type of system according the to the total conditioned floor area of the building. Instead, Standard 90.1-1999 assigns the system type according to the information provided in Figure 11.4.3. Also, Standard 90.1-1999 has a lower limit of 25 hp (19 kW) on the VSD fan size, below which variable inlet vanes are used to meet the VAV specification. (Table 11.4.3.A, Note 4). In a similar fashion as Standard 90.1-1989, Standard 90.1-1999 chooses the number, type and efficiency of the chiller according to the peak building cooling load (Table 11.4.3A to 11.4.3C), with efficiencies determined by sequencing the runs for each plant component.

Using this approach, an ASHRAE Standard 90.1-1999 code-compliant simulation is completed in four simulations: 1) The first run determines the peak building cooling load that is used to determine the number of chillers and boilers, and the size and type of fans; 2) the second simulation then uses this information to determine the size of the chillers from which the type of chiller is chosen; 3) in the third run, the number and type of chiller(s) are fixed and the size determined again by DOE-2 to allow for the efficiency to be determined; and 4) in the fourth run, the number, type, size and efficiency of the fans, chillers, boilers, and domestic water heating equipment are fixed, yielding the total annual energy use for all equipment complying with Standard 90.1-1999.

In difference to Standard 90.1-1989, the physical characteristics of the building are input as-is into the Standard 90.1-1999 simulation, i.e., 122 ft x 122 ft (37 m x 37 m), 6-story building, oriented North-South, to perform the simulation, since Standard 90.1-1999 does not require a specific aspect ratio and orientation[13]. For

[10] This is the default value from the USDOE's COMCHECK program 1.1, release 2 (USDOE, 2003).
[11] Values for equipment quadratics use the appropriate values from the COMCHECK program 1.1, release 2.
[12] Graphs showing these changes can be found in Ahmed et al., 2005.

[13] Standard 90.1-1999 requires that the budget building have the same orientation and aspect ratio as the proposed building, which was assumed to be a square building oriented so each façade faced N, S, E, W.

this example, the window-to-wall ratio was assumed to be 18%, to allow for a more meaningful comparison to Standard 90.1-1989[14]. The envelope characteristics for the Standard 90.1-1999 simulation were taken from Table B-5 of the standard (Harris County). The internal gains from occupancy and equipment were the same as for the Standard 90.1-1989 run, while the lighting power density (LPD) was taken as 1.3 W/ft^2 (14 W/m^2).

In Standard 90.1-1999 (Table 11.4.3.A, Note 4), when the proposed design system has a supply, return, or relief fan motor of 25 hp (19 kW) or larger, the corresponding fan in the VAV system of the budget building shall be modeled assuming a variable speed drive. For smaller fans, a forward-curved centrifugal fan with inlet vanes is required for the budget building model. Therefore, DOE-2's verification report "SV-A" was checked to determine the total fan power consumption of the fan. For this example, the total fan kW was 68.73 kW, from "SV-A", which is equivalent to 92 hp (69 kW), thus allowing a VSD for variable air flow.

From this same simulation output, verification report "PV-A" was checked to determine the number of chillers and boilers required to meet the cooling and heating load. For the sample building simulation, the size of the boiler was 1.166 MMBtu/hr (342 kW) and the size of the chiller was 1.346 MMBtu/hr (112.17 tons or 395 kW). Since the chiller capacity was less than 300 tons (1,056 kW), according to Standard 90.1-1999 (Table 11.4.3.B), the number of chillers was set to "1". In determining the code-compliant boiler characteristics, Standard 90.1-1999 (Table 11.4.3.A, Note 6) requires that the budget building design boiler shall be modeled with a single boiler if the budget building design plant load is 600,000 Btu/h (176 kW) or less, or with two equally-sized boilers for plant capacities exceeding 600,000 Btu/h (175,860 W). Since the size of the boiler of the sample building exceeded 600,000 Btu/h (175,860 W), two boilers were chosen with a final size of 583,000 Btu/hr[15] (171 kW) for each boiler.

For the second simulation, the above adjustments were incorporated into the input file. From the "PV-A" report of the second simulation output, the size of the cooling equipment was re-evaluated using the number of chillers from the first simulation. However, in this example, it remained the same because only one chiller was used for the simulation. Since the chiller size was between 100 and 300 tons (352 and 1056 kW), a screw-type chiller should be selected according to Standard 90.1-1999 (Table 11.4.3.C)[16].

In the third simulation, the updated chiller type and performance curves were used to determine the size of the chiller. Boiler and domestic water heater sizes were also determined. From the "PV-A" report of the third simulation output, the chiller size is 1.346 MMBtu/hr (112.17 ton or 395 kW), the boiler size is 0.583 MMBtu/hr (171 kW), and the DHW-heater is 0.017 MBtu/hr. According to Standard 90.1-1999 (Table 6.2.1.C), if the chiller is a water-cooled, electrically operated, positive displacement machine (rotary screw and scroll) and the size is less than 150 tons (528 kW), then the COP is determined to be 4.45. In the case of the boiler, from Standard 90.1-1999 (Table 6.2.1.F), the efficiency of the boiler is determined to be 75% if boiler size is between 300,000 Btu/hr (88 kW) and 2,500,000 Btu/hr (733 kW). For the domestic water heater, the energy factor (EF)[17] is 0.4775 using the equation indicated in Figure 2.

In the fourth simulation, the annual energy consumption reflects equipment that complies with Standard 90.1-1999. The variations in the system sizing, type of equipment and efficiencies for all four simulations cause varying increases and decreases in heating/cooling use. For the first two runs, there were no changes in the cooling energy consumption and the DHW consumption. However, the heating energy use went down by around 5%, due to the selection of two boilers in the third simulation, from the previous one boiler in the first two simulations, with the decreased energy use attributable to the part load operation of the one boiler versus the previous two boilers.

In the third simulation, updating the chiller type and curves from centrifugal to screw increased the energy consumption by 9%. The heating and DHW consumption remained the same. In the fourth simulation, use of the required efficiencies for the chiller, boiler, fans and DHW increased the cooling energy and DHW consumption. This is because, in the case of the chiller, the default COP of 5 (used in the third simulation) is more efficient than the COP of 4.45 required by Standard 90.1-1999, and for the DHW, the default 75% efficiency used in the third simulation was

[14] Standard 90.1-1999 requires that the budget building have the same window-to-wall ratio as the proposed building. Hence, if one were running one's building against 90.1-1989 and 90.1-1999, Standard 90.1-1989 would require the fixed aspect ratio of 2.5:1, and Standard 90.1-1999 would use the aspect ratio of the proposed building. In most cases, this fixed aspect ratio for the budget building makes Standard 90.1-1989 more stringent.

[15] This is obviously an unrealistic boiler size, since boilers are usually available in fixed sizes. Therefore, a more realistic simulation would have an index of actual boiler sizes to choose from.

[16] For this simulation the performance curves from the USDOE's COMCHECK program input file were used, Version 1.1, Release 2.

[17] This uses the same approach as Standard 90.1-1989.

more efficient than the energy factor of 0.4775 required by Standard 90.1-1999.

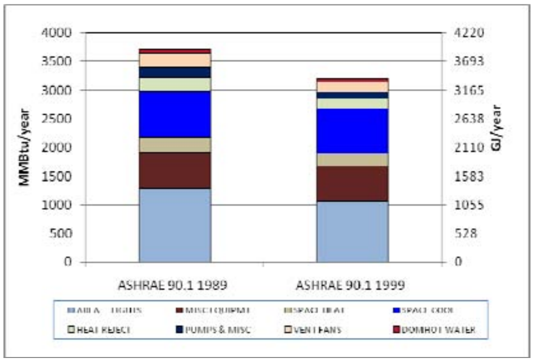

Figure 3 Comparison of Total Annual Energy Use (90.1-1989 vs 90.1-1999)

Figure 3 summarizes the comparison between the annual energy performance of the example building in Houston constructed according to ASHRAE 90.1-1989 and 1999. Overall, the total annual energy use of ASHRAE Standard 90.1-1999 (3,207.81 MMBtu/year or 3,384 x 10^6 kJ/year) is 13.4% less than the same building built to the specifications of ASHRAE Standard 90.1-1989 (3,705 MMBtu/year or 3,909 x 10^6 kJ/year). The major portion of this (45% of the annual decrease, or a 17% reduction in the lighting load, comes from the more stringent LPD criteria in ASHRAE Standard 90.1-1999 which limits the LPD to 1.3 W/ft^2 (14 W/m^2). Another significant improvement comes from the use of two smaller, staged boilers in the 1999 versus the one large boiler in 1989, which runs at lower part-load levels for a larger portion of the year (i.e., 12% of the total annual savings, or a 21% reduction in the heating energy use). The fans, cooling energy and cooling tower also show an improvement because of the lower heating/cooling loads and more stringent envelope and interior load requirements (i.e., the BEPS categories: heat rejection, pumps and misc., and vent fans, or 39% of the total annual savings).

CONCLUSION

This paper explains in detail the commercial DOE-2 simulation models that are employed in the Energy Systems Laboratory's web-based emissions reduction calculator (ecalc.tamu.edu) and provides an example performance comparison for a six-story building in Houston, Texas, built to meet ASHRAE Standard 90.1-1989 or Standard 90.1-1999. These models are used to determine the annual and peak day energy savings attained by constructing code-complaint buildings for office and retail buildings[18]. In the original application, the resultant savings from the simulations were then processed by the EPA's eGRID program to calculate the annual and peak NOx emissions reductions at the power plants that provided the electricity to the building.

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[18] Additional models are being developed for other commercial/institutional building types, such as schools, hotels, etc., with migrations planned to EnergyPlus and TRNSYS (for combined solar and PV analysis).

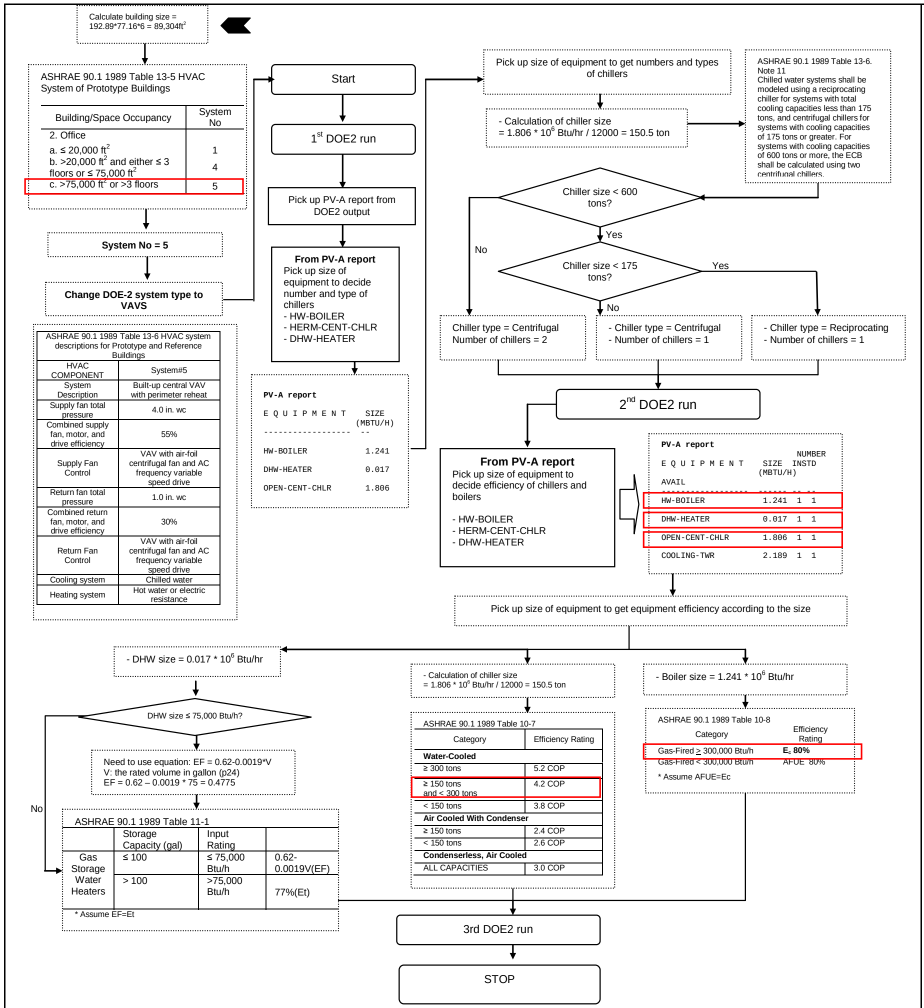

Figure 1 Flow chart of the procedure required to run an ASHRAE 90.1 1989 simulation.

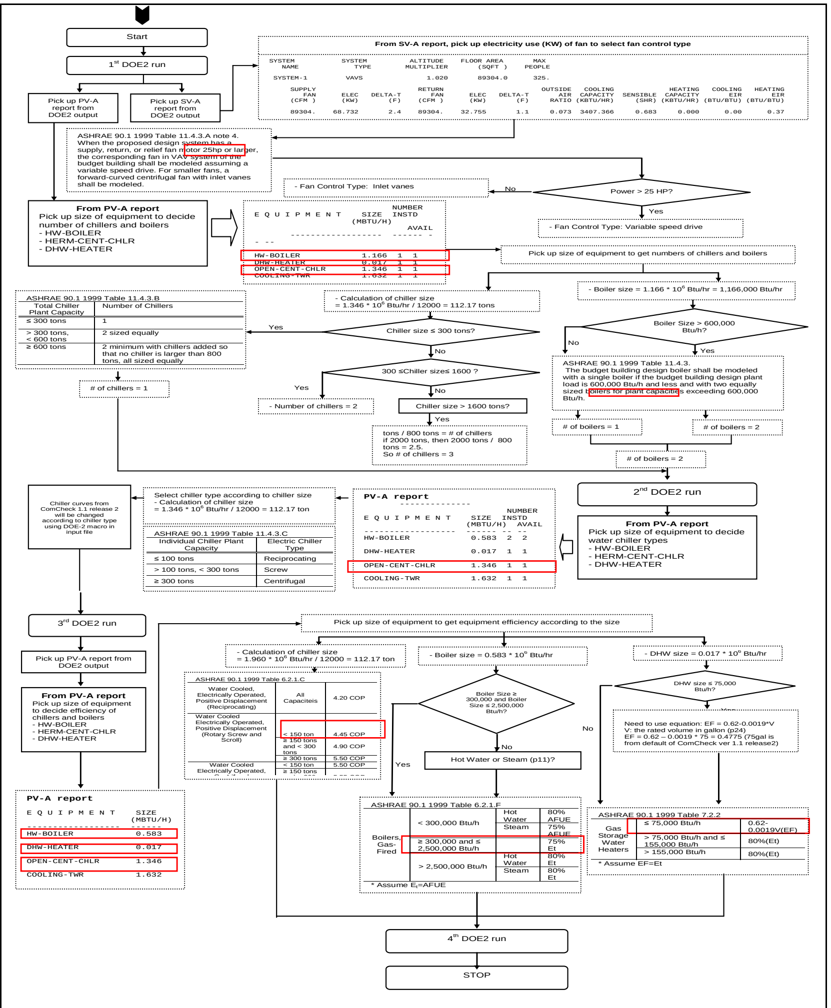

Figure 2 Flow chart of the procedure required to run an ASHRAE 90.1 1999 simulation.

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