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REDUCING ENERGYPLUS RUN TIME FOR CODE COMPLIANCE TOOLS

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ABSTRACT

Integration of the EnergyPlus ™ simulation engine into performance-based code compliance software raises a concern about simulation run time, which impacts timely feedback of compliance results to the user. EnergyPlus annual simulations for proposed and code baseline building models result in simulation run times beyond acceptable limits.

This paper presents a study that compares the results of a shortened simulation time period using 4 weeks of hourly weather data (one per quarter), to an annual simulation using full 52 weeks of hourly weather data. Three representative building types, based on DOE Prototype Building Models developed by PNNL, and three climate zones were used for determining the validity of using a shortened simulation run period. Further sensitivity analysis and run time comparisons were made to evaluate the robustness and run time savings of using this approach. The results of this analysis show that the shortened simulation run period provides compliance index calculations within 1% of those predicted using annual simulation results, and typically saves about 75% of simulation run time.

INTRODUCTION

COM*check* software developed by DOE provides an option to demonstrate compliance with the prescriptive and envelope trade-off options with various editions of ASHRAE Standard 90.1 (ASHRAE 2004, ASHRAE 2007 and ASHRAE 2010) and the IECC (ICC 2012) codes for commercial and high-rise residential buildings. COM*check* supports component trade-off using the regression methodology detailed in ASHRAE 90.1-1999 Appendix-C (Bartlett et al. 2012). Revisions to the ASHRAE 90.1 envelope trade-off methodology in 2013 have replaced the regression equations with the need for hourly simulation. Hence innovative approaches to integrate hourly simulation without compromising the current functionality of COMcheck need to be explored.

The addition of a whole building performance trade-off option is being considered for COMcheck. For that option compliance is achieved if the annual energy cost of the proposed building is lower than that of the baseline building. One of the challenges of developing energy code compliance software, such as COM*check*, is the detailed input and simulation run time of the whole building energy simulation software employed, which impacts the dynamic feedback often expected by users.

EnergyPlus™ is the state-of-the-art whole building energy simulation program developed by DOE and used by engineers, architects, and researchers to model energy use in buildings. Annual hourly simulation of the baseline and proposed design in COM*check* using EnergyPlus for typical commercial buildings resulted in run times of at least 5 minutes, with complex buildings taking much longer. Such long run times clearly compromise the capability of energy code compliance software to report the impact of incremental changes to a building configuration immediately to the user.

To address the run time issue and user feedback problem, it was proposed that simulation runs could be initiated by the user instead of being launched immediately with each configuration change. Furthermore, it was recognized that shorter run times might be achievable if the simulation periods could be shortened. If results from the shortened simulation period proved to be good approximations of the full period simulation results, the user could have a more productive experience in designing and defining the building configuration that achieves energy code compliance. After the building configuration was fully defined, the user could run a full simulation to determine the final compliance result.

This paper describes the development of a methodology (hereafter called “QuickSim”) for reducing the EnergyPlus simulation run time when used specifically for energy code compliance determinations.

QUICKSIM METHODOLOGY

The main principle behind QuickSim is a shortened run period compared to an annual run period for the simulation. Several approaches have been applied in the past for simplified energy calculations, such as degree day and bin methods (ASHRAE 2009). It is impossible to capture the full variation of conditions in a year by selecting just a few days or weeks. However, a subset of conditions that mimic the average or typical conditions of an annual run may be adequate. The subset should be selected such that it adds little to no preprocessing time in setting up such a simulation run. It is also important that the subset run periods be constant across building types and climate locations.

There are several methods to select the subset of time that would best represent the annual weather conditions. The easiest method would be to select a subset of time for each season in a year. For example, weeks 4, 17, 30, 43 would represent spring, summer, fall and winter. It is assumed that 1 week in each of these seasons would be enough to capture the typical variations. Another method would be to use some predefined categorization for each weather file. For example, in EnergyPlus, the STAT file for each EPW weather file includes typical summer, winter, autumn and spring weeks, and these could be used for the subset. Finally, processing and selecting subsets of time for each individual weather file was another method considered, but it was discounted because of the volume of work required in evaluating the full spectrum of files.

Based on professional judgment and simplicity of implementation, the static four-week strategy is chosen for this research. Weeks 4, 17, 30 and 43 are chosen as representative weeks for the four seasons in a year. These particular weeks have no special significance to each season they are associated with, but they consistently span 13 weeks. To evaluate the sensitivity of the selected weeks, alternative subsets of weeks are considered, again using 13-week increments, to cover all four seasons.

EVALUATING THE QUICKSIM METHOD

EnergyPlus version 4.0 (released in October 2009) (DOE 2009) is used for the performance simulation software to simulate the proposed and baseline buildings in order to determine their energy performance. While there have been significant improvements in speed in newer EnergyPlus versions (DOE 2014), the QuickSim method is still relevant because of the relative improvements in speed it will allow even while using the latest version of EnergyPlus.

An annual compliance index is used as a measure of the proposed building's performance relative to a baseline building. The compliance index is simply the difference in the energy use intensity (EUI) of the baseline building and the proposed building divided by the energy use intensity of the baseline building. It is typically expressed as a percentage.

$$Compliance\ Index = \frac{EUI_{base} - EUI_{target}}{EUI_{base}} \qquad (1)$$

where, EUI is the energy use intensity in kBtu/ft^2.

While COM*check* uses energy cost to calculate the compliance index, a similar range of compliance indices can be expected when energy use intensity is used, as in this analysis, to determine the compliance index. When evaluating the QuickSim methodology, the QuickSim compliance index is compared to the annual compliance index. The absolute difference in the two compliance indices, expressed as percentages, is used to evaluate the accuracy of the QuickSim method. The EUI from the QuickSim run are not scaled to the full year in the calculation of the compliance index.

Tests to evaluate the QuickSim method are performed on three building prototypes in three representative climate locations. Each of the four weeks are run as separate run periods with warm-up in EnergyPlus. It is assumed that if the QuickSim method provides a reasonable and reliable approximation of the annual simulation results, then it could be applied to other building prototypes and climate locations also.

Buildings Selected for the Analysis

A representative cross-section of building types is selected for the analysis. These building types included Medium Office, Strip Mall and Primary School. These models are based on DOE prototype building models developed by Pacific Northwest National Laboratory (PNNL) for evaluating ASHRAE Standard 90.1 (Thornton et al. 2011). They have been modified to comply minimally with ASHRAE Standard 90.1-2004 (also referred to as Standard 90.1-2004 or 90.1-2004). Table 1 shows the properties of the prototype building models used in the analysis.

Climate Zones

As with building types, a cross-section of representative climate zones are selected for the QuickSim analysis. These climate zones are used by ASHRAE and the IECC in their energy Standards. For this analysis, a specific climate location (city) is selected as a representative of each climate zone. The selected climate locations are Houston (2A), Chicago (5A) and Duluth (7).

Evaluation Criteria

For all the tests in the study, the "baseline" building complies minimally with ASHRAE Standard 90.1-2004. The following evaluation criteria are developed to test the QuickSim methodology:

1. Trade-off Analysis: In energy code compliance determinations, the performance of building envelope assembly types can be balanced against one another as long as the overall proposed building energy metric is less than or equal to the budget building energy metric. For QuickSim to

Table 1 Properties of Prototype Buildings Used in QuickSim Analysis

Building Properties	Medium Office	Strip Mall	Primary School
	General		
Gross Floor Area	53,600 ft²	22,500 ft²	73,960 ft²
Building Shape	Rectangle	Rectangle	Classroom wings + core
Aspect Ratio/ Footprint	1.5 (164 ft x 109 ft)	4.0 (300 ft x 75 ft)	270 ft x 340 ft
Number of Floors	3	1	1
Window-to-Wall Ratio	33%	10.5%	35%
Floor Height	13 ft	17 ft	13 ft
Floor-to-Ceiling Height	9 ft	17 ft	13 ft
	Envelope		
Exterior Wall	Steel-framed wall	Steel-framed wall	Steel-framed Wall
Roof	Flat with insulation above decking	Flat with insulation above decking	Flat with insulation above decking
Floor	8” Slab-on-grade	6” Slab-on-grade	6” Slab-on-grade
	Internal Loads		
Occupancy	5 people / 1000 ft²	8 people / 1000 ft²	19 people / 1000 ft² (peak)
Average Lighting Power Density	1.0 W/ft²	1.65 W/ft²	1.19 W/ft²
Average Plug Load Power Density	0.75 W/ft²	0.4 W/ft²	4.80 W/ft²
	HVAC		
Heating Type	Gas furnace	Gas furnace	Gas Furnace Gas Boiler
Cooling Type	Packaged DX Unit	Packaged DX Unit	Packaged AC, Packaged VAV
Fan Control	Variable air volume	Constant Air Volume	Constant Air Volume, Variable Air Volume
Distribution/Terminal Units	VAV terminal box with electric reheating coil	CAV	CAV, VAV with terminal box with hot water reheat
Cooling T-stat	75°F (80°F setback)	75°F (85°F setback)	75°F (80°F setback)
Heating T-stat	70°F (60°F setback)	70°F (60°F setback)	70°F (60°F setback)

be successful, it must reliably determine compliance indices for common trade-off possibilities.

2. Sensitivity Analysis: Sensitivity of QuickSim to incremental changes in individual building components is evaluated in this test.
3. Run time Comparison: The run times for full year and QuickSim partial year simulations are collected and compared to determine if reliable and consistent run time reductions are obtainable with the methodology.

ANALYSIS SETUP

All energy simulations are completed within a PNNL Linux energy simulation infrastructure, which manages inputs and outputs of the EnergyPlus simulations. This infrastructure creates EnergyPlus input files, submits input files to a computing cluster with 80 central processing units (CPUs) for batch simulation, and extracts and compiles results.

Trade-off Analysis

Six typical trade-off options are selected to test the QuickSim method. Trade-offs are evaluated by reducing the component level by 10% over the value prescribed in Standard 90.1-2004 (the baseline level) and by increasing the level of the other component to the corresponding prescriptive requirement in ASHRAE Standard 90.1-2010 (also referred to as Standard 90.1-2010 or 90.1-2010). Standard 90.1-2010 has more stringent requirements compared to Standard 90.1-2004 for HVAC equipment efficiency and lighting power density (LPD) for the three building types considered in this analysis. The six trade-off cases are described below.

1. Wall and roof insulation to HVAC equipment efficiency: The wall and roof insulation is reduced

by 10%, while the HVAC equipment efficiency is set to the 90.1-2010 level.

2. Wall and roof insulation to fenestration: The wall and roof insulation R-values are reduced by 10%, while the fenestration U-factor and SHGC are set to the 90.1-2010 level.
3. Wall and roof insulation to LPD: The wall and roof insulation R-values are reduced by 10%, while the LPD is set to the 90.1-2010 level.
4. Fenestration to HVAC equipment efficiency: Fenestration U-factor and SHGC is fixed at the baseline level while HVAC equipment efficiency is set to the 90.1-2010 level.
5. Fenestration to LPD: Fenestration U-factor and SHGC is fixed at the baseline level while LPD is set to the 90.1-2010 level.
6. LPD to HVAC equipment efficiency: The LPD is increased by 10% while the HVAC equipment efficiency is set to the 90.1-2010 level.

The six trade-off cases are simulated using the three prototype buildings in three climate locations for annual and QuickSim run periods, giving rise to 42 cases per prototype and 126 cases in total.

Sensitivity Analysis

A sensitivity analysis is performed on the QuickSim method to analyze its response to different magnitudes of change in the trade-off components. The trade-off cases created in the previous test are used again for the sensitivity analysis, but the changes made to the components are more gradual. For each trade-off case, six performance levels are created by assigning one of the components in the pair a fixed value, and gradually increasing or decreasing the other component. These performance levels are described below.

1. Wall and roof insulation to HVAC equipment efficiency: The wall and roof insulation levels are changed between -30%, -20%, -10%, +10%, +20%, +30%, compared to the baseline level and the HVAC equipment efficiency is fixed at the 90.1-2010 level. Table 2 shows the R-values (h-ft^2-F/Btu) and LPDs (W/ft^2) that are used in the test cases for the three prototypes. The 0% level

Table 2 Insulation R-value and LPD for different component levels

Building	Climate Location	Component[1]	Component Level						
			-30%	-20%	-10%	0%	10%	20%	30%
Strip Mall	Houston	Wall R-value	5.6	6.5	7.3	8.1	8.9	9.7	10.5
		Roof R-value	11.1	12.7	14.3	15.9	17.5	19	20.6
		LPD	1.6	1.82	2.05	2.28	2.51	2.74	2.96
	Chicago	Wall R-value	10.9	12.5	14.1	15.6	17.2	18.8	20.3
		Roof R-value	11.1	12.7	14.3	15.9	17.5	19	20.6
		LPD	1.6	1.82	2.05	2.28	2.51	2.74	2.96
	Duluth	Wall R-value	10.9	12.5	14.1	15.6	17.2	18.8	20.3
		Roof R-value	11.1	12.7	14.3	15.9	17.5	19	20.6
		LPD	1.6	1.82	2.05	2.28	2.51	2.74	2.96
Medium Office	Houston	Wall R-value	5.6	6.5	7.3	8.1	8.9	9.7	10.5
		Roof R-value	11.1	12.7	14.3	15.9	17.5	19	20.6
		LPD	0.7	0.8	0.9	1	1.1	1.2	1.3
	Chicago	Wall R-value	8.3	9.5	10.7	11.9	13.1	14.3	15.5
		Roof R-value	11.1	12.7	14.3	15.9	17.5	19	20.6
		LPD	0.7	0.8	0.9	1	1.1	1.2	1.3
	Duluth	Wall R-value	10.9	12.5	14.1	15.6	17.2	18.8	20.3
		Roof R-value	11.1	12.7	14.3	15.9	17.5	19	20.6
		LPD	0.7	0.8	0.9	1	1.1	1.2	1.3
Primary School	Houston	Wall R-value	5.6	6.5	7.3	8.1	8.9	9.7	10.5
		Roof R-value	11.1	12.7	14.3	15.9	17.5	19	20.6
		LPD	0.98	1.12	1.26	1.4	1.54	1.68	1.82
	Chicago	Wall R-value	8.3	9.5	10.7	11.9	13.1	14.3	15.5
		Roof R-value	11.1	12.7	14.3	15.9	17.5	19	20.6
		LPD	0.98	1.12	1.26	1.4	1.54	1.68	1.82
	Duluth	Wall R-value	10.9	12.5	14.1	15.6	17.2	18.8	20.3
		Roof R-value	11.1	12.7	14.3	15.9	17.5	19	20.6
		LPD	0.98	1.12	1.26	1.4	1.54	1.68	1.82

(1) Wall R-value is expressed as h-ft^2-F/Btu and LPD is expressed as W/ft^2.

Table 3 Fenestration properties for trade-off cases and sensitivity

Building	Climate Location	90.1-2004 Baseline		Window 1		Window 2	
		U-factor*	SHGC	U-factor*	SHGC	U-factor*	SHGC
Strip Mall	Houston	1.22	0.25	0.72	0.25	0.62	0.25
	Chicago	0.57	0.49	0.57	0.39	0.42	0.4
	Duluth	0.57	0.49	0.46	0.45	0.33	0.45
Medium Office	Houston	1.22	0.25	0.72	0.25	0.62	0.25
	Chicago	0.57	0.39	0.45	0.31	0.42	0.4
	Duluth	0.57	0.49	0.46	0.45	0.33	0.45
Primary School	Houston	1.22	0.25	0.72	0.25	0.62	0.25
	Chicago	0.62	0.39	0.57	0.39	0.42	0.4
	Duluth	0.62	0.49	0.46	0.45	0.33	0.45

*U-factor expressed as Btu/h-ft^2-F

corresponds to the prescribed value in Standard 90.1-2004.

2. Wall and roof insulation to fenestration: Again, to obtain six performance levels, the window type is fixed at the baseline level. The wall and roof insulation level is then varied between -30%, -20%, -10%, +10%, +20%, +30% compared to the baseline level.
3. Wall and roof insulation to lighting power: The wall and roof insulation levels are varied between -30%, -20%, -10%, +10%, +20%, +30%, over the baseline while keeping the LPD at the baseline level.
4. Fenestration to HVAC equipment efficiency: This is a special case, where both components must be varied to obtain six performance levels. Using the prescriptive values for equipment efficiency in Standards 90.1-2004, 90.1-2007 and 90.1-2010, and using three different windows for fenestration, six performance levels are chosen. Table 3 shows fenestration properties of the baseline window and the two other windows used to combine with the HVAC equipment efficiency to derive the six performance levels. The six levels are shown in Table 4.

Table 4 Performance levels for fenestration to HVAC equipment efficiency trade-off

Level	Equipment Efficiency	Fenestration Properties
0*	90.1-2004	90.1-2004
1	90.1-2004	Window 1
2	90.1-2007	90.1-2004
3	90.1-2010	90.1-2004
4	90.1-2004	Window 2
5	90.1-2007	Window 1
6	90.1-2010	Window 1

*Used for calculating baseline compliance index.

5. Fenestration to lighting power: In this case, the fenestration properties are held constant at the baseline level, and the LPD is varied between -30%, -20%, -10%, +10%, +20%, +30%, over the baseline.
6. HVAC equipment efficiency to lighting power: HVAC equipment efficiency is raised to the 90.1-2010 level while the LPD is varied between -30%, -20%, -10%, +10%, +20%, +30%, over the baseline.

HVAC equipment efficiency is varied only between the prescribed values in Standard 90.1-2004, Standard 90.1-2007 and Standard 90.1-2010. The reader is directed to these Standards for information on these values used in the analysis.

RESULTS AND DISCUSSION

Trade-off Analysis

Table 5 shows the compliance index variation between the annual run and the QuickSim run for the three prototype buildings. The compliance index for the annual run and the QuickSim run is calculated as shown in equation (1). Of the 54 compliance index comparisons, only two are above 1% – 1.4% and 1.3% for Primary School in climate zone 7 (Duluth). For all other cases, the performance of the QuickSim method is comparable to the annual run. Additionally, the compliance index sign never changes between the QuickSim and annual run, which is important for compliance determination.

Sensitivity Analysis

Table 6 shows the compliance index variation for the sensitivity analysis cases for the Medium Office prototype building. Again, all cases show compliance index variations smaller than 1%. The maximum difference in compliance indices between the annual run and QuickSim is 0.8%. The results for Strip Mall

Table 5 Compliance index difference between QuickSim run and annual run for trade-off cases

Trade-off Case	Compliance Index Difference (%)								
	Strip Mall			Medium Office			Primary School		
	Houston	Chicago	Duluth	Houston	Chicago	Duluth	Houston	Chicago	Duluth
Wall and Roof Insulation to Equipment Efficiency	-0.1	-0.2	-0.2	-0.4	-0.4	0.0	-0.1	-0.4	-0.4
Wall and Roof Insulation to Fenestration	-0.1	-0.3	0.0	0.0	0.2	0.4	0.1	0.2	-0.1
Wall and Roof Insulation to LPD	0.2	-0.3	-0.1	0.1	-0.2	0.1	0.3	-0.2	-0.2
Fenestration to Equipment Efficiency	-0.3	-0.2	0.1	0.0	-0.1	-0.1	-0.1	-0.8	-1.4
Fenestration to LPD	0.1	-0.3	0.1	0.2	0.2	0.0	0.2	-0.7	-1.3
LPD to Equipment Efficiency	-0.2	0.0	0.0	-0.3	-0.3	0.0	-0.2	-0.1	-0.1

Table 6 Compliance index difference between QuickSim run and annual run for sensitivity analysis of Medium Office prototype

Trade-off Case	Climate Location	Compliance Index Difference (%)					
		Performance Level					
		-30%	-20%	-10%	10%	20%	30%
Wall and Roof Insulation to Equipment Efficiency	Chicago	-0.7	-0.7	-0.4	-0.3	-0.2	-0.2
	Duluth	0.2	0.1	0.0	0.0	-0.1	-0.2
	Houston	-0.3	-0.4	-0.4	-0.3	-0.4	-0.2
Wall and Roof Insulation to Fenestration	Chicago	-0.4	-0.2	-0.1	0.1	0.2	0.2
	Duluth	0.2	0.2	0.1	0.0	-0.2	-0.3
	Houston	-0.1	0.0	0.0	0.0	0.1	0.1
Wall and Roof Insulation to LPD	Chicago	-0.4	-0.3	-0.1	0.1	0.1	0.2
	Duluth	0.3	0.3	0.2	0.0	-0.1	-0.2
	Houston	0.0	0.0	0.1	0.1	0.1	0.2
Fenestration to Equipment Efficiency	Chicago	0.0	-0.1	-0.2	0.8	-0.1	-0.2
	Duluth	0.1	0.0	0.1	-0.2	0.1	0.2
	Houston	0.1	0.0	-0.3	0.3	0.1	-0.1
Fenestration to LPD	Chicago	-0.1	-0.1	-0.1	-0.1	0.0	-0.1
	Duluth	0.3	0.2	0.1	-0.1	-0.2	-0.3
	Houston	0.3	0.2	0.1	-0.1	-0.2	-0.3
LPD to Equipment Efficiency	Chicago	-0.4	-0.4	-0.4	-0.3	-0.3	-0.4
	Duluth	0.3	0.3	0.2	0.0	-0.3	-0.4
	Houston	-0.1	-0.1	-0.2	-0.3	-0.4	-0.7

and Primary School prototype buildings are not shown in this paper. The maximum compliance index variation for the Strip Mall prototype building out of all the cases is 0.8%. For the Primary School, the compliance index variation reaches a high of 1.7%, again for Duluth and for the trade-off between fenestration and HVAC equipment efficiency. For all other cases, the compliance index difference remains below 1%. The change in the QuickSim compliance index tracks the change in the annual compliance index. Figure 2 shows the compliance index trends for the Primary School prototype building and trade-off option 4.

Note the change in scale (y-axis) and the change in the order of levels (x-axis). This is the case where the compliance index variation is highest (1.7%) in all the cases analyzed in this study. Table 4 shows the choices for the six performance levels. It can be seen that for the trade-off between fenestration and HVAC equipment efficiency, the compliance indices are all positive and that the swing in compliance index is quite high, reaching almost 14% for level 2 and level 5. These are the cases for which the compliance index variation is the highest between the annual run and the QuickSim run.

The results indicate that the reduced run period is insensitive to climate location and, for a majority of the cases, to building type as well.

Run Time Comparison

To evaluate the actual saving in run time from the QuickSim analysis, the trade-off cases are run on a Windows workstation. This would be the case when running the desktop version of COM*check*. The Windows version of EnergyPlus is used. A batch simulation utility is available in EnergyPlus, and it is

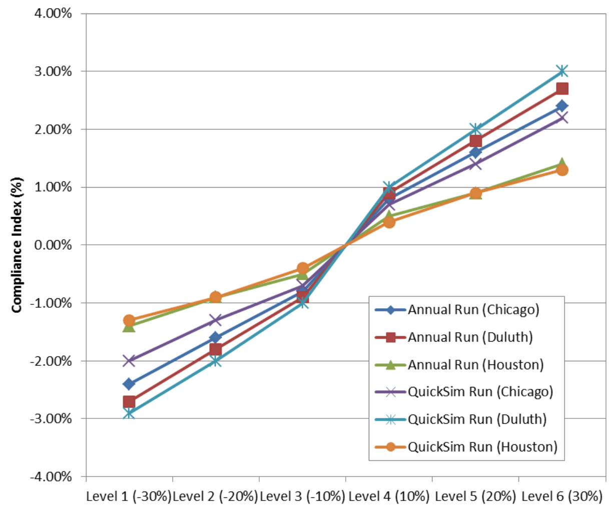

Figure 1 Change in compliance index with change in component level for QuickSim and annual runs for the Strip Mall prototype and trade-off option 1.

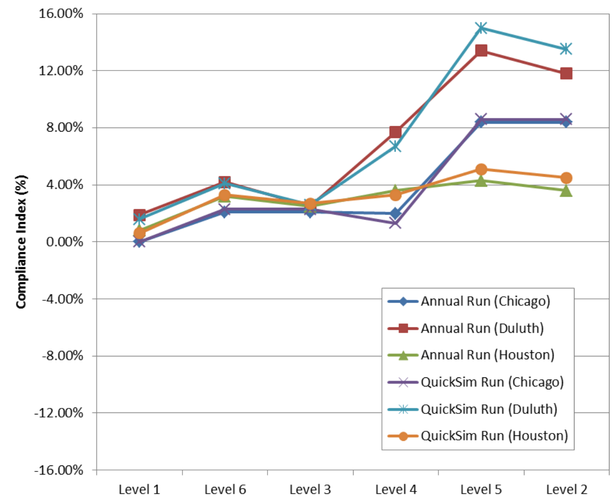

Figure 2 Change in compliance index with change in component level for QuickSim and annual runs for the Primary School prototype and trade-off option 1.

used to setup the simulation runs. The workstation uses an Intel Xeon E5530 processor running at 2.40 GHz together with a total physical memory of 4 GB. Table 7 shows the percent reduction in run time using QuickSim when compared to the annual run. A reduction of almost 75% is seen in all the cases using the reduced run period of the QuickSim method.

Sensitivity to Choice of Weeks

The trade-off comparison and sensitivity analysis provided strong evidence that the QuickSim method is indeed able to reliably predict compliance indices compared to the annual run. The four weeks selected for the QuickSim run period were representative of each season in the year but were arbitrarily chosen for that season. Another test is run to determine if a different but similar quartet of weeks would yield results that matched those of the previous selection. The new set of four weeks is selected such that, each of the weeks is offset by four weeks from the earlier selection. This method yields the following four weeks: 8, 21, 34, and 47. The Medium Office building type is chosen for this test. Trade-off comparison cases 1 and 6 are run for all the climate locations for the Medium Office building type. The results showed that use of the alternate set of weeks does not result in significant differences in compliance indices compared to the first set of weeks. The variation between the annual and QuickSim compliance indices is well within the 1.0% threshold.

CONCLUSIONS

1. Evaluation of the QuickSim methodology suggests that QuickSim could be reliably used with EnergyPlus for code compliance determinations while significantly reducing simulation run times. The compliance index variation between an annual simulation and a QuickSim simulation is within 1.0% for almost all the cases tested in this study. Moreover, the compliance index sign does not change between QuickSim and the annual run.
2. QuickSim is as sensitive as an annual simulation to changes in building components. The seasonal variations in weather appear to be captured by the four week run period. The insensitivity of QuickSim to building types or climate locations tested in this study implies that it may be used for other building types and climate locations.
3. For compliance indices greater than 10%, greater than normal deviation was observed for the QuickSim cases. Even in these cases, the variation is only slightly higher (1.7%) than 1%.
4. The simulation run time could be reduced by 75% compared to the annual run time by applying the QuickSim method.
5. This study investigates the accuracy of the QuickSim method in predicting compliance indices for energy code compliance. While it may be possible to use this approach in other applications, such as initial parametric analysis, the tests do not imply that the method can be applied to determine

Table 7 Percent Reduction in run time between QuickSim run and annual run

Trade-off Case	Percent Reduction in Run Time								
	Strip Mall			Medium Office			Primary School		
	Houston	Chicago	Duluth	Houston	Chicago	Duluth	Houston	Chicago	Duluth
Baseline	74	75	75	73	73	72	80	79	79
Wall and Roof Insulation to Equipment Efficiency	75	75	75	73	73	73	80	79	79
Wall and Roof Insulation to Fenestration	75	75	75	73	73	73	80	79	79
Wall and Roof Insulation to LPD	75	75	75	73	73	73	80	79	79
Fenestration to Equipment Efficiency	75	75	75	73	73	62	80	79	79
Fenestration to LPD	75	75	75	73	73	73	80	79	80
LPD to Equipment Efficiency	75	75	75	73	72	73	80	79	79
Average Percent Reduction	75			72			79		

building energy consumption for other applications.

FUTURE WORK

The test cases presented here show that the relative comparison of energy performance between the proposed and budget building is within acceptable margins using a shortened run period of four weeks. Additional testing using different building types, building geometry and complex HVAC systems is required before the method can be deployed widely in COM*check*. For example, testing with a system that uses evaporative heat rejection will reveal the sensitivity to wet-bulb temperatures, which can vary drastically from week-to-week in some climate zones. Other measures affected by seasonal changes, such as daylighting, also need to be tested. In such cases, alternate approaches to selecting the run periods could be used. For example, every 15^{th} day of the year could be used. This approach could pick-up some of the short seasonal variations observed in a few climate locations.

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