Arnold Schwarzenegger
Governor

ENERGYPLUS RUN TIME ANALYSIS:

DEVELOPMENT OF ENERGYPLUS FOR USE IN TITLE 24 AND SUPPORT FOR ENERGY COMMISSION STAFF USE OF ENERGYPLUS

PIER FINAL PROJECT REPORT

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Disclaimer

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Preface

The California Energy Commission's Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
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- Renewable Energy Technologies
- Transportation

EnergyPlus Run-Time Analysis: Development of EnergyPlus for Use in Title 24 and Support for California Energy Commission Staff Use of EnergyPlus is the final report for the EnergyPlus Run Time Analysis project (Contract Number 500-07-008) conducted by Lawrence Berkeley National Laboratory. The information from this project contributes to PIER's Buildings End-Use Energy Efficiency Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-654-4878.

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Abstract

EnergyPlus is a new-generation building performance simulation program. It offers many new modeling capabilities and does more accurate performance calculations integrating building components in subhourly time steps that can be down to one minute. EnergyPlus simulations run much slower than the old generation simulation programs. This has become a major concern and barrier to its widespread adoption, and the research team is trying to make the simulations run faster.

This project analyzed EnergyPlus run time from comprehensive perspectives to identify the key issues and challenges of improving EnergyPlus run time: Studying the historical trends of EnergyPlus run time based on the advancement of computer computing power and improvements to EnergyPlus code, comparing with DOE-2.1E to quantify the differences in computer run time, identifying key user simulation settings and model features that have significant impacts on EnergyPlus run time, performing code profiling to identify, and understanding what EnergyPlus code routines consume the most amount of run time. Researchers found that they could reduce the EnergyPlus run time by creating a clean and concise model.

This report provides recommendations to improve EnergyPlus run time from the modeler's perspective and adequate computing platform. Experiments of code changes to improve EnergyPlus run time based on the code profiling results are ongoing and will be available in a companion report.

Keywords: building simulation, code profile, computer run time, EnergyPlus, simulation program.

Executive Summary

Overview of EnergyPlus Run Time

EnergyPlus is a building energy simulation program developed by the Department of Energy and was first released on April 12, 2001, as Version 1.0, Build 11. Since then, there has been a new release approximately every six months. The past seven years of continuous new feature development and enhancements have made it possible for EnergyPlus to model new and complex building technologies, which cannot be modeled by other simulation programs. EnergyPlus has become more important as the building industry moves toward the goal of net zero energy buildings.

The underlying building thermal zone calculation method and the sub-hourly calculations used by EnergyPlus are different than those used by DOE-2,[1] which results in EnergyPlus running significantly slower than DOE-2. DOE-2 is currently used for Title 24 compliance calculations. The EnergyPlus development team has been making continuous progress in reducing computer run time since the early release of EnergyPlus by fine-tuning the FORTRAN[2] compiler settings, which transforms FORTRAN source code into computer language, and by identifying run time bottlenecks. Even so, the longer computer run time has become a major barrier to the effective use of EnergyPlus in the Title 24 code and standard development. It is also a major hurdle for EnergyPlus widespread use by design practitioners to evaluate design alternatives that offer potential energy savings beyond current building energy code and standards.

The run time required to perform an EnergyPlus simulation is a complex issue, as the computer execution time required to complete an EnergyPlus simulation run depends on many factors:

- The simulation settings users specified in the EnergyPlus model.
- The computer platform used to run the model, including computer hardware and operating system.
- The energy features defined in the EnergyPlus model.
- The version of EnergyPlus source code.
- The FORTRAN compiler and its settings.

The EnergyPlus development team, when making design tradeoffs, has focused more on code readability, extensibility, and modularity than on speed of code execution. As noted in the section of Code Readability vs. Speed of Execution in the EnergyPlus documentation – Guide for Module Developers:

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1. DOE-2 is a Building Energy Use and Cost Analysis Software developed by James J. Hirsch & Associates in collaboration with Lawrence Berkeley National Laboratory.

2. EnergyPlus is written in the FORTRAN computer programming language.

"Programmers throughout time have had to deal with speed of code execution and it's an ongoing concern. However, compilers are pretty smart these days and, often, can produce speedier code for the hardware platform than the programmer can when he or she uses "speed up" tips. The EnergyPlus development team would rather the code be more "readable" to all than to try to outwit the compilers for every platform. First and foremost, the code is the true document of what EnergyPlus does – other documents will try to explain algorithms and such but must really take a back seat to the code itself."

The building simulation community, either researchers or design practitioners, often needs to do parametric analysis that involves hundreds or even more simulation runs. It is crucial for EnergyPlus to be able to complete a large volume of simulation runs in a reasonable amount of computer run time to be widely adopted as a routine simulation program by the industry.

The California Energy Commission has been looking forward to using EnergyPlus for parametric runs to evaluate code proposals in the development of future Title 24 or advanced standards. In the near future, the Energy Commission is also looking at the feasibility of using EnergyPlus for code compliance calculations. To meet the Energy Commission's needs, it is critical to identify bottlenecks that cause lengthy EnergyPlus run times and to find solutions that speed up EnergyPlus simulation runs.

Analysis Method

EnergyPlus run time is a complex issue and can be analyzed from various perspectives. The run time issue was first approached from an outside, non-programming perspective of EnergyPlus, known as a "black box"view. In the black box approach, parametric runs were conducted to identify key variables that have significant run time impacts. Then, EnergyPlus was approached from the inside perspective which includes consideration of internal programming code operation, or the "white box" view. In the white box approach, EnergyPlus code profiles were established using typical simulation runs. Each of the two methods provide unique insight to the run time problem, and when combined lead to recommendations for improving EnergyPlus run time.

From the black box perspective (outside of EnergyPlus), the following areas were studied:

- From the historical perspective, what is the trend of EnergyPlus run time? What can be expected in future if the historical trend continues?
- From a peer review perspective, how does EnergyPlus run time compare with that of DOE-2?
- From the user perspective, what simulation settings should be specified and how do they affect the run time? What is the best practice to reduce run time without sacrificing simulation accuracy?
- From the model perspective, what model features require the greatest amount of resources and/or time for calculation? How should EnergyPlus deal with large models?

- From the computer platform perspective, what hardware and software is required to run EnergyPlus, and how do they affect the run time? What is the recommended computer platform?
- From the EnergyPlus compiler perspective, which compiler should be used to turn source code into computer code? What are the compiler settings, and how do they affect the run time?

From the white box perspective (inside EnergyPlus), the following areas were studied:

- Which FORTRAN subroutines, or functions, use the greatest amount of time?
- Which FORTRAN subroutines get called most frequently?
- What is the critical path of the run time?

EnergyPlus Version 2.2.0.023 is used in most simulation runs, while Versions 1.2.1.012, 1.2.2.030, and 2.1.0.023 are used for historical runs only. In this analysis, the focus is on EnergyPlus running on typical personal computers with Intel 32-bit central processing units (CPUs) and Microsoft Windows® operating systems, as these are the dominant personal computer platforms used today for building performance simulations. Therefore, most simulation runs are done on a personal desktop computer with Intel® Core 2 Duo (two CPUs at 3 gigahertz), 2 gigabytes of random-access memory and Microsoft Windows® XP Service Pack 2. Three other computer platforms are also used for the history runs.

Although not expected to show different behavior of EnergyPlus run time, please note that this run time analysis does not profile EnergyPlus performance on 64-bit CPUs or computers with non-Windows operation systems like UNIX®, Linux®, or Macintosh® OS.

Summary of Findings

Historical Trend of EnergyPlus Run Time

EnergyPlus has been making impressive progress in reducing simulation run time from the history perspective, which is mostly due to the improvement of EnergyPlus code, the newer and better FORTRAN compilers, and the faster computers used to run EnergyPlus simulations. For a typical office building model with 15 thermal zones and 1 central variable air volume system with water-cooled chillers and hot water boilers, the EnergyPlus run time (annual run) is reduced by a factor of 56 from 1 hour and 56 minutes with a typical personal computer in 2000 and EnergyPlus 1.2.2.030 in 2005 to about two minutes with a typical personal computer in 2007 and EnergyPlus 2.2.0.023 in 2008. The same model that took about 11 minutes to run three to four years ago would take only two minutes to run in 2008, with the then-available typical personal computer and EnergyPlus releases. This is a significant reduction in run time by a factor of 5.5 in about three to four years. However, the trend of EnergyPlus run time improvement has slowed down mainly due to EnergyPlus code getting larger and more complex, FORTRAN compilers becoming mature (less room for additional optimization), and a deceleration of CPU clock speed technological advances.

Run Time Comparisons Between EnergyPlus and DOE-2.1E

Compared with DOE-2.1E, EnergyPlus runs much slower. The main reason EnergyPlus runs much slower than DOE-2.1E is that EnergyPlus normally does the integrated heat balance calculations for loads, systems, and plant at 15-minute time intervals (time steps), while DOE-2.1E does sequential calculations from loads to systems to plant at an hour time step. EnergyPlus performs necessary iterative calculations at a smaller time step (down to one minute) for heating, ventilating, and air-conditioning systems to achieve heating, ventilating, and air-conditioning convergent solutions.

When DOE-2 was developed in late 1970s, computing power was very limited. Even a model with 50 zones of interest could take hours if not days to complete an annual run. With today's personal computer computing power, the question is not to develop simulation programs that run as fast as DOE-2, but rather to develop programs that can do subhourly and more accurate building thermal performance calculations in a reasonable amount of time. For the rather simple modeling runs performed for the comparisons, EnergyPlus in all cases performed faster than 10 seconds per zone. For cases where only monthly and annual energy consumption results are needed, hourly time step may be sufficient. In that case, EnergyPlus is in the range of two seconds per zone.

Effects of Simulation Settings and Model Features on EnergyPlus Run Time

Simulation settings are user-controllable inputs that can affect EnergyPlus run time and accuracy. Simulation settings that can have significant impacts on EnergyPlus run time include the length of the run period, the number of loads calculation time steps per hour, the model solution algorithms (envelope heat transfer, solar shading, daylighting, thermal comfort, and natural ventilation with airflow network), the minimum heating, ventilating, and air-conditioning (HVAC) time step, the maximum HVAC iterations, and the type and frequency of output reports. For EnergyPlus, up to Version 2.2.0.023, the loads and HVAC time steps and the heat transfer algorithm can significantly impact the accuracy of simulation results. The EnergyPlus development team has investigated and found potential solutions to address why the hourly loads time step and the heat conduction algorithm were causing large discrepancies in simulation results.

EnergyPlus models with high numbers of surfaces, windows/skylights, thermal zones, or primary and secondary air and water loops would take much longer to run. Models with smaller time steps and higher solution resolution also take much longer to run. Models with complex geometry and shades will take much longer to run if using certain algorithms for calculating solar shadows, heat conduction, or natural ventilation airflow.

Certain simulation settings, such as the loads and system time steps and some algorithms for heat conduction or convection may have significant effects on the results of HVAC energy use. The EnergyPlus development team is aware of some of the issues and addressing them.

Computer Platforms

For small EnergyPlus models (with small number of surfaces, zones, and systems) that do not require large amount of computer memory, personal computers with faster CPUs are more effective in reducing run time than personal computers with more memory. For large models, more and faster computer memory including random-access memory and internal cache may be more effective in reducing run time. The amount of computer memory only helps to a certain point; it is not "the more, the better." If an energy model run will produce lots of hourly or time step reports, the hard drive access speed also becomes important in reducing run time.

EnergyPlus, as of Version 2.2.0.023, is a single-thread application running on a single CPU, which means one command is processed at a time. Personal computers with multiple CPUs would not perform better than personal computers with one CPU, assuming no other time-consuming processes occur simultaneously with the EnergyPlus simulation runs. However, for a large volume of parametric runs on personal computers with multiple CPUs, users can still harness the potential of launching multiple parallel EnergyPlus runs from separate folders with their own copies of the EnergyPlus engine files.

The recent trend of personal computer progress is to embed more CPUs rather than to increase the operating frequency of a single CPU for a personal computer. This poses a challenge to EnergyPlus as one EnergyPlus simulation only runs on a single CPU.

EnergyPlus is used for building performance simulations that involve a sequential run period and the integrated coupling of building envelope, lighting/daylighting, HVAC, service water heating, and on-site energy generation. Parallel computing is a method of calculation where multiple calculations are calculated concurrently, offering advantages to run time. However, the time step correlation of calculations makes it difficult to rewrite the EnergyPlus code for parallel computing..

Compiler optimization settings can also greatly affect EnergyPlus run time. The official release of EnergyPlus already implements optimizations for fast speed.

Recommendations to Improve EnergyPlus Run Time

Compared with creating energy models, EnergyPlus run time is normally a small fraction of the total time needed to complete an energy modeling job. Therefore it is very important to build a clean and concise EnergyPlus model up front. Techniques for simplifying large and complex building and systems should be used during the creation of energy models, especially during the early design process when detailed zoning and other information is not available. Producing lots of hourly or sub hourly reports from EnergyPlus runs can take significant amount of time. Modelers should request time step reports only when necessary. On the other hand, producing summary reports and typical monthly reports take relatively small amount of run time. These reports are valuable references for troubleshooting and model fine tuning.

With powerful personal computers becoming more affordable, EnergyPlus modelers should choose to use current available personal computers with three or more gigahertz and three or more gigabyte of random-access memory. For a large volume of EnergyPlus parametric runs, modelers can launch multiple runs in parallel. In this case, personal computers will more CPUs definitely help in reducing total EnergyPlus run time.

For modelers, most time is spent on troubleshooting and fine-tuning energy models. During the early modeling process, it is recommended to keep the model as simple as possible and make quick runs to identify problems. Then modify the model to fix problems and rerun the model. This is a repetitious process that continues until satisfactory solutions are found. The simulation process can be split into three phases: the diagnostic runs, the preliminary runs, and the final runs. The three phases would use different simulation settings. The diagnostic runs would use a set of simulation settings to speed up the runs with simulation accuracy being set as the second priority. The diagnostic runs will help catch most model problems by running simulations on summer and winter design days. The preliminary runs use a tighter set of simulation settings to catch problems missed in the diagnostic runs, and provide better results for quality assurance. The final runs use the EnergyPlus-recommended set of simulation settings to achieve better accuracy for simulation results ready for review and reporting.

Inside EnergyPlus, there should be code review and enhancements to the critical subroutines as identified in the Technical Recommendations section below. This task is ongoing, and a separate report will document the findings and results.

Another potential improvement in EnergyPlus run time is to make EnergyPlus capable of parallel computing on current and future personal computers that carry more CPUs but do not increase CPU clock speed much over the past. To make this happen, the EnergyPlus code needs to be made to utilize parallel computing by programmers rather than relying on compiler settings.

EnergyPlus development was started in late 1990s. The FORTRAN 90/95 language, used by EnergyPlus code, has some object based features, but is not an object-oriented computer programming language that fully supports enhanced object-oriented features. FORTRAN is especially inefficient in handling string operations, which are used intensively in EnergyPlus code. DOE-2 was rewritten twice from scratch to have better software architecture, data structure, and better run time performance. Therefore, in the long term, it is worth considering rewriting EnergyPlus in an object oriented language like C++, so that EnergyPlus can better integrate with future computer hardware, software, operating systems, and make it easier to add new features to EnergyPlus and allow EnergyPlus to operate more effectively with other simulation programs.

Specific Technical Recommendations From EnergyPlus Code Profiling

Code profiling is a performance analysis of an application's behavior. The code profiling results showed that input and output subroutines, string operations, [3] zone surface long wave radiation

3. String operations are operations that involve text or symbols instead of numbers.

calculations,[4] and psychrometric[5] functions get called the greatest number of times and consume the greatest amount of EnergyPlus run time.

Proposed actions are to:

- Investigate why and how the input- and output-related subroutines get called so many times and consume so much time. Separate functionality of data updates for time step calculations and for output reporting to reduce or avoid unnecessary calls. Identify reasons that some reporting subroutines get called the same number of times even if no reports are requested. Explore the feasibility and potential of rewriting certain subroutines for parallel computing to reduce EnergyPlus run time.
- Reduce psychrometric functions calling times and run time by simplifying the function algorithm and/or using data table lookup and interpolation. In normal building and HVAC operation conditions, many air properties have a limited range of variations.
- Reduce string operations as much as possible. Avoid unnecessary string operations. Replace string operations with logical or integer type operations, and cache string operation results for later use, which has been adopted by the EnergyPlus development team. Improve string operations by using variable length strings to avoid the use of the trim function. Explore potential of using a string function library written in C or C++ language for better performance.
- Cache (store) intermediate results to avoid unnecessary and time-consuming recalculations. Analyze why certain input subroutines get called so many times. Any way to cache the schedule values once and be accessible for faster later use?
- Explore the potential of short-cutting or bypassing calculation loops. Identify idle loops and avoid the call from the upstream calling subroutines. Investigate why the initialization subroutines get called so many times. Is every call necessary, and is there a way to limit the number of calls?
- Reduce the number of HVAC iterations by developing more intelligent algorithms to automatically adjust the HVAC time step based on system dynamics and history calculation results.
- Research the consistency of many threshold values used to determine the convergence of iterative calculations. For complex software like EnergyPlus, one or a few calculations with high resolutions may not improve the overall resolution at all.

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4. Radiation to and from a surface is one of the three forms of heat transfer. One can feel heat from a warm surface like a fireplace or the sun due to radiative heat transfer.

5. Psychrometrics or psychrometry describe the field of engineering concerned with the determination of physical and thermodynamic properties of gas-vapor mixtures. The principles of psychrometry apply to any physical system consisting of gas-vapor mixtures; the most common systems of interest involve mixtures of water vapor and air because of its application in HVAC and meteorology.

- Review EnergyPlus code for possibilities of software architecture improvement and data structure re-engineering, with the goal of improving computer execution time.

Benefits to California

This project supports California's goal to evaluate energy-using technologies for possible incorporation in periodic updates to the state's building and appliance standards per the *2005 Integrated Energy Policy Report* by enhancing software analysis tools so that energy efficient envelope and HVAC technologies can be incorporated into future efficiency standards.

About This Report

This report is organized as follows:

- Executive Summary
- Historical Trend of EnergyPlus Run Time
- Comparison of Run Time Between EnergyPlus and DOE-2
- Impacts of Simulation Settings on EnergyPlus Run Time
- Impacts of Model Features on EnergyPlus Run Time
- EnergyPlus Code Profiling
- Computer Platform
- Recommendations to Improve EnergyPlus Run Time
- Benefits to California

A separate report, as the second deliverable for the same task, will test and implement the recommendations identified in the code profiling section of this report and make enhancements to EnergyPlus code to speed up the simulation runs.

1.0 Historical Trend of EnergyPlus Run Time

History always helps humans think about future. With the enhancements to EnergyPlus code made by the development team, the improvements of FORTRAN compilers, and more powerful computers with faster CPUs and more computer memory, EnergyPlus has been making significant progress in reducing the computer run time.

Table 1 shows the computer run time results for the author's computer runs of an annual simulation of the large office building model with four public release versions of EnergyPlus on four different computer platforms. The large office building model is included in the EnergyPlus release as an example file. It has multiple stories (middle floors modeled as floor multiplier) with a total of 15 thermal zones and 1 central VAV systems with water-cooled chillers and hot-water boilers. The loads time step is set to 15 minutes, and HVAC autosizing calculations are specified. The Chicago O'Hare TMY2 weather file is used in the runs.

Table 1. Historical Trend of EnergyPlus Run Time

Run ID	EnergyPlus Version	PC Platform	EnergyPlus Run Time (Seconds)
H1a	1.2.1.012	Current Desktop	400
H1b	1.2.2.030	Current Desktop	265
H1c	2.1.0.023	Current Desktop	107
H1d	2.2.0.023	Current Desktop	124
H2a	1.2.1.012	Current Laptop	578
H2b	1.2.2.030	Current Laptop	418
H2c	2.1.0.023	Current Laptop	242
H2d	2.2.0.023	Current Laptop	250
H3a	1.2.1.012	Old Laptop	992
H3b	1.2.2.030	Old Laptop	645
H3c	2.1.0.023	Old Laptop	424
H3d	2.2.0.023	Old Laptop	461
H4a	1.2.1.012	Very Old Desktop	11136
H4b	1.2.2.030	Very Old Desktop	7007
H4c	2.1.0.023	Very Old Desktop	4472
H4d	2.2.0.023	Very Old Desktop	2211

Source: Lawrence Berkeley National Laboratory

Table 2. Computer Platforms for the History Runs

Platform ID	Platform Description
Current Desktop (2007-2008)	Intel Core 2 Duo with two CPUs of 3 GHZ and 2 GB of RAM and Microsoft Windows XP SP2
Current Laptop (2007-2008)	Intel Core 2 Duo with two CPUs of 2 GHZ and 3 GB of RAM and Microsoft Windows Vista Home Premium
Old Laptop (2004)	Intel Pentium M Processor with one CPU of 1.5 GHZ and 500 MB of RAM and Microsoft Windows XP SP2
Very Old Desktop (2000)	Intel Pentium III with one CPU of 450 MHZ and 192 MB of RAM and Microsoft Windows 98 2nd Edition

Source: Lawrence Berkeley National Laboratory

Table 3. EnergyPlus Versions for the History Runs

Version	Release Date	Description
2.2.0.023	April 22, 2008	All real variables are changed from 32-bit to 64-bit. Use the compiler settings for release build; The EnergyPlus.exe file size is 11,392 KB.
2.1.0.023	October 31, 2007	Use the compiler settings for release build; Improve string handling in EnergyPlus subroutines. The EnergyPlus.exe file size is 10,504 KB.
1.2.2.030	April 22, 2005	Use the compiler settings for release build; The EnergyPlus.exe file size is 8,309 KB.
1.2.1.012	October 1, 2004	Use the compiler settings for debug build. The EnergyPlus.exe file size is 12,141 KB.

Source: Lawrence Berkeley National Laboratory

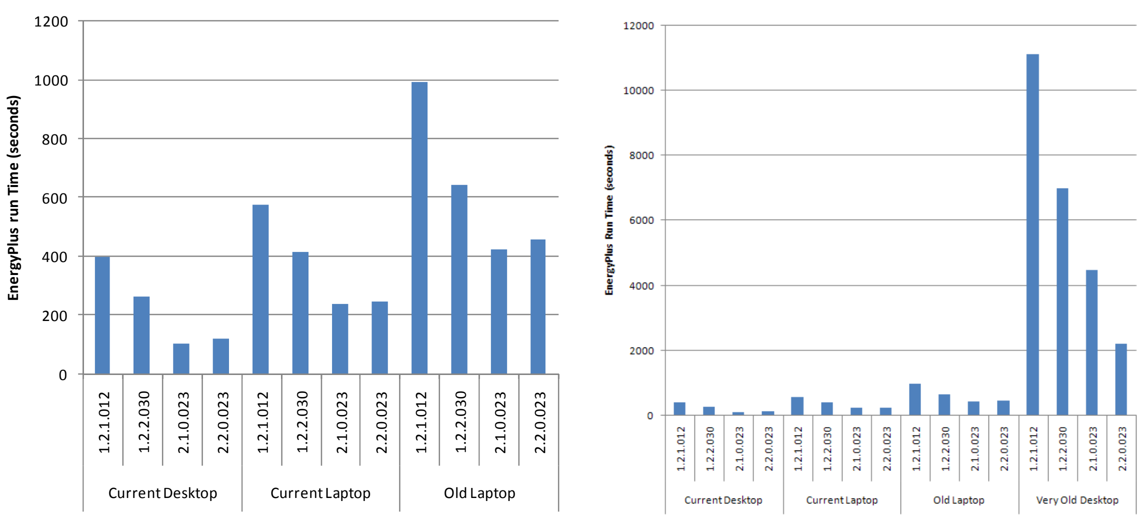


Figure 1. EnergyPlus Run Time – History Runs

Source: Lawrence Berkeley National Laboratory

Two major trends can be observed from these runs:

- Significant run time reduction is achieved with newer versions of EnergyPlus.

  On the current desktop computer, EnergyPlus run time is reduced from 400 seconds (H1a Run) with Version 1.2.1.012 to 265 seconds (H1b Run) with Version 1.2.2.030, to 107 seconds (H1c Run) with Version 2.1.0.023, and to 124 seconds (H1d Run) with Version 2.2.0.023. The run time reduction is by a factor of 3.2 (400/124) from version 2.2.0.023 to 1.2.1.012, and by a factor of 2.1 from version 2.2.0.023 to 1.2.2.030, but run time is increased by about 16% from version 2.1.0.023 to 2.2.0.023.

On the current laptop computer, EnergyPlus run time is reduced from 578 seconds with Version 1.2.1.012 to 418 seconds with Version 1.2.2.030, to 242 seconds with Version 2.1.0.023, and to 250 seconds with Version 2.2.0.023. The run time reduction is by a factor of 2.4 from Version 2.2.0.023 to 1.2.1.012, and by a factor of 1.7 from Version 2.2.0.023 to 1.2.2.030, but run time is increased by about 3% from version 2.1.0.023 to 2.2.0.023.

On the old laptop computer, EnergyPlus run time is reduced from 992 seconds with Version 1.2.1.012 to 645 seconds with Version 1.2.2.030, to 424 seconds with Version 2.1.0.023, and to 461 seconds with Version 2.2.0.023. The run time reduction is by a factor of 2.3 from version 2.2.0.023 to 1.2.1.012, and by a factor of 1.4 from Version 2.2.0.023 to 1.2.2.030, but run time is increased by about 9% from Version 2.1.0.023 to 2.2.0.023.

On the very old desktop computer, EnergyPlus run time is reduced from 11136 seconds with Version 1.2.1.012 to 7007 seconds with Version 1.2.2.030, to 4472 seconds with version 2.1.0.023, and further to 2211 seconds with Version 2.2.0.023. The run time reduction is by a factor of 5.0 from Version 2.2.0.023 to 1.2.1.012, by a factor of 3.2 from Version 2.2.0.023 to 1.2.2.030, and by a factor of 2.0 from Version 2.2.0.023 to 2.1.0.023.

- Significant run time reduction is also achieved with newer faster computers.

  With EnergyPlus Version 2.2.0.023, the run time is reduced from 2211 seconds on the very old desktop to 461 seconds on the old laptop, to 250 seconds on the current laptop, and to 124 seconds on the current desktop. The run time reduction is by a factor of 4.8, 8.8, and 17.8 respectively.

  With EnergyPlus Version 2.1.0.023, the run time is reduced from 4472 seconds on the very old desktop to 424 seconds on the old laptop, to 242 seconds on the current laptop, and to 107 seconds on the current desktop. The run time reduction is by a factor of 10.5, 18.5, and 41.8 respectively.

  With EnergyPlus Version 1.2.2.030, the run time is reduced from 7007 seconds on the very old desktop to 645 seconds on the old laptop, to 418 seconds on the current laptop, and to 265 seconds on the current desktop. The run time reduction is by a factor of 10.9, 16.8, and 26.4 respectively.

  With EnergyPlus Version 1.2.1.012, the run time is reduced from 11,136 seconds on the very old desktop to 992 seconds on the old laptop, to 578 seconds on the current laptop, and to 400 seconds on the current desktop. The run time reduction is by a factor of 11.2, 19.3, and 27.8 respectively.

Several interesting findings are also observed:

- EnergyPlus run time is very close between Version 2.2.0.023 and 2.1.0.023, with Version 2.2.0.023 slightly slower than Version 2.1.0.023, except on the very old desktop computer which has very limited computer memory compared with the other three computers. It is unclear whether this slow down is due to the change of real variables from 32-bit to 64-bit or the additions of new features and modules, or other code changes incorporated in Version 2.2.0.023. It would be interesting to see how these runs perform on computers with 64-bit CPUs, and with the EnergyPlus execution file compiled with 64-bit FORTRAN compilers.

- EnergyPlus Version 1.2.1.012 is very slow compared with the other three versions. The main reason is that Version 1.2.1.012 is a debug version which incorporated full debugging information, while the other three versions are release versions that do not have debugging information built in the EnergyPlus execution file. This might also be derived by comparing the size of the EnergyPlus executive files between Version 1.2.1.012 (12,141 KB) and Version 1.2.2.030 (8,309 KB) – Version 1.2.2.030 adds new features to EnergyPlus Version 1.2.1.012, but the exe file is about 50% smaller. In this sense, it is not an apples-to-apples comparison between version 1.2.1.012 and the other three versions. More meaningful runtime comparisons should be based on the other three EnergyPlus versions.

From these runs, it can be seen that with the current available computer and current version of EnergyPlus in 2008 (H1d), the EnergyPlus run time can be reduced by a factor of up to 56 (from 7007 to 124 seconds) compared with the computer in 2000 and EnergyPlus in 2005 (H4b). The large office building model that took about 11 minutes to run (H3b) three to four years ago would take only 2 minutes to run (H1d) in 2008. This is an impressive progress in reducing EnergyPlus run time by a factor of 5.5 in about 3 to 4 years. Whether this trend will continue is a question hard to answer at the moment. On one hand, there are potential runtime improvements changes can be made to EnergyPlus code and data structure to improve the data exchange between modules and subroutines, and new algorithms can be developed to automatically and intelligently adjust the HVAC system time step. On the other hand, EnergyPlus adds more and more modeling features, which make the program more complex and the size of the compiled exe file bigger. There are also possible future changes to EnergyPlus to improve calculation accuracy that may require more iterative calculations, which will slow the simulation runs.

The recent trend of progress in personal computer technologies is to incorporate more CPUs rather than to increase the speed of a single CPU, which is getting more and more limited to current silicon chip technologies. EnergyPlus, as of version 2.2, only runs on a single CPU for a simulation run, it does not use the potentials of multiple CPUs in current computers. To make sure the history trend continues or even accelerates, EnergyPlus has to be able to take advantages of multiple CPUs. Whether this is done by reengineering EnergyPlus code or using future parallel computer language compilers is an interesting and challenging question hard to answer at the moment.

2.0 Comparison of Run Time Between EnergyPlus and DOE-2

With the trend toward energy-efficient building designs, energy simulation programs are increasingly employed in the design process to help architects and engineers to determine which design alternatives save energy and are cost-effective. DOE-2 is one of the popular programs used by the building simulation community. With today's PC computing power, a DOE-2 energy model normally takes less than a few minutes to complete an annual simulation run. DOE-2's computational efficiency results from its hour-by-hour calculations and the sequential software structure of LOADS-SYSTEMS-PLANT-ECONOMICS, which does not solve the building envelope thermal dynamics with the HVAC system operating performance simultaneously. EnergyPlus is a new generation simulation program built upon the best features of DOE-2 and BLAST and adds new modeling features beyond the two programs. With DOE-2's limitations in modeling emerging technologies, more modelers have begun using EnergyPlus for their simulation needs, especially for LEED green building designs and low or net-zero energy buildings. EnergyPlus does subhourly calculations and integrates the load and system dynamic performance into the whole building energy balance calculations, which can provide more accurate simulation results.

The fact is that compared with DOE-2, EnergyPlus runs much slower. But why and how does EnergyPlus run slower? What is the basis of the comparison? Is the comparison apples-to-apples? It is worth digging into these questions to find out what are the real drivers for a full and clear understanding of computer run time of simulation programs.

Energy models developed from same building prototypes with similar simulation settings should be the basis of runs with different simulation programs for the purpose of comparing computer run time. Modelers should not expect different programs to run at the same speed if these programs have very different modeling capabilities and run at different time steps with different calculation algorithms for different simulation accuracy.

2.1 Approach

2.1.1. Metric for Comparing Simulation Run Time

For the automobile industry, miles per gallon is the metric or criterion to benchmark the fuel efficiency of vehicles. Unfortunately there is no such de facto metric to compare computer run time of simulation programs. Key factors that have significant impacts on simulation run time include: the calculation algorithm and modeling capabilities of the program, the run period, the simulation time step, the complexity of the energy models, the simulation settings, and the software and hardware configurations of the computer that is used to make the simulation runs. With the complexity involved, it is almost impossible to define a theoretical metric to represent the computing efficiency of a simulation program. Fortunately, in practice, the authors can use simple metrics such as SPZ (seconds per zone) to compare computer run time among simulation programs.

SPZ is defined as the total amount of computer run time (for annual runs) divided by the total number of thermal zones of an energy model with a simulation program. SPZ has a unit of seconds per zone. The less the SPZ, the more efficient computing a simulation program has.

2.1.2. Complexity of Energy Models

It is hard to quantitatively define the complexity of an energy model. What is certain is that the types of energy features and the size of building and HVAC systems, to a great extent, determine the complexity of an energy model. The energy features may include: shading of envelope and windows, daylighting and controls, HVAC system types and configurations, plant equipment types and controls, service water heating systems, and renewable energy productions. The size of building and HVAC systems relates to the number of opaque surfaces, the number of openings (windows, doors, and skylights), the number of thermal zones, the number and types of HVAC systems, and the number of primary loops and plant equipment.

Even with DOE-2, if there are lots of shading devices and daylighting calculation is turned on, an annual 8760-hour simulation can take much longer to run.

2.1.3. Simulation Settings

For a specific simulation program, user inputs to some of the simulation settings play a significant role in the amount of computer run time needed to complete a simulation run. The simulation settings include the number of simulation time steps per hour, choice of solution algorithm, and convergence resolution.

For DOE-2, users have very limited inputs to control the simulation run time as the computing time step is fixed at an hour and it is almost impossible to change the calculation algorithms. What users can change are the run period, whether to consider the self shading effects of building facades, accuracy of the shading calculations, and which output reports to produce.

For EnergyPlus, users have much more control on run time. Users can choose simulation time step, heat balance solution algorithm, system convergence limits, solar distribution method, shadow calculation interval, and report generation. Details are described in the next section.

2.1.4. Basis of Comparing Computer Run Time

As different simulation programs may have different software architecture, use different algorithms to model building and energy systems, and require different user inputs even to describe the same building envelope or HVAC system component; it is not feasible to develop an identical energy model with two simulation programs. To get as close as possible for an apple-to-apple comparison of computer run time of simulation programs, simulation programs must be run on a common basis with:

- The same building and energy systems and their control strategies.
- The same simulation run period.
- The same physical and temporal resolutions.

- The same or as close as possible simulation settings: time step, calculation algorithm, and solver convergence tolerance.
- The same computer with same hardware and software configurations.

2.2 Simulation Runs

To demonstrate the above described approach, several building prototypes with different occupancy types, different number of zones, and system types are used to generate the EnergyPlus and DOE-2 models. These models were originally developed by Joe Huang at Lawrence Berkeley National Laboratory and further modified and enhanced by NREL and PNNL for the DOE commercial building benchmarks. Both DOE-2.1E Version 124 and EnergyPlus Version 2.1.0 are used to run these models, and computer run times are listed in tables for comparisons.

2.2.1. Description of EnergyPlus and DOE-2 Models

Three building prototypes are used for comparing the simulation run time. Details of these prototypes are documented in score cards developed by Joe Huang at LBNL for the commercial building prototypes (Huang 2007).

The Large Office Building

The large office building has a rectangular shape with 12 floors. The top, bottom and a typical middle floor are modeled explicitly. The middle floor has a floor multiplier of 10 to represent other 9 middle floors. Each floor has four perimeter and one core zones. The total number of zones is 15. The building is served by one central variable air volume (VAV) systems with chillers and boilers. Perimeter zones have reheat boxes. The window-wall-ratio is 40% with windows uniformly distributed on four facades.

The Secondary School

The secondary school is a campus with 11 buildings. The energy model has a total of 79 thermal zones. The building is served by 11 packaged single zone systems with direct expansion cooling and gas furnace heating. The window-wall-ratio is 33%.

The Hospital Building

The hospital building has a rectangular shape with five floors. Each floor has different zoning pattern. The total number of zones is 55. The building is served by 7 central VAV systems and 1 constant volume air system. The window-wall-ratio is 20%.

2.2.2. Weather Data

The San Francisco TMY2 weather file is used for all simulation runs.

2.2.3. Run Time Results

Annual runs of these prototype models are performed with both DOE-2 and EnergyPlus on a desktop PC with Intel Core 2 Duo of 2 CPUs of 3 GHZ and 2GB of RAM and Microsoft

Windows XP SP2. The DOE-2 runs do not consider any shades. The EnergyPlus runs have default settings of minimal solar shading, 15-minute loads time step, system minimum time step of 6 minutes, 20 system maximum interactions, and conduction transfer function heat balance calculations. HVAC is autosized in all DOE-2 and EnergyPlus runs. All standard summary reports are requested from both DOE-2 and EnergyPlus runs. No daylighting is considered in these runs.

Tables 4 to 6 show EnergyPlus runs at 15-minute time step compared with DOE-2's 60-minute time step.

Table 4. Computer Run Time of the Large Office Building (EnergyPlus 15-minute Time Step)

Simulation Program	Total Run Time (seconds)	SPZ (seconds/zone)
DOE-2.1E v124	0.74	0.049
EnergyPlus v2.1.0	77	5.13

Source: Lawrence Berkeley National Laboratory

Table 5. Computer Run Time of the Secondary School (EnergyPlus 15-minute Time Step)

Simulation Program	Total Run Time (seconds)	SPZ (seconds/zone)
DOE-2.1E v124	5.1	0.065
EnergyPlus v2.1.0	657	8.32

Source: Lawrence Berkeley National Laboratory

Table 6 Computer Run Time of the Hospital Building (EnergyPlus 15-minute Time Step)

Simulation Program	Total Run Time (seconds)	SPZ (seconds/zone)
DOE-2.1E v124	2.6	0.047
EnergyPlus v2.1.0	499	9.24

Source: Lawrence Berkeley National Laboratory

To have a fair comparison, another set of EnergyPlus runs are made at 60-minute loads and system time step with 5 maximum HVAC iterations. Tables 7 to 9 show the results.

Table 7 Computer Run Time of the Large Office Building (EnergyPlus 60-minute Time Step)

Simulation Program	Total Run Time (seconds)	SPZ (seconds/zone)
DOE-2.1E v124	0.74	0.049
EnergyPlus v2.1.0	18.4	1.23

Source: Lawrence Berkeley National Laboratory

Table 8 Computer Run Time of the Secondary School (EnergyPlus 60-minute Time Step)

Simulation Program	Total Run Time (seconds)	SPZ (seconds/zone)
DOE-2.1E v124	5.1	0.065
EnergyPlus v2.1.0	158	2.0

Source: Lawrence Berkeley National Laboratory

Table 9 Computer Run Time of the Hospital Building (EnergyPlus 60-minute Time Step)

Simulation Program	Total Run Time (seconds)	SPZ (seconds/zone)
DOE-2.1E v124	2.6	0.047
EnergyPlus v2.1.0	138	2.55

Source: Lawrence Berkeley National Laboratory

2.3 Run Time Analysis

At 15-minute time step, EnergyPlus runs much slower than DOE-2.1E by a factor of from 105 for the large office building to 196 for the hospital building. At 60-minute time step, EnergyPlus still runs slower than DOE-2.1E by a factor of from 25 for the large office building to 54 for the hospital building, but EnergyPlus computer run time improves by a factor of about 4, which corresponds to the reduction of number of time steps per hour from 4 to 1.

The main reason EnergyPlus runs much slower than DOE-2.1E is that EnergyPlus does the integrated heat balance calculations for loads, systems, and plant at a given time step while DOE-2 does sequential calculations from loads to systems to plant with no feedbacks from plant to systems or from systems to loads. This means EnergyPlus may need a few iterations within a time step in order to reach a convergent solution. A comparison of the modeling features of DOE-2 and EnergyPlus can be found in the article (Crawley et al. 2005).

When DOE-2 was first developed in late 1970s, the computer computing power was very limited. Even an annual run of a 50-zone model could take hours if not days to run. With today’s PC computing power, the question is not to develop simulation programs that run as fast as DOE-2, but rather to develop programs that can do sub-hourly and more accurate building thermal performance calculations in a reasonable amount of time. If EnergyPlus can reach 10 seconds per zone, a typical 50-zone, 5-system model would need about 10 minutes to complete an annual run with currently available PCs (3 GHZ CPU and 2 GB of RAM). Note that for the rather simple modeling runs performed for the comparisons, EnergyPlus in all cases performed faster than 10 seconds per zone. For cases where only monthly and annual energy consumption results are needed, hourly time step may be sufficient. In that case EnergyPlus is in the range of 2 seconds per zone.

3.0 Impacts of Simulation Settings on EnergyPlus Run Time

For a simulation program, user inputs to the simulation settings can play a significant role in the amount of computer run time needed to complete a simulation run. Major simulation settings of EnergyPlus include the length of the run period, the number of calculation time steps per hour, the choice of solution algorithms, the convergence resolutions, and output reports.

3.1. Simulation Settings of EnergyPlus Runs

Users can change the simulation settings of EnergyPlus models with a few EnergyPlus IDD objects to control the run time:

- Length of the run period. Users can choose from a whole year, to one or more months, to one or more weeks, and even to one or more days.
- Number of time steps per hour for loads calculations. Users can choose from one time step (60 minutes) to 60 time steps (1 minute) per hour.
- Heat balance solution algorithm. Users can choose either the CTF (Conduction Transfer Function) or the CondFD (Conduction Finite Difference) method. The CondFD method could handle material properties that depend on temperature including PCMs (phase change material). If moisture absorption and storage effect of zone inside surfaces is to be considered, the EMPD (Empirical Moisture Penetration Depth) method should be used.
- Solar distribution and reflection calculation algorithm. Users can choose among MinimalShadowing, FullExterior, FullInteriorAndExterior, FullExteriorWithReflections, and FullInteriorAndExteriorWithReflections.

  The MinimalShadowing option requires the least amount of calculations. There is no exterior shadowing except from window and door reveals. All beam solar radiation entering the zone is assumed to fall on the floor, where it is absorbed according to the floor's solar absorptance. Any reflected by the floor is added to the transmitted diffuse radiation, which is assumed to be uniformly distributed on all interior surfaces.

  For FullExterior and FullExteriorWithReflections, shadow patterns on exterior surfaces caused by detached shading, wings, overhangs, and exterior surfaces of all zones are computed. Shadowing by window and door reveals is also calculated. Beam solar radiation entering the zone is treated as for MinimalShadowing.

  FullInteriorAndExterior and FullInteriorAndExteriorWithReflections are the same as FullExterior, except that instead of assuming all transmitted beam solar falls on the floor the program calculates the amount of beam radiation falling on each surface in the zone, including floor, walls and windows, by projecting the sun's rays through the exterior windows, taking into account the effect of exterior shadowing surfaces and window shading devices.

- System convergence limits. Choices of minimum system time step (from 1 to 60 minutes) and maximum HVAC iterations (from 5 to 200 or more). In EnergyPlus, HVAC system calculations are started at the loads time step and adjusted downward during iterations as necessary to reach convergence solutions based on loads and temperature criteria.
- Shadow calculation interval. Choices from one day to three weeks, or to whatever is appropriate for the application. This can have significant impact on run time if the energy model has complex building shapes with lots of shading and the activation of daylighting calculations.
- Length of the warm-up runs. Users can set the maximum number of days and the loads and temperature convergence criteria for the warm up runs. Buildings with heavy thermal mass need longer warm up runs.
- Amount and frequency of output reports to be generated during runs. Whether to produce summary reports, monthly reports, and hourly or subhourly reports.

Table 10 summarizes the relevant EnergyPlus IDD objects and fields that the authors have determined users can input to control the run time of an EnergyPlus model. Full details of these IDD objects and their fields can be found in the EnergyPlus Input Output Reference and Engineering Reference manuals, which are available on EnergyPlus web site www.EnergyPlus.gov.

Table 10. EnergyPlus IDD Objects and Fields Related to Simulation Settings

Category of Settings	IDD Object	IDD Field(s)	Description
Length of Run Period	Run Period	Begin Month, Begin Day Of Month, End Month, End Day Of Month, Day Of Week For Start Day, Number of times Run Period to be done	This defines the beginning and end of the run period. The run period can be repeated by the specified times.
LOADS Time Step	TimeStep In Hour	Time Step in Hour	Number of time steps in an hour, used in the heat balance calculations. Value ranges from 1 to 60.
System Convergence Limits	System Convergence Limits	Minimum System Time Step	Minimum time step in HVAC system calculations. Value ranges from 1 to 15 minutes.
	System Convergence Limits	Maximum HVAC Iterations	Maximum number of iterations in HVAC system calculations. Value ranges from 5 to 200.
Heat Balance Solution Algorithm	Solution Algorithm	SolutionAlgo	This specifies what type of heat and moisture transfer algorithm to use for the building envelope. Three choices: CTF, EMPD, CondFD.
Solar Distribution and Reflection Algorithm	Building	Solar Distribution	This determines how EnergyPlus treats beam solar radiation and reflectance from exterior surfaces that strike the building and, ultimately, enter the zone. Five choices: MinimalShadowing, FullExterior and FullInteriorAndExterior, FullExteriorWithReflections, FullInteriorAndExteriorWithReflections.
Shadow Calculations	Shadow Calculations	PeriodForCalculations	Number of days to recalculate shadow. Value of 0 means periodic calculations. Value ranges from 0 to 20.
	Shadow Calculations	MaxFiguresShadowOverlap	Number of allowable figures in shadow overlap calculations. Value ranges from 200 to 15000 and more
Length of Warmup Period	Building	Loads Convergence Tolerance Value	Maximum loads difference to reach warmup convergence. Value ranges from 0.01 to 0.05 representing 1 to 5%.
	Building	Temperature Convergence Tolerance Value	Maximum temperature difference to reach warmup convergence. Value ranges from 0.1 to 0.5°C.
	Building	Maximum Number of Warmup Days	Maximum number of days to run in order to reach convergence for the first simulation day. Value ranges from 7 to 25 or more.
Autosizing Calculations	Run Control	Do the zone sizing calculation	Whether to do the zone autosizing calculations. Two choices: Yes, No.
	Run Control	Do the system sizing calculation	Whether to do the system autosizing calculations. Two choices: Yes, No.
	Run Control	Do the plant sizing calculation	Whether to do the plant autosizing calculations. Two choices: Yes, No.
Design Day Runs	Run Control	Do the design day simulation	Whether to do the design day simulation runs. Two choices: Yes, No.
Weather File Runs	Run Control	Do the weather file simulation	Whether to do the weather file simulation runs. Two choices: Yes, No.
Convection Algorithm	Inside Convection Algorithm	Algorithm	This specifies which algorithm to use in calculating the convection heat transfer of inside surfaces. Three choices: Simple, Detailed, CeilingDiffuser.
	Outside Convection Algorithm	Algorithm	This specifies which algorithm to use in calculating the convection heat transfer of outside surfaces. Three choices: Simple, Detailed, BLAST, TARP, DOE-2, MoWiTT.
Debugging Information	Debug Output	YesNo	Whether to output debugging information in the eplusout.dbg file. Value of 1 means yes.

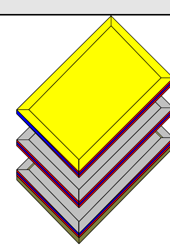
Category of Settings	IDD Object	IDD Field(s)	Description
	Debug Output	EvenDuringWarmup	Whether to output debugging information during warmup runs. Value of 1 means yes.
	Report	Type_of_Report	Variable Dictionary, Surfaces, Construction, Schedules, Materials.
	Report:Table:Predefined	ReportName	Choice of tabular summary reports: ABUPS, IVRS, Climate Summary, Equipment Summary, Envelope Summary, Surface Shadowing Summary, Shading Summary, Lighting Summary, HVAC Sizing Summary, System Summary, Component Sizing Summary, Outside Air Summary, All Summary.
	Report:Table:TimeBins		Define bin reports for variables
	Report:Table:Monthly		Define monthly reports for variables
	Report Variable	Key_Value, Variable_Name	Define the variable to report
Output Reports	Report Variable	Reporting_Frequency	Define the report frequency. Choices are: detailed (for every HVAC time step), timestep (loads/zone time step), hourly, daily, monthly, runperiod/annual.
	Report Meter	Meter_Name, Reporting_Frequency	Define meter name and report frequency. Choices are: timestep (loads/zone time step), hourly, daily, monthly, runperiod/annual.
	Report Cumulative Meter	Meter_Name, Reporting_Frequency	Define meter name and report frequency. Choices are: timestep (loads/zone time step), hourly, daily, monthly, runperiod/annual.
	Report Environmental Impact Factors	Reporting_Frequency	Define the report frequency. Choices are: timestep, hourly, daily, monthly, runperiod.
	Report Variable Dictionary		Output all available report variables in the rdd file.

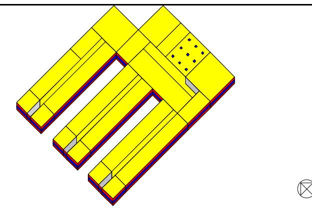
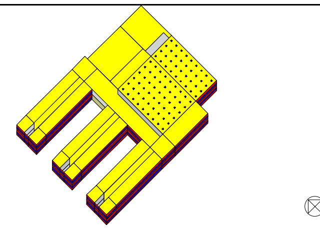
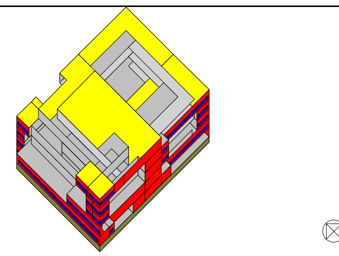
Source: Lawrence Berkeley National Laboratory

3.2. EnergyPlus Models

Four EnergyPlus models are chosen from Version 2 of the DOE commercial building benchmarks for the run time analysis. These are representative new commercial constructions for the United States based on the 2003 CBECS database. The performance of these models is set to meet the prescriptive requirements of ASHRAE Standard 90.1-2004. Table 11 summarizes the four models. Details of these models are documented in the NREL/LBNL/PNNL report- *DOE Commercial Building Research Benchmarks for Commercial Buildings*.

Table 11. Summary of the Four DOE Commercial Building Benchmarks

Building Benchmark	Building Description	Number of HVAC Systems	HVAC System Description	Number of Zones	3D View
The large office building	12 stories, each story 5 zones, use floor multipliers for the middle story	1	1 central VAV with water-cooled chillers and hot-water boilers	15 conditioned zones and 1 unconditioned zone	

The elementary school buildings	1 story	5	4 packaged VAV systems with hot water boiler and 1 PSZ system with gas furnace	25 conditioned zones	
The high school buildings	2 stories	7	3 PSZ systems with gas furnace and 4 central VAV water-cooled chillers and hot-water boilers	46 conditioned zones and 1 unconditioned zone	
The hospital buildings	5 stories	2	2 central VAV with water-cooled chillers and hot-water boilers	54 conditioned zones and 1 unconditioned zone	

Source: Lawrence Berkeley National Laboratory

These represent typical EnergyPlus models with the number of zones from 16 to 55, number of systems from 1 to 7, and HVAC system types from packaged single zone (PSZ) to packaged VAV (PVAV), and to central built-up VAV systems. Plant equipment varies from none to hot-water boilers and/or water-cooled chillers with cooling towers. HVAC equipment is autosized to meet peak loads.

3.3. Parametric Runs

The four base case runs are based on the four commercial building benchmarks with simulation settings listed in Table 12.

Table 12. Simulation Settings for the Base Case Runs

Parameter	Value
Run Period	Annual
Loads Time Step	4 (15 minutes)
Maximum Number of HVAC Iterations	20
Minimum HVAC Time Step	5 minutes
Solar Distribution Algorithm	MinimalShadowing
Heat Balance Solution Algorithm	CTF
Warmup Loads Convergence Limit	0.04 (4%)
Warmup Temperature Convergence Limit	0.2°C
Inside Convection Algorithm	Simple
Outside Convection Algorithm	Simple
Reports	Monthly (56 selected variables)

Source: Lawrence Berkeley National Laboratory

The parametric runs are done with EnergyPlus Version 2.2.0.023 on the current desktop computer specified in the history runs section. For each parametric run, only the parametric variable is different from the base case. The San Francisco TMY2 weather file is used in the simulation runs.

Table 13. Parametric Runs for Different Simulation Settings of the Large Office Building Model

Run ID	Parametric Variable	Variable Value	EnergyPlus Run Time (Seconds)
S1	The large office base case		89
S1a1	Run Period	One month: July only	14
S1a2	Run Period	Three Months: May to July	27
S1a3	Run Period	Six Months: January to June	47
S1a4	Run Period	Nine Months: January to September	69
S1b1	Loads Time Step	1 (60 minutes)	73
S1b2	Loads Time Step	2 (30 minutes)	72
S1b3	Loads Time Step	3 (20 minutes)	80
S1b4	Loads Time Step	6 (10 minutes)	120
S1b5	Loads Time Step	12 (5 minutes)	221
S1c1	Maximum Number of HVAC Iterations	5	88
S1c2	Maximum Number of HVAC iterations	50	88
S1d1	Minimum HVAC Time Step	2 minutes	94
S1d2	Minimum HVAC Time Step	10 minutes	85
S1d3	Minimum HVAC Time Step	20 minutes (also for Loads time step)	65
S1d4	Minimum HVAC Time Step	60 minutes (also for Loads time step)	28
S1e1	Solar Distribution Algorithm	FullExterior	88
S1e2	Solar Distribution Algorithm	FullInteriorAndExterior	90
S1e3	Solar Distribution Algorithm	FullExteriorWithReflections	88
S1e4	Solar Distribution Algorithm	FullInteriorAndExteriorWithReflections	88
S1f1	Heat Balance Solution Algorithm	CTF with Loads and System time step set to 3 minutes	368

S1f2	Heat Balance Solution Algorithm	CondFD with Loads and System time step set to 3 minutes	980
S1g1	Warmup Loads Convergence Limit	0.02 (2%)	88
S1g2	Warmup Temperature Convergence Limit	0.1°C	88
S1h1	Inside Convection Algorithm	Detailed	92
S1h2	Inside Convection Algorithm	CeilingDiffuser	88
S1i1	Outside Convection Algorithm	Detailed	90
S1i2	Outside Convection Algorithm	BLAST	92
S1i3	Outside Convection Algorithm	TARP	91
S1i4	Outside Convection Algorithm	DOE-2	91
S1i5	Outside Convection Algorithm	MoWiTT	90
S1j1	Reports	None	82
S1j2	Reports	Summary	82
S1j3	Reports	Daily	137
S1j4	Reports	Hourly	251
S1j5	Reports	TimeStep	649

Source: Lawrence Berkeley National Laboratory

Table 14. Parametric Runs for Different Simulation Settings of the Elementary School Model

Run ID	Parametric Variable	Variable Value	EnergyPlus Run Time (Seconds)
S2	The elementary school base case		285
S2a1	Run Period	One month: July only	38
S2a2	Run Period	Three Months: May to July	86
S2a3	Run Period	Six Months: January to June	148
S2a4	Run Period	Nine Months: January to September	209
S2b1	Loads Time Step	1 (60 minutes)	177
S2b2	Loads Time Step	2 (30 minutes)	198
S2b3	Loads Time Step	3 (20 minutes)	234
S2b4	Loads Time Step	6 (10 minutes)	356
S2b5	Loads Time Step	12 (5 minutes)	601
S2c1	Maximum Number of HVAC Iterations	5	274
S2c2	Maximum Number of HVAC iterations	50	274
S2d1	Minimum HVAC Time Step	2 minutes	350
S2d2	Minimum HVAC Time Step	10 minutes	251
S2d3	Minimum HVAC Time Step	20 minutes	167
S2d4	Minimum HVAC Time Step	60 minutes	71
S2e1	Solar Distribution Algorithm	FullExterior	274
S2e2	Solar Distribution Algorithm	FullInteriorAndExterior	274
S2e3	Solar Distribution Algorithm	FullExteriorWithReflections	278
S2e4	Solar Distribution Algorithm	FullInteriorAndExteriorWithReflections	278
S2f1	Heat Balance Solution Algorithm	CTF with Loads and System time step set to 3 minutes	986
S2f2	Heat Balance Solution Algorithm	CondFD with Loads and System time step set to 3 minutes	3853
S2g1	Warmup Loads Convergence Limit	0.02 (2%)	274

S2g2	Warmup Temperature Convergence Limit	0.1°C	275
S2h1	Inside Convection Algorithm	Detailed	289
S2h2	Inside Convection Algorithm	CeilingDiffuser	279
S2i1	Outside Convection Algorithm	Detailed	275
S2i2	Outside Convection Algorithm	BLAST	275
S2i3	Outside Convection Algorithm	TARP	275
S2i4	Outside Convection Algorithm	DOE-2	275
S2i5	Outside Convection Algorithm	MoWiTT	276
S2j1	Reports	None	260
S2j2	Reports	Summary	261

Source: Lawrence Berkeley National Laboratory

Table 15. Parametric Runs for Different Simulation Settings of the High School Model

Run ID	Parametric Variable	Variable Value	EnergyPlus Run Time (Seconds)
S3	The high school base case		778
S3a1	Run Period	One month: July only	105
S3a2	Run Period	Three Months: May to July	229
S3a3	Run Period	Six Months: January to June	412
S3a4	Run Period	Nine Months: January to September	593
S3b1	Loads Time Step	1 (60 minutes)	478
S3b2	Loads Time Step	2 (30 minutes)	567
S3b3	Loads Time Step	3 (20 minutes)	674
S3b4	Loads Time Step	6 (10 minutes)	1001
S3b5	Loads Time Step	12 (5 minutes)	1639
S3c1	Maximum Number of HVAC Iterations	5	778
S3c2	Maximum Number of HVAC iterations	50	778
S3d1	Minimum HVAC Time Step	2 minutes	1108
S3d2	Minimum HVAC Time Step	10 minutes	714
S3d3	Minimum HVAC Time Step	20 minutes	479
S3d4	Minimum HVAC Time Step	60 minutes	215
S3e1	Solar Distribution Algorithm	FullExterior	780
S3e2	Solar Distribution Algorithm	FullInteriorAndExterior	781
S3e3	Solar Distribution Algorithm	FullExteriorWithReflections	797
S3e4	Solar Distribution Algorithm	FullInteriorAndExteriorWithReflections	800
S3f1	Heat Balance Solution Algorithm	CTF with Loads and System time step set to 3 minutes	2613
S3f2	Heat Balance Solution Algorithm	CondFD with Loads and System time step set to 3 minutes	6033
S3g1	Warmup Loads Convergence Limit	0.02 (2%)	779
S3g2	Warmup Temperature Convergence Limit	0.1°C	779
S3h1	Inside Convection Algorithm	Detailed	787
S3h2	Inside Convection Algorithm	CeilingDiffuser	750
S3i1	Outside Convection Algorithm	Detailed	778
S3i2	Outside Convection Algorithm	BLAST	777

S3i3	Outside Convection Algorithm	TARP	778
S3i4	Outside Convection Algorithm	DOE-2	779
S3i5	Outside Convection Algorithm	MoWiTT	777
S3j1	Reports	None	744
S3j2	Reports	Summary	741

Source: Lawrence Berkeley National Laboratory

Table 16. Parametric Runs for Different Simulation Settings of the Hospital Model

Run ID	Parametric Variable	Variable Value	EnergyPlus Run Time (Seconds)
S4	The hospital base case		508
S4a1	Run Period	One month: July only	85
S4a2	Run Period	Three Months: May to July	160
S4a3	Run Period	Six Months: January to June	276
S4a4	Run Period	Nine Months: January to September	391
S4b1	Loads Time Step	1 (60 minutes)	327
S4b2	Loads Time Step	2 (30 minutes)	343
S4b3	Loads Time Step	3 (20 minutes)	413
S4b4	Loads Time Step	6 (10 minutes)	712
S4b5	Loads Time Step	12 (5 minutes)	1362
S4c1	Maximum Number of HVAC Iterations	5	509
S4c2	Maximum Number of HVAC iterations	50	509
S4d1	Minimum HVAC Time Step	2 minutes	520
S4d2	Minimum HVAC Time Step	10 minutes	522
S4d3	Minimum HVAC Time Step	20 minutes	418
S4d4	Minimum HVAC Time Step	60 minutes	188
S4e1	Solar Distribution Algorithm	FullExterior	534
S4e2	Solar Distribution Algorithm	FullInteriorAndExterior	527
S4e3	Solar Distribution Algorithm	FullExteriorWithReflections	529
S4e4	Solar Distribution Algorithm	FullInteriorAndExteriorWithReflections	531
S4f1	Heat Balance Solution Algorithm	CTF with Loads and System time step set to 3 minutes	2250
S4f2	Heat Balance Solution Algorithm	CondFD with Loads and System time step set to 3 minutes	3953
S4g1	Warmup Loads Convergence Limit	0.02 (2%)	510
S4g2	Warmup Temperature Convergence Limit	0.1°C	510
S4h1	Inside Convection Algorithm	Detailed	519
S4h2	Inside Convection Algorithm	CeilingDiffuser	505
S4i1	Outside Convection Algorithm	Detailed	510
S4i2	Outside Convection Algorithm	BLAST	510
S4i3	Outside Convection Algorithm	TARP	511
S4i4	Outside Convection Algorithm	DOE-2	511
S4i5	Outside Convection Algorithm	MoWiTT	511
S4j1	Reports	None	468
S4j2	Reports	Summary	470

Source: Lawrence Berkeley National Laboratory

3.4 Run Time Analysis

From the above 135 EnergyPlus simulation runs, the following can be observed:

- As expected, the length of run period has a significant impact on run time. The longer the run period, the longer the EnergyPlus run time. The annual run time of the four models (S1, S2, S3 and S4) are 89, 285, 778, and 508 seconds respectively, while the monthly run times (S1a1, S2a1, S3a1, S4a1) are 14, 38, 105, and 85 seconds respectively. The run time is a linear function of run period in term of number of days as shown in Figure 2 with linear trend lines. The trend lines do not extend to cross the origin. The intercepts at the run time vertical axis represent the one-time simulation overheads that are independent of the length of run period: the number of warm up runs, the reading and parsing of the IDD and IDF file, and the preparation of output reports. For the high school case, the intercept is about 44 seconds, which is equivalent to the run time of a 22-day simulation run as one day of simulation consumes about 2 seconds. The actual number of days for the warmup runs in this case is 3 days; therefore the other run time overheads are equivalent to the run time of a 19-day simulation run without overheads.

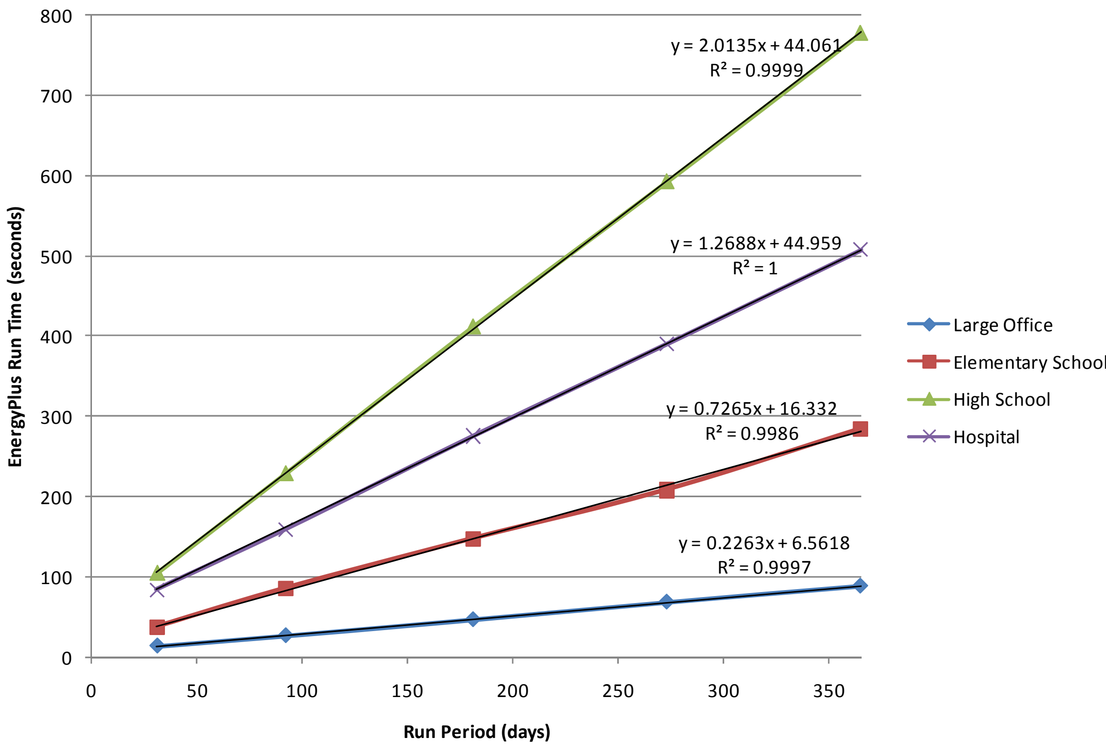


Figure 2. Run Period vs. EnergyPlus Run Time

Source: Lawrence Berkeley National Laboratory

- The loads time step has a significant impact on run time. The shorter the loads time step, the longer the EnergyPlus run time. The 60-minute time step runs (S1b1, S2b1, S3b1, S4b1) consume 73, 177, 478, and 327 seconds respectively, while the 5-minute time step runs (S1b5, S2b5, S3b5, S4b5) consume 221, 601, 1639, and 1362 seconds respectively. The run time increases are by a factor of between 3 and 4, which is not proportional to the reduction of the interval of the loads time step. This is mainly due to the minimum system time step (5 minutes) is set independently of the loads time step.

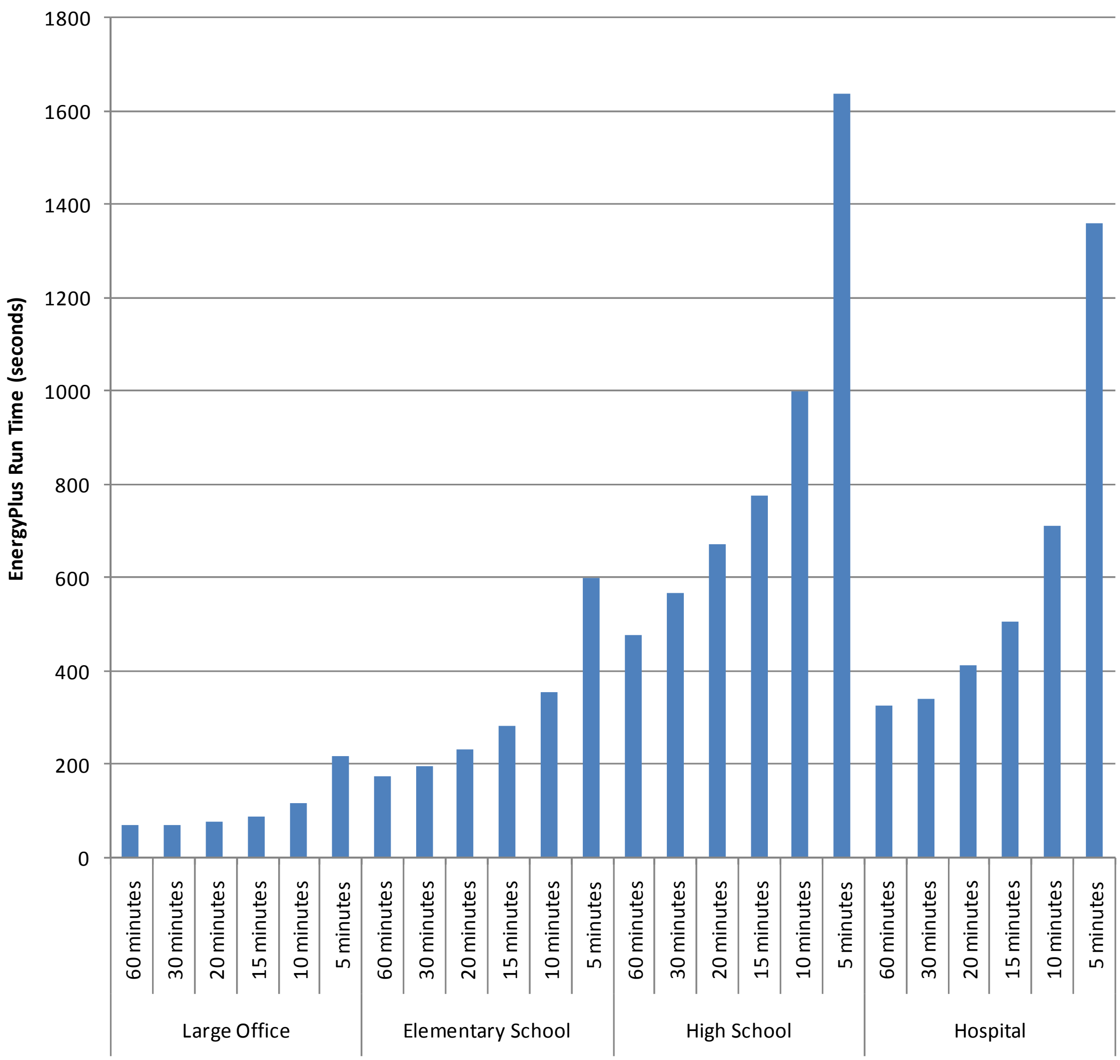


Figure 3. Loads Time Step vs. EnergyPlus Run Time

Source: Lawrence Berkeley National Laboratory

- The maximum HVAC iterations (the c series runs - S1c1, S1c2, S2c1, S2c2, S3c1, S3c2, S4c1, and S4c2) do not have noticeable impact on run time. This implies that the HVAC calculations need no more than 5 iterations for the four models. For more complex HVAC system configurations and control strategies, the maximum HVAC iterations will definitely have a noticeable impact on EnergyPlus run time.

- The minimum HVAC time step has significant impact on EnergyPlus run time as can be seen in the d series runs (S1d1 to S1d4, S2d1 to S2d4, S3d1 to S3d4, and S4d1 to S4d4) listed in tables 13 to 16. For the large office and hospital models, the run time starts to drop when minimum system time step is increased from 10 minutes to 60 minutes. The variations of run times of the 2, 5, and 10 minutes system time step are within the 5% range. This implies that for these two models, the system iterative calculations converge around the time step of 10 minutes. Less than 10 minutes of minimum HVAC time step does not increase run time. For the elementary and high school models, the run time drops when minimum system time step is increased from 2 minutes to 60 minutes. This implies that for these two models, the system iterative calculations converge around the time step of 2 minutes.

The reduction of EnergyPlus run time by increasing the minimum system time step from 2 minutes to 60 minutes is by a factor of 3.4, 4.9, 5.2, and 2.8 for the four models respectively.

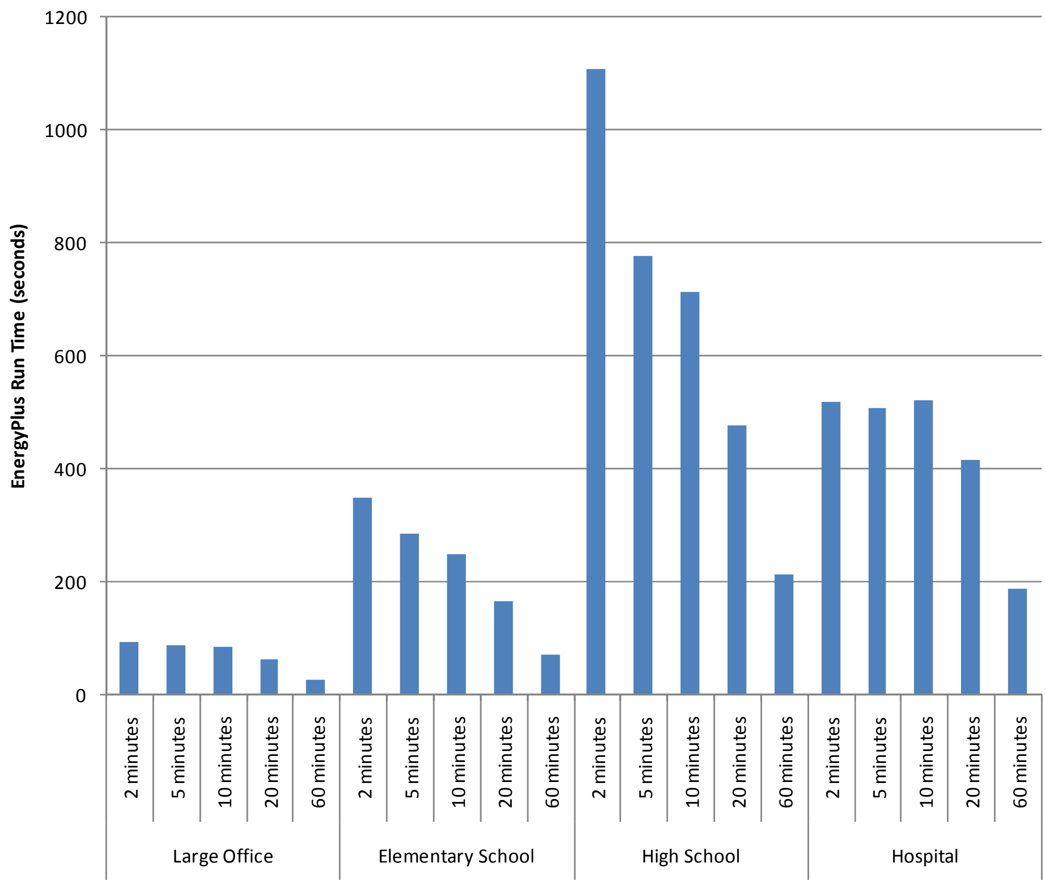


Figure 4. Minimum System Time Step vs. EnergyPlus Run Time

Source: Lawrence Berkeley National Laboratory

- The impact of solar distribution algorithm on EnergyPlus run time is marginal partly because the four models have rather simple building geometry and without daylighting features. The high school model shows an increase of run time by about 3% if solar distribution algorithm is changed from the simplest MinimalShadowing in the base case to the most detailed FullInteriorAndExteriorWithReflections; for the hospital model, the run time increase is about 5%. It is unclear though why EnergyPlus run time is reduced in the large office and the elementary school models when solar distribution algorithm gets more detailed and complex.

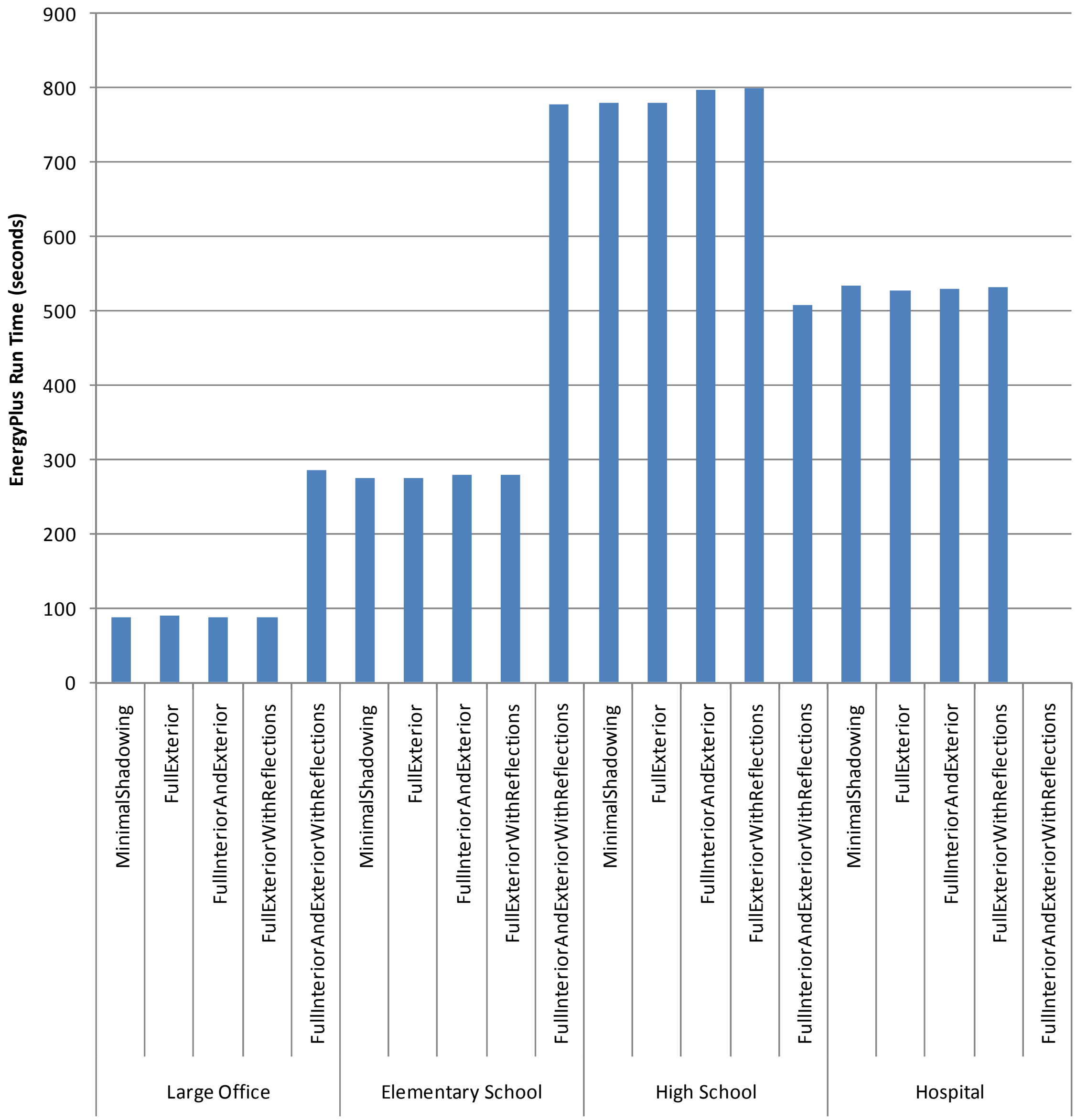


Figure 5. Solar Distribution Algorithm vs. EnergyPlus Run Time

Source: Lawrence Berkeley National Laboratory

- The choice of heat balance solution algorithm has a significant impact on EnergyPlus run time as can be seen from Figure 6. EnergyPlus recommends loads and systems time step of 3 minutes for the CondFD algorithm. In order to compare with the CTF algorithm, new runs are created with the CTF and the same 3 minutes time step for loads and systems. It can be seen that even with the same time steps for CTF and CondFD, the CondFD runs take much longer to complete. The run time increases by a factor of 1.8 for the hospital model and up to 3.9 for the elementary school model. Therefore, unless the building material properties have strong dependency on temperature, the CondFD should be used with the awareness of long run time. The third choice of EMPD is used for situations when the moisture absorption and release of zone inside surfaces is to be considered. EMPD method does not simulate moisture transfer across surfaces. Further investigations need to be done to look at how EMPD will impact the simulation run time.

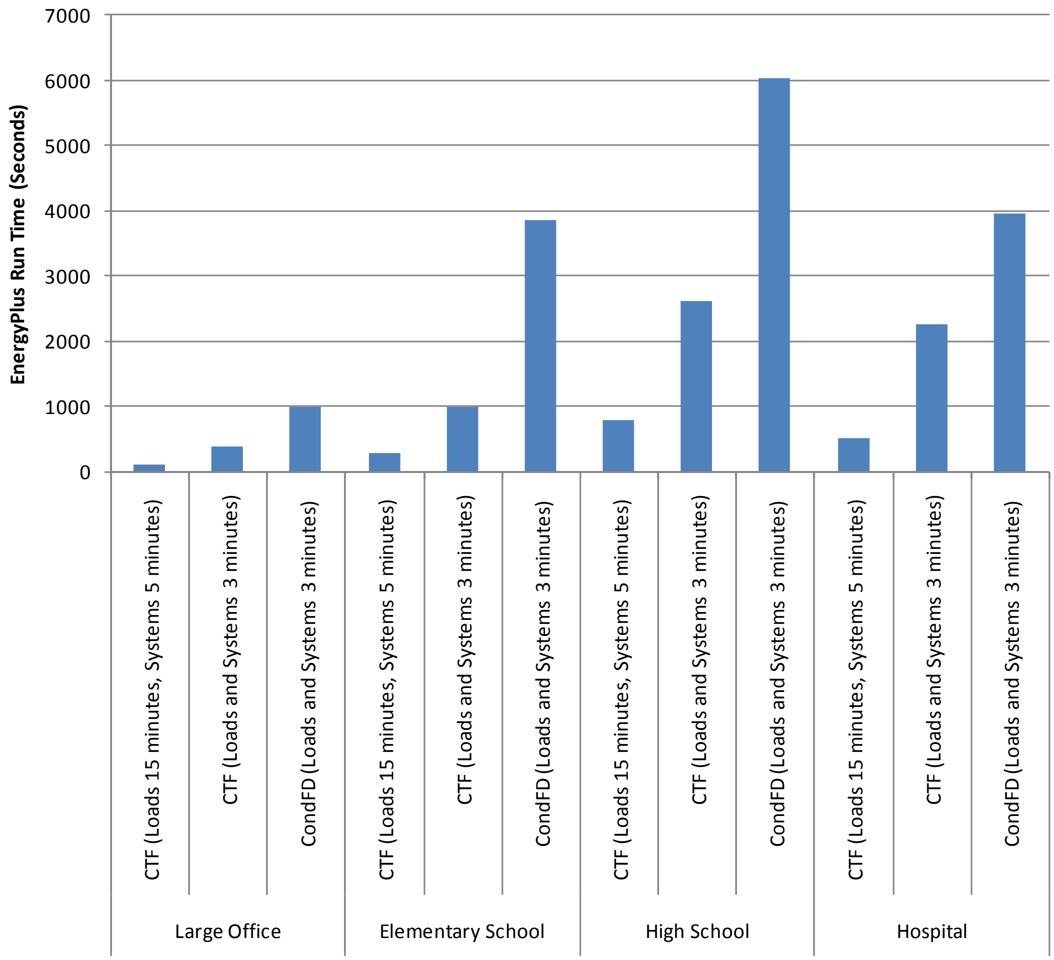


Figure 6. Heat Balance Solution Algorithm vs. EnergyPlus Run Time

Source: Lawrence Berkeley National Laboratory

- Only the elementary school g series runs (S2g1 and S2g2) show a marginal about 4% difference of run time compared with the base case. It is interesting though that, in these two runs, the run time reduces when the convergence limits tighten. EnergyPlus calculates the differences between the minimum and maximum zone temperatures and minimum and maximum zone cooling and heating loads on the current and previous day; if the differences are not greater than the convergence limits, the warmup runs will stop. The warmup runs will stop if the number of warmup runs reaches the maximum number of warmup runs defined in the Building object.

It should be noted that the loads and temperature convergence limits defined in the Building object are only used to determine when to stop the warmup runs; they do not have impact on normal runs. Buildings with heavy thermal mass will need more warmup runs to reach the convergence state.

- Different inside convection algorithms have small impact on run time based on the h series runs (S1h1, S1h2, S2h1, S2h2, S3h1, S3h2, S4h1, and S4h2). The maximum difference of run time is less than 3.6% for the high school model. Three choices are: Simple, Detailed, and CeilingDiffuser. The Simple is for the constant natural convection (ASHRAE); the Detailed is for variable natural convection based on temperature difference (ASHRAE); and the CeilingDiffuser is for ACH based forced and mixed convection correlations for ceiling diffuser configuration with simple natural convection limit.

- Different outside convection algorithms have small impact on run time based on the i series runs (S1i1 to S1i5, S2i1 to S2i5, S3i1 to S3i5, and S4i1 to S4i5). The maximum difference of run time is less than 3.5% for the elementary school model. Six exterior convection models are available in EnergyPlus. In the simple convection model, heat transfer coefficients depend on the roughness of surface and wind speed. The combined heat transfer coefficient includes radiation to sky, ground, and air. In all other convection models, heat transfer coefficients depend on the roughness, wind speed, and terrain of the building's location. These are convection only heat transfer coefficients; radiation heat transfer coefficients are calculated automatically by the program.

- The j series runs are to look at the impact of output reports on EnergyPlus run time. The base cases have monthly reports for the selected 56 report variables (most are for all types of end use and their peak demands). Five choices can be made for output reports:

  - None – no reports are produced (removed all report objects in the IDF files)
  - Summary – all predefined summary reports are produced
  - Daily – daily reports are produced for all available variables in the rdd file
  - Hourly - hourly reports are produced for all available variables in the rdd file
  - TimeStep – detailed time step (sub hourly) reports are produced for all available variables in the rdd file

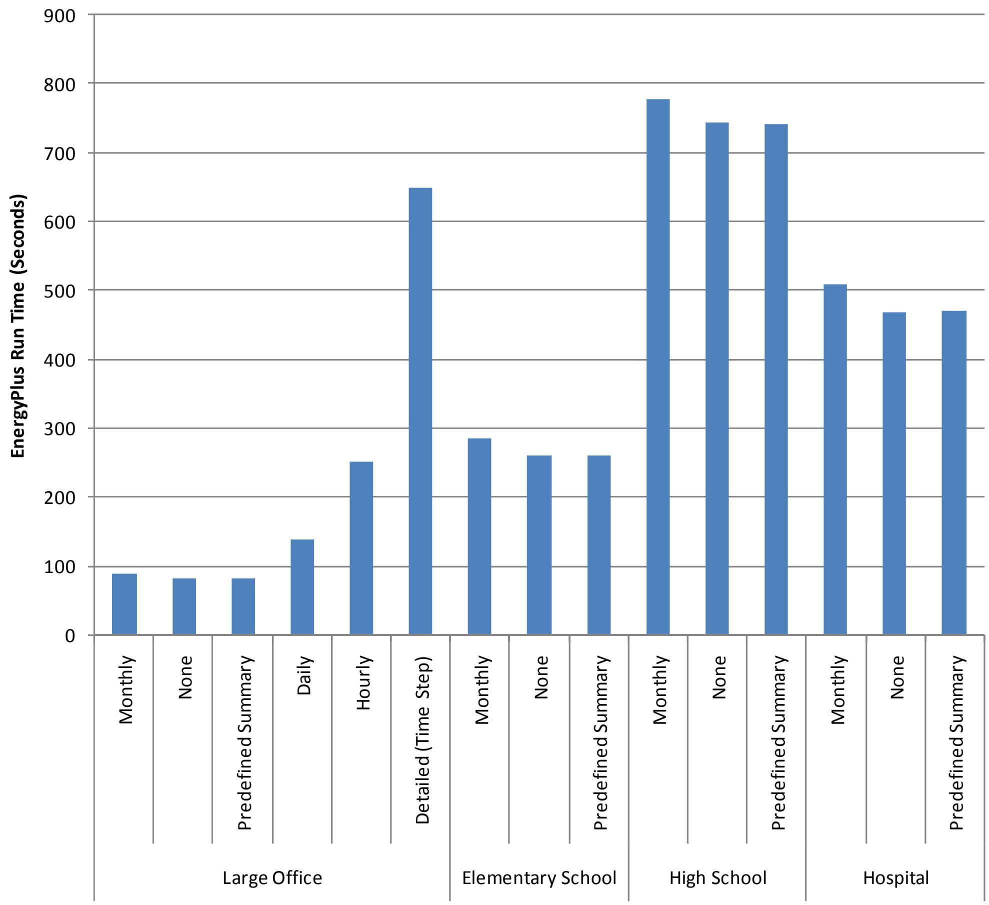


Figure 7. Output Reports vs. EnergyPlus Run Time

Source: Lawrence Berkeley National Laboratory

The large office model is run for all five choices while the other three models are run for only two choices. Three important findings are: 1) producing all predefined summary reports does not take more run time than not producing any report at all; 2) producing monthly reports takes a little bit longer to run. Compared with producing all predefined summary reports, the run time increase is between 5.0% and 8.4% for the four models; 3) producing all available variables in the rdd file take significant amount of run time. Compared with producing all predefined summary reports for the large office model, the run time increases by a factor of 1.7, 3.1, and 7.9 to produce the daily, hourly, and detailed (time step) reports (a total of 523 active report variables) respectively. The size of EnergyPlus standard output (eso) file also increases from 19.8 KB for the monthly reports to 134,298 KB for the daily reports, to 1,196,477 KB for the hourly reports, and to 4,761,972 KB for the detailed reports.

It should be noted that the inside and outside convection algorithms can be set at zone level. There are also convergence tolerances that can be set for many EnergyPlus objects: FAN COIL UNIT:4 PIPE, AIR CONDITIONER:WINDOW:CYCLING, PACKAGEDTERMINAL:HEATPUMP:AIRTOAIR, Unit Ventilator, and Unit Heater, SINGLE DUCT:CONST VOLUME:REHEAT, SINGLE DUCT:VAV:REHEAT, SINGLE DUCT:VAVHEATANDCOOL:REHEAT, SINGLE DUCT:SERIES PIU:REHEAT, SINGLE

DUCT:PARALLEL PIU:REHEAT, SINGLE DUCT:CONST VOLUME:4 PIPE INDUC, BASEBOARD HEATER:Water:Convective, AIRFLOWNETWORK SIMULATION, CONTROLLER:SIMPLE, UnitarySystem:HeatPump:WaterToAir, and UnitarySystem:HeatPump:WaterToAir. These convergence settings may have impacts on EnergyPlus run time and they need to be investigated when models with these objects run very slowly.

The weather data used for the simulation runs may also have impacts, although not expected to be significant, on EnergyPlus run time, as different outdoor conditions can trigger different operation modes and controls for the building envelope, daylighting, and HVAC systems.

3.5 Sensitivity of Simulation Results

Speed and accuracy are two pillars of building performance simulations. In most cases, better accuracy requires more comprehensive solution algorithm and smaller time steps. Therefore, besides the impact on EnergyPlus run time, another important aspect of the run time analysis is to look at the sensitivity of EnergyPlus simulation results to variations of simulation settings.

Tables 17 to 20 summarize the HVAC end use and facility peak electric demand for the four buildings with various simulation settings. The percentage differences are compared with the base cases.

For the large office building, the following can be observed:

- The loads time step (b series) has significant impacts on the total HVAC electricity and gas usage. Compared with the base case, when the loads time step is set to 1 (hourly at 60 minutes), total HVAC electricity use increases by 50.9% with cooling, pumps, and tower electricity use about double. The gas use for space heating also increases by 28.5%, and facility peak electric demand increases by 19.7%. Although the simulation results are expected to be, to a small degree, dependent on the loads time step, this large discrepancy is a big surprise. The 5 and 10 minutes time step results show decreases in total HVAC electricity by up to 5.5% and in gas use by up to 15.9%.

- The maximum HVAC iterations runs (c series) do not show differences in energy use. This is due to reasons given in the run time analysis section.

- In most cases, the percentage differences in gas use are much higher than differences in electricity use.

- Except for the two outliners (S1b1 and S1d4), the differences in facility peak electric demand is less than 5%. This is partly due to the peak demand from the HVAC is only portion of the facility demand which includes demands from the lighting and plug loads, which are the same for all runs.

- The minimum HVAC time step has significant impacts on HVAC electricity and gas use. Again the hourly (60 minutes) run (S1d4) shows large differences in energy use. This is partly due to the loads time step also set to 60 minutes. For the 20 minutes HVAC time step (S1d3), HVAC electricity use decreases by 6.2%, and gas use decreases by 14.7%.

- Different solar distribution algorithms (e series) have very small impacts, less than 1%, on HVAC energy use. This is partly due to the simple geometry of the large office that does not result in countable differences in shadowing calculations.
- The heat balance algorithm (f series) runs show the CondFD run has significant impacts on HVAC energy use – electricity use down by 13.9%, gas use down by 39.4%, and facility electric demand down by 4.8%. These differences are mainly due to the use of the CondFD algorithm, because even compared with the CTF algorithm with the same loads and system time step, the CondFD results in much lower HVAC energy use.
- The warmup convergence limits (g series) do not have noticeable impact on HVAC energy use as expected due to the reasons given in the run time analysis section.
- The inside convection algorithm runs (h series) show significant differences in HVAC energy use. Compared with the base case results, the Detailed algorithm results show decrease of HVAC electricity use by 8.2% and gas use by 23.7%; while the CeilingDiffuser run results show decrease of HVAC electricity use by 6.3% but increase of gas use by 5.2%.
- The outside convection algorithm runs (I series) show small differences in HVAC electricity use (0.5%), but large differences in gas use (down by up to 25%).

Table 17. HVAC End Use and Facility Electric Peak Demand – the Large Office Building Model

		Electricity (kWh)						Gas (Therm)		Electricity Demand	
Run ID	Run Description	Cooling	Fans	Pumps	Heat Rejection	Total HVAC	% Difference in Total HVAC	Space Heating	% Difference in Space Heating	Facility Peak kW	% Difference in Facility Peak
S1	base case	565,806	1,036,692	276,772	138,322	2,017,592	n.a.	27,867	n.a.	1,419	n.a.
S1b1	Load time step 1 (60 minutes)	1,002,797	1,160,089	590,947	290,056	3,043,889	50.9%	35,815	28.5%	1,698	19.7%
S1b2	Load time step 2 (30 minutes)	591,319	1,088,172	287,014	144,067	2,110,572	4.6%	30,844	10.7%	1,439	1.4%
S1b3	Load time step 3 (20 minutes)	574,369	1,055,080	280,839	140,011	2,050,299	1.6%	28,869	3.6%	1,426	0.5%
S1b4	Load time step 6 (10 minutes)	535,283	978,594	260,658	131,283	1,905,818	-5.5%	24,917	-10.6%	1,394	-1.8%
S1b5	Load time step 12 (5 minutes)	548,786	989,094	268,267	138,294	1,944,441	-3.6%	23,438	-15.9%	1,406	-0.9%
S1c1	Max HVAC iterations 5	565,806	1,036,692	276,772	138,322	2,017,592	0.0%	27,867	0.0%	1,419	0.0%
S1c2	Max HVAC iterations 50	565,806	1,036,692	276,772	138,322	2,017,592	0.0%	27,867	0.0%	1,419	0.0%
S1d1	Min HVAC time step 2 minutes	582,022	1,073,442	285,031	142,208	2,082,703	3.2%	29,882	7.2%	1,434	1.1%
S1d2	Min HVAC time step 10 minutes	540,475	984,658	263,728	132,103	1,920,964	-4.8%	25,191	-9.6%	1,396	-1.6%
S1d3	Min HVAC time step 20 minutes	547,203	934,939	273,925	136,619	1,892,686	-6.2%	23,776	-14.7%	1,387	-2.3%
S1d4	Min HVAC time step 60 minutes	845,828	909,506	520,917	251,836	2,528,087	25.3%	24,500	-12.1%	1,561	10.0%
S1e1	FullExterior	565,806	1,036,692	276,772	138,322	2,017,592	0.0%	27,867	0.0%	1,419	0.0%
S1e2	FullInteriorAndExterior	564,472	1,034,064	276,058	137,958	2,012,552	-0.2%	27,621	-0.9%	1,418	-0.1%
S1e3	FullExteriorWithReflections	565,683	1,036,525	276,711	138,286	2,017,205	0.0%	27,929	0.2%	1,419	0.0%
S1e4	FullInteriorAndExteriorWithReflections	564,350	1,033,897	276,008	137,925	2,012,180	-0.3%	27,683	-0.7%	1,418	-0.1%
S1f1	CTF (LOADS/SYSTEMS Time Step 3 min)	538,064	979,847	261,517	136,228	1,915,656	-5.1%	24,309	-12.8%	1,397	-1.5%
S1f2	CondFD (LOADS/SYSTEMS Time Step 3 min)	495,900	890,903	229,578	120,364	1,736,745	-13.9%	16,890	-39.4%	1,352	-4.8%
S1g1	Loads convergence 2%	566,353	1,037,733	277,078	138,469	2,019,633	0.1%	27,908	0.1%	1,420	0.0%
S1g2	Temperature convergence 0.1°C	565,800	1,036,750	276,731	138,322	2,017,603	0.0%	27,935	0.2%	1,419	0.0%
S1h1	Inside convection - Detailed	521,342	950,553	253,711	127,231	1,852,837	-8.2%	21,270	-23.7%	1,372	-3.3%
S1h2	Inside convection - CeilingDiffuser	531,783	964,333	263,872	130,519	1,890,507	-6.3%	29,328	5.2%	1,445	1.8%
S1i1	Outside convection - Detailed	569,567	1,042,358	276,700	138,408	2,027,033	0.5%	20,909	-25.0%	1,418	-0.1%
S1i2	Outside convection - BLAST	569,567	1,042,358	276,700	138,408	2,027,033	0.5%	20,909	-25.0%	1,418	-0.1%
S1i3	Outside convection - TARP	569,567	1,042,358	276,700	138,408	2,027,033	0.5%	20,909	-25.0%	1,418	-0.1%
S1i4	Outside convection - DOE-2	569,028	1,040,336	276,908	138,581	2,024,853	0.4%	21,807	-21.7%	1,418	-0.1%
S1i5	Outside convection - MoWiTT	570,478	1,041,975	277,131	138,764	2,028,348	0.5%	20,948	-24.8%	1,421	0.1%

Source: Lawrence Berkeley National Laboratory

For the elementary school model, the results listed in Table 18 show similar patterns as described in the large office model, but differences in HVAC energy use are much smaller. The larger differences come from the use of hourly loads and system time step, CondFD, CeilingDiffuser, and MoWiTT.

Table 18. HVAC End Use and Facility Electric Peak Demand – the Elementary School Model

		Electricity (kWh)						Gas (Therm)		Electricity Demand	
Run ID	Run Description	Cooling	Fans	Pumps	Heat Rejection	Total HVAC	% Difference in Total HVAC	Space Heating	% Difference in Space Heating	Facility Peak kW	% Difference in Facility Peak
S2	base case	265,039	375,683	436	-	641,158	n.a.	15,515	n.a.	480	n.a.
S2b1	Load time step 1 (60 minutes)	258,083	361,644	453	-	620,180	-3.3%	16,149	4.1%	478	-0.5%
S2b2	Load time step 2 (30 minutes)	257,753	361,878	444	-	620,075	-3.3%	15,800	1.8%	479	-0.2%
S2b3	Load time step 3 (20 minutes)	264,061	375,361	444	-	639,866	-0.2%	15,757	1.6%	479	-0.2%
S2b4	Load time step 6 (10 minutes)	265,411	377,706	439	-	643,556	0.4%	15,377	-0.9%	480	-0.2%
S2b5	Load time step 12 (5 minutes)	266,958	383,583	433	-	650,974	1.5%	15,338	-1.1%	481	0.0%
S2c1	Max HVAC iterations 5	265,039	375,683	436	-	641,158	0.0%	15,515	0.0%	480	0.0%
S2c2	Max HVAC iterations 50	265,039	375,683	436	-	641,158	0.0%	15,515	0.0%	480	0.0%
S2d1	Min HVAC time step 2 minutes	264,564	374,278	528	-	639,370	-0.3%	15,617	0.7%	480	0.0%
S2d2	Min HVAC time step 10 minutes	266,672	379,314	419	-	646,405	0.8%	15,344	-1.1%	480	0.0%
S2d3	Min HVAC time step 20 minutes	262,092	378,453	422	-	640,967	0.0%	15,317	-1.3%	479	-0.2%
S2d4	Min HVAC time step 60 minutes	253,656	367,036	419	-	621,111	-3.1%	14,985	-3.4%	478	-0.4%
S2e1	FullExterior	263,244	373,289	442	-	636,975	-0.7%	15,623	0.7%	479	-0.4%
S2e2	FullInteriorAndExterior	263,544	373,672	442	-	637,658	-0.5%	15,629	0.7%	479	-0.3%
S2e3	FullExteriorWithReflections	262,803	372,769	444	-	636,016	-0.8%	15,710	1.3%	478	-0.4%
S2e4	FullInteriorAndExteriorWithReflections	263,028	373,083	442	-	636,553	-0.7%	15,712	1.3%	478	-0.4%
S2f1	CTF (LOADS/SYSTEMS Time Step 3 min)	267,208	384,414	481	-	652,103	1.7%	15,460	-0.4%	480	0.0%
S2f2	CondFD (LOADS/SYSTEMS Time Step 3 min)	242,956	346,500	406	-	589,862	-8.0%	14,394	-7.2%	462	-3.9%
S2g1	Loads convergence 2%	265,039	375,683	436	-	641,158	0.0%	15,515	0.0%	480	0.0%
S2g2	Temperature convergence 0.1°C	265,039	375,683	436	-	641,158	0.0%	15,515	0.0%	480	0.0%
S2h1	Inside convection - Detailed	256,089	372,739	411	-	629,239	-1.9%	14,790	-4.7%	467	-2.9%
S2h2	Inside convection - CeilingDiffuser	246,478	350,864	361	-	597,703	-6.8%	12,541	-19.2%	466	-3.0%
S2i1	Outside convection - Detailed	267,022	377,397	419	-	644,838	0.6%	14,699	-5.3%	480	0.0%
S2i2	Outside convection - BLAST	267,022	377,397	419	-	644,838	0.6%	14,699	-5.3%	480	0.0%
S2i3	Outside convection - TARP	267,022	377,397	419	-	644,838	0.6%	14,699	-5.3%	480	0.0%
S2i4	Outside convection - DOE-2	268,136	378,897	419	-	647,452	1.0%	14,712	-5.2%	481	0.2%
S2i5	Outside convection - MoWiTT	275,172	387,992	411	-	663,575	3.5%	14,562	-6.1%	487	1.4%

Source: Lawrence Berkeley National Laboratory

For the high school model, the results listed in Table 19 show similar patterns as described in the large office model, but differences in HVAC energy use are much smaller. The larger differences come from the use of hourly loads and system time step, CondFD, CeilingDiffuser, and MoWiTT.

Table 19. HVAC End Use and Facility Electric Peak Demand – the High School Model

		Electricity (kWh)						Gas (Therm)		Electricity Demand	
Run ID	Run Description	Cooling	Fans	Pumps	Heat Rejection	Total HVAC	% Difference in Total HVAC	Space Heating	% Difference in Space Heating	Facility Peak kW	% Difference in Facility Peak
S3	base case	519,306	1,397,114	175,817	87,756	2,179,993	n.a.	33,250	n.a.	1,206	n.a.
S3b1	Load time step 1 (60 minutes)	495,883	1,358,617	168,808	84,292	2,107,600	-3.3%	34,441	3.6%	1,184	-1.8%
S3b2	Load time step 2 (30 minutes)	493,528	1,337,980	164,175	80,686	2,076,369	-4.8%	33,945	2.1%	1,198	-0.7%
S3b3	Load time step 3 (20 minutes)	516,947	1,393,242	178,636	88,728	2,177,553	-0.1%	33,823	1.7%	1,202	-0.3%
S3b4	Load time step 6 (10 minutes)	525,500	1,413,183	181,669	91,386	2,211,738	1.5%	32,699	-1.7%	1,206	0.1%
S3b5	Load time step 12 (5 minutes)	541,700	1,438,264	201,325	103,417	2,284,706	4.8%	33,686	1.3%	1,211	0.4%
S3c1	Max HVAC iterations 5	519,306	1,397,114	175,817	87,756	2,179,993	0.0%	33,250	0.0%	1,206	0.0%
S3c2	Max HVAC iterations 50	519,306	1,397,114	175,817	87,756	2,179,993	0.0%	33,250	0.0%	1,206	0.0%
S3d1	Min HVAC time step 2 minutes	512,528	1,382,578	166,578	84,386	2,146,070	-1.6%	33,424	0.5%	1,206	0.0%
S3d2	Min HVAC time step 10 minutes	534,956	1,422,772	191,972	95,517	2,245,217	3.0%	33,395	0.4%	1,205	0.0%
S3d3	Min HVAC time step 20 minutes	535,189	1,400,956	205,542	101,200	2,242,887	2.9%	35,742	7.5%	1,201	-0.3%
S3d4	Min HVAC time step 60 minutes	509,386	1,337,864	189,747	95,064	2,132,061	-2.2%	37,114	11.6%	1,181	-2.0%
S3e1	FullExterior	515,878	1,388,725	174,975	87,275	2,166,853	-0.6%	33,474	0.7%	1,202	-0.3%
S3e2	FullInteriorAndExterior	516,850	1,390,844	175,111	87,425	2,170,230	-0.4%	33,472	0.7%	1,202	-0.3%
S3e3	FullExteriorWithReflections	514,322	1,386,006	174,597	87,061	2,161,986	-0.8%	33,737	1.5%	1,200	-0.5%
S3e4	FullInteriorAndExteriorWithReflections	515,231	1,388,181	174,636	87,150	2,165,198	-0.7%	33,738	1.5%	1,201	-0.4%
S3f1	CTF (LOADS/SYSTEMS Time Step 3 min)	538,642	1,442,280	197,017	102,575	2,280,514	4.6%	33,639	1.2%	1,210	0.3%
S3f2	CondFD (LOADS/SYSTEMS Time Step 3 min)	498,575	1,364,797	189,517	99,222	2,152,111	-1.3%	30,002	-9.8%	1,172	-2.8%
S3g1	Loads convergence 2%	519,306	1,397,114	175,817	87,756	2,179,993	0.0%	33,250	0.0%	1,206	0.0%
S3g2	Temperature convergence 0.1°C	519,306	1,397,114	175,817	87,756	2,179,993	0.0%	33,250	0.0%	1,206	0.0%
S3h1	Inside convection - Detailed	510,233	1,354,592	173,503	87,506	2,125,834	-2.5%	31,621	-4.9%	1,175	-2.6%
S3h2	Inside convection - CeilingDiffuser	475,544	1,295,597	166,872	82,700	2,020,713	-7.3%	27,333	-17.8%	1,179	-2.2%
S3i1	Outside convection - Detailed	529,917	1,404,106	176,747	88,325	2,199,095	0.9%	30,546	-8.1%	1,208	0.2%
S3i2	Outside convection - BLAST	529,917	1,404,106	176,747	88,325	2,199,095	0.9%	30,546	-8.1%	1,208	0.2%
S3i3	Outside convection - TARP	529,917	1,404,106	176,747	88,325	2,199,095	0.9%	30,546	-8.1%	1,208	0.2%
S3i4	Outside convection - DOE-2	527,183	1,400,386	176,267	88,108	2,191,944	0.5%	30,645	-7.8%	1,207	0.1%
S3i5	Outside convection - MoWiTT	539,833	1,423,189	178,886	89,475	2,231,383	2.4%	30,260	-9.0%	1,219	1.1%

Source: Lawrence Berkeley National Laboratory

For the hospital model, the results listed in Table 20 show relatively small differences in HVAC electricity use, but the gas use can up or down by up to 12.8%. The larger differences come from the use of CondFD, different inside and outside convection algorithms. The hourly runs (S4b1 and S4d4) show very small differences in HVAC energy use compared with the other three buildings.

Table 20. HVAC End Use and Facility Electric Peak Demand – the Hospital Model

		Electricity (kWh)						Gas (Therm)		Electricity Demand	
Run ID	Run Description	Cooling	Fans	Pumps	Heat Rejection	Total HVAC	% Difference in Total HVAC	Space Heating	% Difference in Space Heating	Facility Peak kW	% Difference in Facility Peak
S4	base case	408,442	900,078	342,097	178,925	1,829,542	n.a.	25,550	n.a.	1,064	n.a.
S4b1	Load time step 1 (60 minutes)	405,800	894,794	342,700	177,281	1,820,575	-0.5%	24,868	-2.7%	1,054	-0.9%
S4b2	Load time step 2 (30 minutes)	407,986	898,872	342,869	177,736	1,827,463	-0.1%	25,417	-0.5%	1,061	-0.3%
S4b3	Load time step 3 (20 minutes)	408,161	899,594	342,258	177,972	1,827,985	-0.1%	25,510	-0.2%	1,063	-0.1%
S4b4	Load time step 6 (10 minutes)	408,597	900,569	342,064	180,467	1,831,697	0.1%	25,599	0.2%	1,065	0.1%
S4b5	Load time step 12 (5 minutes)	413,394	907,472	344,981	184,222	1,850,069	1.1%	25,235	-1.2%	1,073	0.8%
S4c1	Max HVAC iterations 5	408,442	900,078	342,097	178,925	1,829,542	0.0%	25,550	0.0%	1,064	0.0%
S4c2	Max HVAC iterations 50	408,442	900,078	342,097	178,925	1,829,542	0.0%	25,550	0.0%	1,064	0.0%
S4d1	Min HVAC time step 2 minutes	408,419	900,072	341,908	178,908	1,829,307	0.0%	25,550	0.0%	1,064	0.0%
S4d2	Min HVAC time step 10 minutes	408,511	900,103	342,258	178,969	1,829,841	0.0%	25,551	0.0%	1,064	0.0%
S4d3	Min HVAC time step 20 minutes	408,186	899,528	342,053	177,683	1,827,450	-0.1%	25,511	-0.2%	1,062	-0.1%
S4d4	Min HVAC time step 60 minutes	406,128	894,797	340,108	173,156	1,814,189	-0.8%	25,065	-1.9%	1,051	-1.2%
S4e1	FullExterior	408,442	900,078	342,097	178,925	1,829,542	0.0%	25,550	0.0%	1,064	0.0%
S4e2	FullInteriorAndExterior	407,669	898,803	341,222	178,550	1,826,244	-0.2%	25,491	-0.2%	1,064	0.0%
S4e3	FullExteriorWithReflections	408,272	899,806	341,967	178,853	1,828,898	0.0%	25,595	0.2%	1,063	0.0%
S4e4	FullInteriorAndExteriorWithReflections	407,503	898,530	341,117	178,492	1,825,642	-0.2%	25,536	-0.1%	1,063	0.0%
S4f1	CTF (LOADS/SYSTEMS Time Step 3 min)	410,883	903,831	343,336	184,117	1,842,167	0.7%	25,536	-0.1%	1,070	0.6%
S4f2	CondFD (LOADS/SYSTEMS Time Step 3 min)	395,856	880,733	333,408	178,867	1,788,864	-2.2%	22,283	-12.8%	1,020	-4.1%
S4g1	Loads convergence 2%	408,442	900,078	342,097	178,925	1,829,542	0.0%	25,550	0.0%	1,064	0.0%
S4g2	Temperature convergence 0.1°C	408,447	900,078	342,106	178,928	1,829,559	0.0%	25,550	0.0%	1,064	0.0%
S4h1	Inside convection - Detailed	398,600	885,008	331,967	174,139	1,789,714	-2.2%	24,429	-4.4%	1,055	-0.8%
S4h2	Inside convection - CeilingDiffuser	398,258	879,742	324,558	170,556	1,773,114	-3.1%	26,281	2.9%	1,057	-0.6%
S4i1	Outside convection - Detailed	417,858	911,672	351,703	183,383	1,864,616	1.9%	23,147	-9.4%	1,068	0.4%
S4i2	Outside convection - BLAST	417,858	911,672	351,703	183,383	1,864,616	1.9%	23,147	-9.4%	1,068	0.4%
S4i3	Outside convection - TARP	417,858	911,672	351,703	183,383	1,864,616	1.9%	23,147	-9.4%	1,068	0.4%
S4i4	Outside convection - DOE-2	413,967	907,206	346,433	181,011	1,848,617	1.0%	23,259	-9.0%	1,066	0.2%
S4i5	Outside convection - MoWiTT	420,214	915,300	353,592	184,303	1,873,409	2.4%	22,762	-10.9%	1,071	0.7%

Source: Lawrence Berkeley National Laboratory

Simulation settings, such as the loads and system time steps, the CondFD solution algorithm, the detailed or ceiling diffuser inside convection algorithm, and the MoWiTT outside convection algorithm, may have significant impacts on the results of HVAC energy use. The EnergyPlus development team is aware of some of the issues and addressing them.

4.0 Impacts of Model Features on EnergyPlus Run Time

EnergyPlus can model various configurations of building envelope, lighting and daylighting, service water heating, HVAC systems, and on-site energy generations. The run time of an energy model, to a great extent, depends on the characteristics of the energy features incorporated in the model. Models with simple building components and systems would run much faster than models with complex configurations and control strategies. Considering the broad modeling capabilities of EnergyPlus, it is impossible to try every individual or every combination of energy features in order to quantify their impacts on run time.

4.1. Model Feature Runs

4.1.1. Number of Windows

The M1a and M1b runs are to look at the impact of the number of windows in a model on run time. The base case model (M1a) of the large office building has only 12 windows (one large continuous horizontal band on each perimeter zone). The M1b model is copied from the base case but has 120 windows (10 on each perimeter zone).

Table 21. Parametric Runs with Different Numbers of Windows

Run ID	Description	EnergyPlus Run Time (Seconds)
M1a (S1)	The large office building base case model. One window per perimeter zone. Total of 12 windows for the building.	89
M1b	Based on the large office model. Ten windows per perimeter zone. Total of 120 windows for the building.	230

Source: Lawrence Berkeley National Laboratory

The EnergyPlus run time increases from 89 to 230 seconds (Table 21), this is a dramatic increase by a factor of 2.6, even though both models use simple solar distribution algorithm and no daylighting is involved.

Although no runs are created to look at the impact of the number of building surfaces on run time, it can be expected that the impact will be as significant as the number of windows.

4.1.2. Number of Zones and System Types

Five series of runs (M2 to M5) with different HVAC system types and different numbers of zones and systems are created. The VAV (M2a to M2c) and PVAV (M3c, M4c, and M5c) runs have only one system for the whole building, while the PSZ and PTAC runs have one system for each zone. The buildings have multiple stories with 5 zones (4 perimeters + 1 core) per floor.

Table 22. Parametric Runs with Different Number of Zones and System Types

Run ID	Description	EnergyPlus Run Time (Seconds)
M2a	15 zones, 1 VAV system (central built up with chillers and boilers)	89
M2b	30 zones, 1 VAV system (central built up with chillers and boilers)	232
M2c	45 zones, 1 VAV system (central built up with chillers and boilers)	385
M3a	30 zones, 30 PTAC systems (packaged terminal air-conditioner)	239

M3b	30 zones, 30 PSZ systems (packaged single zone)	267
M3c	30 zones, 1 PVAV system (packaged VAV system)	218
M4a	15 zones, 15 PTAC systems (packaged terminal air-conditioner)	80
M4b	15 zones, 15 PSZ systems (packaged single zone)	85
M4c	15 zones, 1 PVAV system (packaged VAV system)	80
M5a	45 zones, 45 PTAC systems (packaged terminal air-conditioner)	406
M5b	45 zones, 45 PSZ systems (packaged single zone)	456
M5c	45 zones, 1 PVAV system (packaged VAV system)	368

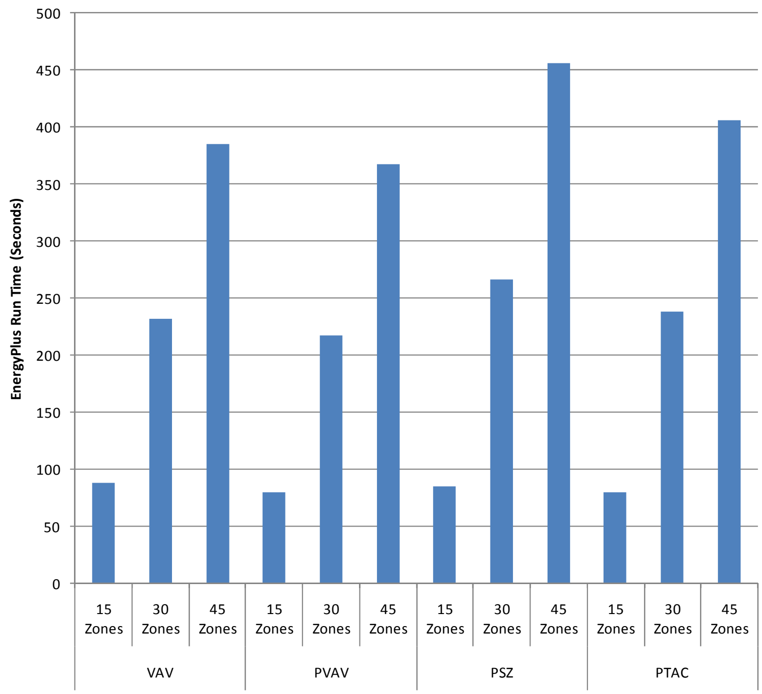


Figure 8. HVAC System Types and Number of Zones vs. EnergyPlus Run Time

Source: Lawrence Berkeley National Laboratory

As can be seen in Figure 8, the number of zones has significant impacts on run time. For the VAV runs, the run time increases by a factor of 2.6 and 4.3 when the number of zones increases from 15 to 30 and to 45 respectively. For the PVAV runs, the run time increases by a factor of 2.7 and 4.6 when the number of zones increases from 15 to 30 and to 45 respectively. For the PTAC runs, the run time increases by a factor of 3.0 and 5.0 when the number of zones increases from 15 to 30 and to 45 respectively. For the PSZ runs, the run time increases by a factor of 3.1 and 5.4 when the number of zones increases from 15 to 30 and to 45 respectively. It should be noted that for the PTAC and PSZ runs, the increases of number of systems also contribute to the increase of run time even though to a less degree.

The run time is more than proportional to the number of zones. It is worth further investigations to determine how and why the relationship between the number of zones and run time would evolve if the number of zones gets greater.

4.1.3. Number of Systems

The M6 series of runs have 60 zones but with different numbers of PVAV systems.

Table 23. Parametric Runs with Different Number of Zones and System Types

Run ID	Description	EnergyPlus Run Time (Seconds)
M6a	60 zones, 1 PVAV system (packaged VAV system)	1109
M6b	60 zones, 2 PVAV systems (packaged VAV system)	1100
M6c	60 zones, 3 PVAV systems (packaged VAV system)	1110
M6d	60 zones, 6 PVAV systems (packaged VAV system)	1139

Source: Lawrence Berkeley National Laboratory

It can be seen that the number of systems have very small impact on run time, less than 3% in this case when the number of systems increases from 1 to 6.

It is worth further investigation for other HVAC system types to see whether this result stays intact.

4.1.4. Thermal Comfort Model

Figure 9 shows the impact of the thermal comfort model on EnergyPlus run time. The thermal comfort model is assigned to each PEOPLE object except for the base case runs. Three thermal comport models are available in EnergyPlus:

- The Fanger Model, developed by P.O. Fanger at Technical University of Denmark in 1967 to 1970. The Fanger theory laid foundations for most other thermal comfort models.
- The Pierce Model, a two-node model developed by J. B. Pierce Foundation at Yale University in 1970 to 1986.
- The KSU Model, a two-node model developed by researchers at Kansas State University in 1977. The KSU model is quite similar to the Pierce model. The main difference is that the KSU model predicts thermal sensation differently for warm and cold environment.

All three models apply an energy balance to a person and use the energy exchange mechanisms along with experimentally derived physiological parameters to predict the thermal sensation and the physiological response of a person due to their environment. The models differ somewhat in the physiological models that represent the human passive system (heat transfer through and from the body) and the human control system (the neural control of shivering, sweating and skin blood flow). The models also differ in the criteria used to predict thermal sensation.

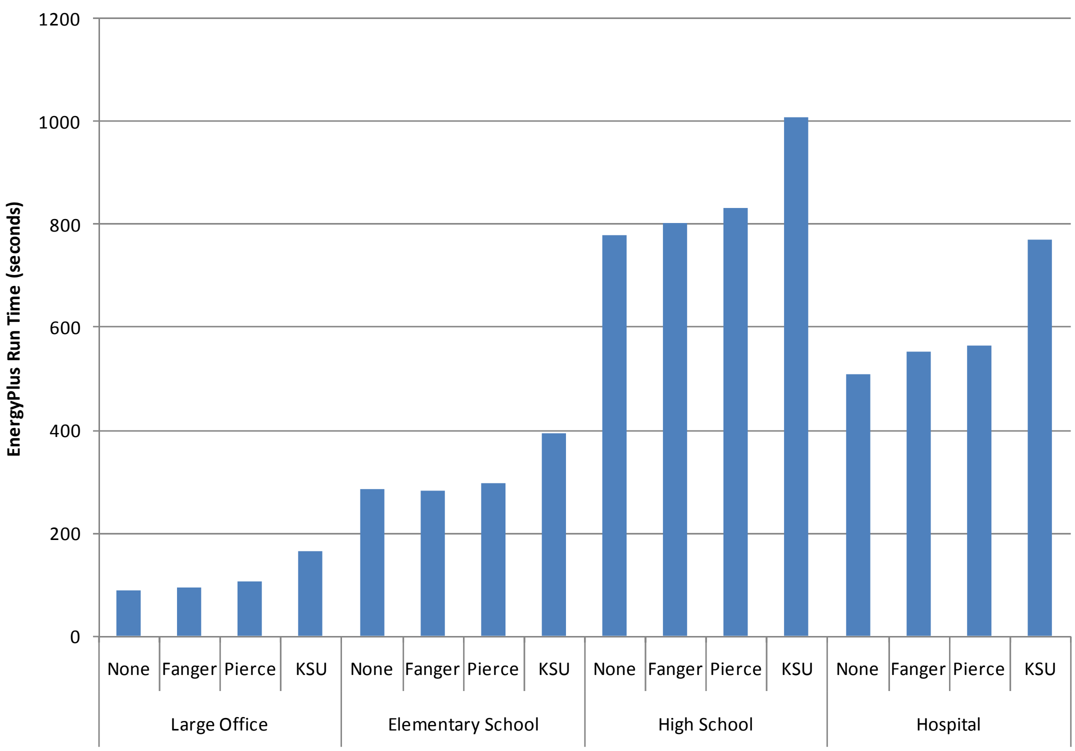


Figure 9. Thermal Comfort Model vs. EnergyPlus Run Time

Source: Lawrence Berkeley National Laboratory

It can be seen that the Fanger and the Pierce thermal comfort models take relatively small amount of more run time than the base cases with no thermal comfort calculations. The KSU model is computationally intensive mainly due to more non-linear equations and iterative calculations. Compared with the base cases, the KSU run time increases by a factor of from 1.3 for the high school model to 1.9 for the large office model.

4.1.5. Other Features

Although not covered in this study, the daylighting and natural ventilation are predicted to have considerable impacts on EnergyPlus run time, especially daylighting with complex building geometry and exterior and interior shading devices, and natural ventilation with the AirflowNetwork method with many cracks and openings (vents, windows, and doors).

4.2 Working With Large Models

With EnergyPlus interface like DesignBuilder and the Energy Design Plugin for Sketchup, it is possible and not hard to quickly create very large complex building models, but modelers should keep in mind the modeling goal before diving in and including every detail of the building design. Otherwise modelers may have created a very detailed model which is impractical to simulate because it is too complex and takes too long to run.

In the early design process, zoning is often simplified as perimeter and interior zones based on their orientations and space functions and operating schedules. In most cases, it is not necessary to model a building on the room-by-room basis for large buildings. If in certain cases that daylighting and shading are not important, multiple windows can be combined into one based on their orientations and construction types.

As rules-of-thumb, EnergyPlus simulations can be slowed down by:

- Many windows
- Many zones
- Many windows per zone
- Many surfaces
- Many surfaces per zone

By lumping building components together rationally, large models can be simplified and thus run much faster. As Einstein said – keep it as simple as possible, but no simpler. Large models can be simplified to a certain degree without sacrificing simulation accuracy. The techniques to simplify large models have been explained in modeling guides, such as the simulation related design briefs and design guidelines in the EnergyDesignResources.com web site, and implemented in some simulation programs, for example, using standard floor shape and layout, adopting typical zoning patterns, and using floor multipliers to represent standard typical floors with similar characteristics.

5.0 EnergyPlus Code Profiling

5.1. Introduction

So far the run time analysis has been done from the outside of EnergyPlus program, i.e. by making parametric runs using the EnergyPlus as a black box without knowing what happens inside EnergyPlus. As Chinese proverb says, "Inherent forces play the decisive roles." Another crucial aspect of run time analysis is to find out from the inside (source code) of EnergyPlus, for a particular simulation run, which subroutines consume the most amount of time, and which subroutines get called the most frequently. Then research on these subroutines can be done to find out potential solutions to speed them up. Code profiling tools can be used to help find out these critical subroutines.

Code profiling means determining how often certain pieces of code are executed. By knowing how frequently a piece of code is used, it can help more accurately gauge the importance of optimizing that piece of code. Proper use of profiling helps to answer these questions and more:

- What lines of code are responsible for the bulk of execution time?
- How many times is this looping construct executed?
- Which approach to coding a block of logic is more efficient?

Without profiling, the answer to the above questions becomes a guessing game. Software developers will oftentimes code PRINT/WRITE/DEBUG statements or manipulate their code in ways to instrument it so they can get response time metrics out that will help them diagnose inefficient code. But such techniques are difficult to do well, plus it is still a very much hunt-and-peck approach. Not so with code profiling.

To do EnergyPlus code profiling, first the EnergyPlus source code has to be complied with the debug information turned on, then EnergyPlus runs are launched by code profiling tools. When the runs complete, the code profiling tools provide statistic summary of the code profiling results. For this study, the EnergyPlus source code, as of version 2.2.0.023, is compiled with the 32-bit version of the Intel Visual FORTRAN (Version 10.1.024) compiler. Intel VTune, version 9.0u11 build 991, is used as the code profiling tool. Compiling and profiling of EnergyPlus is done inside the Microsoft Visual Studio 2005 (Version 8.0.50727.762) development platform. The current desktop computer, described in the history runs section, is the platform for the code profiling analysis.

The expected goals of the code profiling include:

- Locating the EnergyPlus FORTRAN subroutines that consume the most run time.
- Locating the EnergyPlus FORTRAN subroutines that get called the greatest number of times.
- Identifying the critical path of the run time.

- Helping explain EnergyPlus run time behavior in the previous sections of run time analysis.

5.2. Code Profiling Runs

Four EnergyPlus models (Table 24) are selected from Version 2.0 of the DOE commercial building benchmarks for the code profiling analysis. These four models have different number of zones, different number of systems, and different system types. They represent typical EnergyPlus models with various levels of complexity. For the large office model, a separate run (C1a) is made with all reports removed from the EnergyPlus IDF file. This extra run will help identify differences in code profiling for models with and without typical summary and monthly reports. The San Francisco TMY2 weather file is used in these runs.

The VTune analyzer instruments and profiles EnergyPlus runs and displays summaries of function calls and call graphs that show critical functions and call tree.

Table 24. Code Profiling Runs

Run ID	Run Description	Common Simulation Settings
C1	The large office model	Loads time step: 10 minutes System minimum time step: 1 minutes System maximum iterations: 20 Heat balance solution: CTF Inside and outside convection algorithms: detailed Run period: 1/1 to 12/31 HVAC equipment: autosized Solar Distribution: FullInteriorAndExterior Maximum number of warmup days: 25 Reports: All predefined summary reports, monthly reports, thermal comfort report (Fanger)
C1a	The large office model without any reports	
C2	The elementary school model	
C3	The high school model	
C4	The hospital model	

Source: Lawrence Berkeley National Laboratory

5.3. Code Profiling Results

Code profiling results are summarized in tables and figures. Figure 10 shows the EnergyPlus thread call tree up to the main program node. It can be seen that the thread initializes and sets up environment and memory before executing EnergyPlus code. Figure 11 and Figure 12 show the EnergyPlus call tree with the highlighted top 10 self time functions. Figure 13 shows the EnergyPlus critical path in the graph which is the most time-consuming path (call-sequence) originating from the root. It is displayed as a thick red edge in the VTune call graph graphical view and starts from the heaviest, the most time-consuming thread or fiber. Figure 11 to Figure 13 are based on the large office EnergyPlus run.

Function call results for the five model runs (Table 24) are provided as five sets of three tables sorted by function self time, function total time, and number of function calls for only the top 50 functions (subroutines). Full scale function call results are available as Excel files.

Table 25 list the definitions of headers used in Table 26 to Table 40. As the EnergyPlus execution file is compiled with debug and trace back information for code profiling, energy models will run much slower with this version of EnergyPlus than with normal release version. For comparison purpose, the absolute function time is not as important as the relative function time shown as percentages of self time and total time in the results tables. It should be noted that the self and total time shown in the results tables are in micro seconds.

The results tables sorted by function self time show the EnergyPlus FORTRAN subroutines (functions) that consume the most amount of EnergyPlus run time, while the results tables sorted by number of calls show the EnergyPlus FORTRAN subroutines that get called the greatest number of times. These two types of subroutines are the potential key areas to be enhanced or rewritten in order to speed up EnergyPlus runs. The self time is the execution time spent in the function itself without counting its calling subroutines. The total time includes the function self time and the total time of all subroutines called by the function.

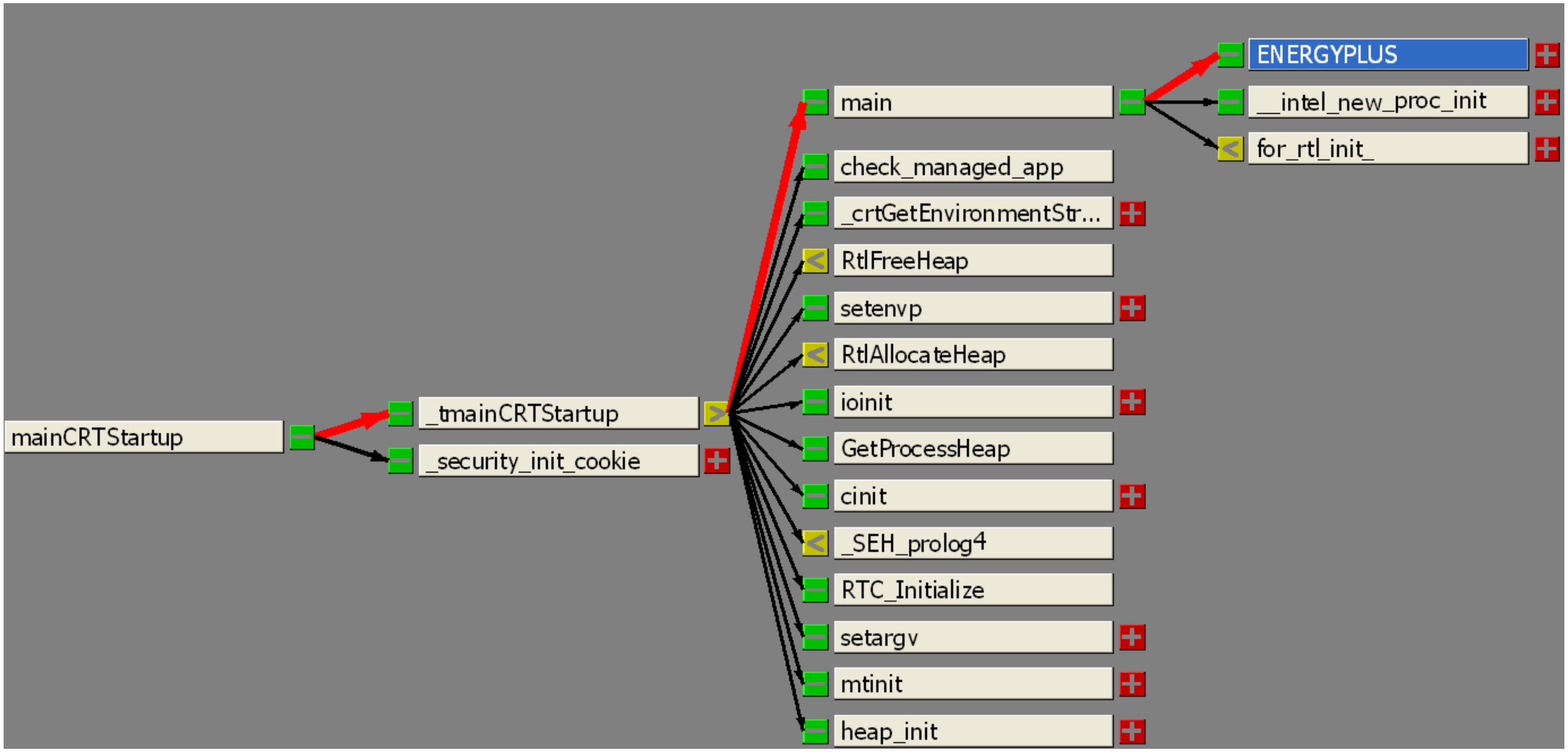


Figure 10. The EnergyPlus Thread Call Tree

Source: Lawrence Berkeley National Laboratory

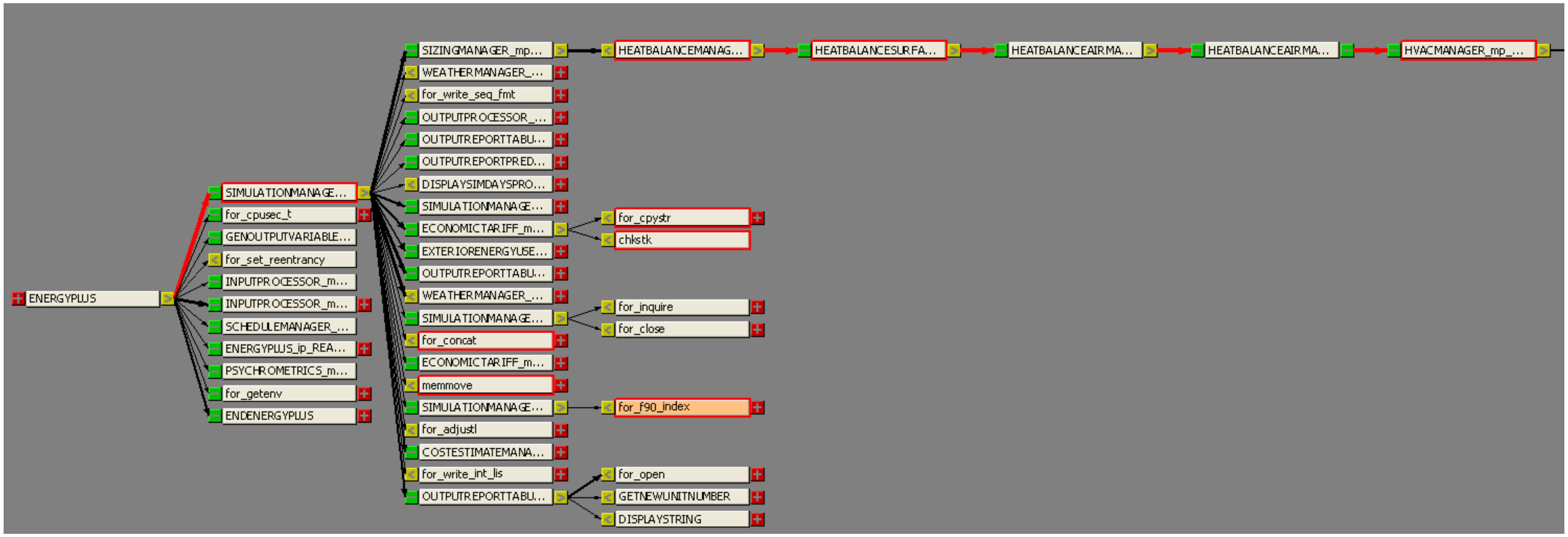


Figure 11. The EnergyPlus Call Tree Starting at EnergyPlus Program

Source: Lawrence Berkeley National Laboratory

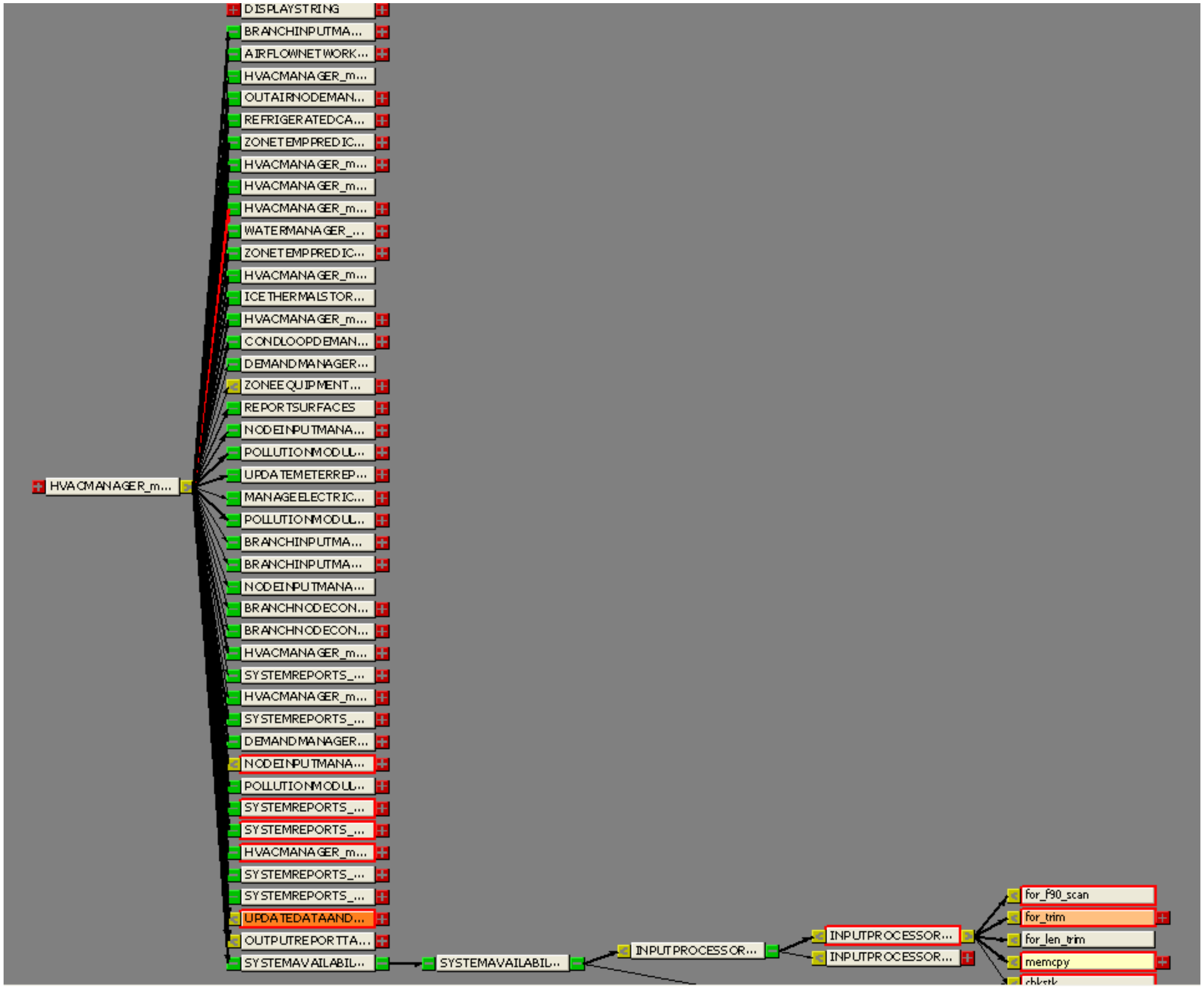


Figure 12. The EnergyPlus Call Tree Continued at HVACManager_mp_ManageHVAC Node

Source: Lawrence Berkeley National Laboratory

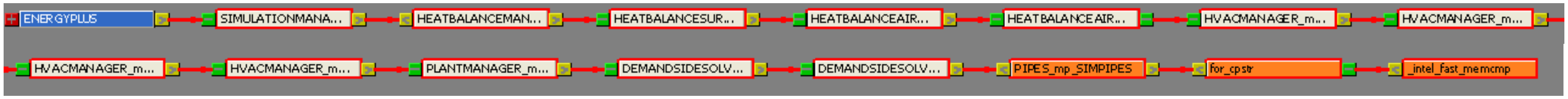


Figure 13. The EnergyPlus Critical Path

Source: Lawrence Berkeley National Laboratory

Table 25. Headers for Function Call Tables

Column	Description
Function	Name of the function.
Self Time	Time (microseconds) spent in the function itself.
% Self Time	Function self time as a percentage of total self time
Total Time	Time (microseconds) spent in the function and in all the callees it called.
% Total Time	Function total time as a percentage of total total time
Calls	Number of times the function was called by all callers.
Callers	Number of caller functions that called the function.
Callees	Number of callee functions the function called.
% in function	Percentage of time was spent in the function itself. You can calculate the ratio using the following formula - Call graph:Self Time/Call graph:Total Time
Average Self time per call	Average distribution of self time in milliseconds. You can calculate the ratio using the following formula: Call graph:Self Time/Call graph:Calls ------------------------------------- 1000
Average Total time per call	Average distribution of self time in milliseconds. You can calculate the ratio using the following formula: Call graph:Total Time/Call graph:Calls -------------------------------------- 1000
Source File	Name of source file to which the function belongs.

Source: Lawrence Berkeley National Laboratory

Table 26. Code Profiling Results Sorted by Subroutine Self Time for the Large Office Run

Rank	Function	Self Time	% Self Time	Total Time	% Total Time	Calls	Callers	Callees	% in function	Average Self time per call	Average Total time per call	Source File
	energyplus.exe - Total	549,553,495	100.0%	553,692,690	100.0%	4,941,074,699						
1	UPDATEDATAANDREPORT	130,229,421	23.7%	185,399,286	33.5%	114,361	2	14	0.7	1.14	1.62	C:\Dev\E+\2.2\OutputProcessor.f90
2	HEATBALANCEINTRADEXCHANGE_mp_CALCINTERIORRADEXCHANGE	39,803,380	7.2%	67,898,185	12.3%	377,524	3	3	0.59	0.11	0.18	C:\Dev\E+\2.2\HeatBalanceIntRadExchange.f90
3	OUTPUTPROCESSOR_mp_SETREPORTNOW	36,767,534	6.7%	36,767,534	6.6%	1,087,157,992	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
4	for_cpstr	33,656,575	6.1%	46,554,673	8.4%	463,138,684	164	1	0.72	0	0	
5	__powr8i4	29,187,636	5.3%	29,187,636	5.3%	749,238,063	14	0	1	0	0	
6	PIPES_mp_SIMPIPES	14,455,702	2.6%	39,672,653	7.2%	78,358,259	3	2	0.36	0	0	C:\Dev\E+\2.2\PlantPipes.f90
7	OUTPUTREPORTTABULAR_mp_GATHERMONTHLYRESULTSFORTIMESTEP	14,083,717	2.6%	18,017,545	3.3%	114,361	1	2	0.78	0.12	0.16	C:\Dev\E+\2.2\OutputReportTabular.f90
8	_intel_fast_memcmp	12,898,098	2.3%	12,898,098	2.3%	463,138,687	2	0	1	0	0	
9	OUTPUTPROCESSOR_mp_SETMINMAX	12,508,481	2.3%	12,508,481	2.3%	463,230,963	2	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
10	CALCHEATBALANCEINSIDESURF	10,587,622	1.9%	82,942,741	15.0%	55,296	1	10	0.13	0.19	1.5	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
11	for_f90_index	8,095,015	1.5%	16,129,808	2.9%	21,709,774	40	3	0.5	0	0	
12	PSYCHROMETRICS_mp_PSYPSATFNTEMP	7,842,541	1.4%	13,415,880	2.4%	61,248,462	8	2	0.58	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
13	PSYCHROMETRICS_mp_PSYCPAIRFNWTDB	7,483,944	1.4%	11,213,459	2.0%	76,720,326	22	1	0.67	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
14	HEATBALANCESURFACEMANAGER_mp_UPDATETHERMALHISTORIES	7,394,804	1.3%	7,394,804	1.3%	55,296	1	2	1	0.13	0.13	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
15	for_trim	5,918,591	1.1%	7,020,499	1.3%	39,667,738	105	1	0.84	0	0	
16	GETINSTANTMETERVALUE	5,158,475	0.9%	5,158,475	0.9%	3,079,296	3	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
17	PSYCHROMETRICS_mp_PSYHFNTDBW	4,646,743	0.8%	4,646,743	0.8%	187,063,090	20	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
18	HEATBALANCESURFACEMANAGER_mp_INITSOLARHEATGAINS	4,403,804	0.8%	5,887,028	1.1%	55,296	1	2	0.75	0.08	0.11	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
19	SYSTEMREPORTS_mp_CALCSYSTEMENERGYUSE	4,381,333	0.8%	14,375,119	2.6%	4,974,785	1	1	0.3	0	0	C:\Dev\E+\2.2\SystemReports.f90
20	memcpy	4,175,703	0.8%	4,175,742	0.8%	87,644,232	156	1	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\memcpy.asm
21	HEATBALANCESURFACEMANAGER_mp_INITSURFACEHEATBALANCE	4,114,441	0.7%	28,521,921	5.2%	55,296	1	19	0.14	0.07	0.52	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
22	FLOWRESOLVER_mp_REQUESTNETWORKFLOWANDSOLVE	4,057,085	0.7%	8,402,722	1.5%	1,435,668	2	2	0.48	0	0.01	C:\Dev\E+\2.2\PlantFlowResolver.f90
23	PLANTLOOPEQUIP_mp_SIMPLANTEQUIP	3,866,070	0.7%	10,449,261	1.9%	5,695,611	2	6	0.37	0	0	C:\Dev\E+\2.2\PlantLoopEquipments.f90
24	WATERCOILS_mp_CALCSIMPLEHEATINGCOIL	3,844,343	0.7%	6,830,974	1.2%	11,885,996	2	6	0.56	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
25	OUTPUTPROCESSOR_mp_UPDATEMETERS	3,560,107	0.6%	5,182,810	0.9%	52,560	1	1	0.69	0.07	0.1	C:\Dev\E+\2.2\OutputProcessor.f90
26	GETINTERNALVARIABLEVALUE	3,462,663	0.6%	3,534,822	0.6%	63,734,186	2	1	0.98	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
27	PLANTCONDLOOPOPERATION_mp_CHECKFOREMSCTRL	3,328,441	0.6%	3,328,441	0.6%	1,504,575	2	0	1	0	0	C:\Dev\E+\2.2\PlantCondLoopOperation.f90
28	log	3,150,980	0.6%	3,150,980	0.6%	63,745,990	7	0	1	0	0	
29	exp	3,135,808	0.6%	3,135,808	0.6%	81,992,221	11	0	1	0	0	
30	PLANTUTILITIES_mp_UPDATEPLANTMIXER	2,732,319	0.5%	2,732,319	0.5%	1,435,668	2	0	1	0	0	C:\Dev\E+\2.2\PlantUtilities.f90
31	DEMANDSIDESOLVERS_mp_SIMULATEPIPES	2,666,066	0.5%	39,927,642	7.2%	4,987,725	1	2	0.07	0	0.01	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
32	DEMANDSIDESOLVERS_mp_SIMPLANTDEMANDSIDES	2,658,361	0.5%	52,960,191	9.6%	332,515	1	7	0.05	0.01	0.16	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
33	FLOWRESOLVER_mp_ENFORCESPLITTERCONTINUITY	2,554,002	0.5%	2,661,553	0.5%	1,435,668	1	1	0.96	0	0	C:\Dev\E+\2.2\PlantFlowResolver.f90
34	CONTROLCOMPOUTPUT	2,370,056	0.4%	17,792,028	3.2%	651,273	1	3	0.13	0	0.03	C:\Dev\E+\2.2\GeneralRoutines.f90
35	GETVARIABLEKEYCOUNTANDTYPE	2,360,687	0.4%	17,523,771	3.2%	1,193	2	11	0.13	1.98	14.69	C:\Dev\E+\2.2\OutputProcessor.f90
36	WATERCOILS_mp_SIMULATEWATERCOILCOMPONENTS	2,315,168	0.4%	18,353,146	3.3%	12,420,340	3	8	0.13	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
37	PSYCHROMETRICS_mp_PSYRHOVFNTDBRH	2,263,952	0.4%	10,106,664	1.8%	34,167,296	1	1	0.22	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
38	free	2,198,515	0.4%	4,347,082	0.8%	21,624,864	6	3	0.51	0	0	f:\sp\vctools\crt_bld\self_x86\crt\src\free.c
39	ZONEEQUIPMENTMANAGER_mp_CALCZONELEAVINGCONDITIONS	2,099,037	0.4%	4,911,339	0.9%	203,970	2	5	0.43	0.01	0.02	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
40	SYSTEMREPORTS_mp_INITENERGYREPORTS	2,083,535	0.4%	2,599,168	0.5%	61,801	1	7	0.8	0.03	0.04	C:\Dev\E+\2.2\SystemReports.f90
41	SCHEDULEMANAGER_mp_GETCURRENTSCHEDULEVALUE	2,080,664	0.4%	2,080,664	0.4%	31,681,606	20	0	1	0	0	C:\Dev\E+\2.2\ScheduleManager.f90
42	for_concat	1,831,854	0.3%	2,611,907	0.5%	19,588,877	74	3	0.7	0	0	
43	PSYCHROMETRICS_mp_PSYTSATFNPB	1,827,213	0.3%	7,198,153	1.3%	1,534,809	2	2	0.25	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
44	pow	1,817,894	0.3%	1,817,894	0.3%	23,632,377	13	0	1	0	0	
45	GETVARIABLEKEYS	1,794,903	0.3%	14,002,496	2.5%	1,193	2	9	0.13	1.5	11.74	C:\Dev\E+\2.2\OutputProcessor.f90
46	PSYCHROMETRICS_mp_PSYRHOAIRFNPBTDBW	1,756,781	0.3%	1,756,781	0.3%	46,019,998	14	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
47	INTERNALHEATGAINS_mp_INITINTERNALHEATGAINS	1,730,018	0.3%	2,053,909	0.4%	55,296	1	7	0.84	0.03	0.04	C:\Dev\E+\2.2\HeatBalanceInternalHeatGains.f90
48	SYSTEMREPORTS_mp_REPORTSYSTEMENERGYUSE	1,728,075	0.3%	16,588,960	3.0%	61,801	1	3	0.1	0.03	0.27	C:\Dev\E+\2.2\SystemReports.f90
49	ZONETEMPPREDICTORCORRECTOR_mp_CALCZONESUMS	1,689,783	0.3%	2,006,135	0.4%	2,285,680	2	1	0.84	0	0	C:\Dev\E+\2.2\ZoneTempPredictorCorrector.f90
50	_intel_fast_memcpy	1,553,211	0.3%	1,553,211	0.3%	60,884,555	16	0	1	0	0	

Source: Lawrence Berkeley National Laboratory

Table 27. Code Profiling Results Sorted by Subroutine Total Time for the Large Office Run

Rank	Function	Self Time	% Self Time	Total Time	% Total Time	Calls	Callers	Callees	% in function	Average Self time per call	Average Total time per call	Source File
	energyplus.exe - Total	549,553,495	100.0%	553,692,690	100.0%	4,941,074,699						
1	ENERGYPLUS	14	0.0%	553,656,901	100.0%	1	1	20	0	0.01	553656.9	C:\Dev\E+\2.2\EnergyPlus.f90
2	SIMULATIONMANAGER_mp_MANAGESIMULATION	68,731	0.0%	550,354,084	99.4%	1	1	30	0	68.73	550354.08	C:\Dev\E+\2.2\SimulationManager.f90
3	HEATBALANCEMANAGER_mp_MANAGEHEATBALANCE	83,012	0.0%	547,169,577	98.8%	55,296	2	7	0	0	9.9	C:\Dev\E+\2.2\HeatBalanceManager.f90
4	HEATBALANCESURFACEMANAGER_mp_MANAGESURFACEHEATBALANCE	68,379	0.0%	403,652,093	72.9%	55,296	1	9	0	0	7.3	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
5	HEATBALANCEAIRMANAGER_mp_MANAGEAIRHEATBALANCE	24,412	0.0%	270,370,444	48.8%	55,296	1	4	0	0	4.89	C:\Dev\E+\2.2\HeatBalanceAirManager.f90
6	HEATBALANCEAIRMANAGER_mp_CALCHEATBALANCEAIR	41,911	0.0%	270,238,669	48.8%	55,296	1	1	0	0	4.89	C:\Dev\E+\2.2\HeatBalanceAirManager.f90
7	HVACMANAGER_mp_MANAGEHVAC	403,083	0.1%	270,196,758	48.8%	55,296	1	44	0	0.01	4.89	C:\Dev\E+\2.2\HVACManager.f90
8	UPDATEDATAANDREPORT	130,229,421	23.7%	185,399,286	33.5%	114,361	2	14	0.7	1.14	1.62	C:\Dev\E+\2.2\OutputProcessor.f90
9	HEATBALANCEMANAGER_mp_REPORTHEATBALANCE	81,030	0.0%	141,156,701	25.5%	55,296	1	5	0	0	2.55	C:\Dev\E+\2.2\HeatBalanceManager.f90
10	HVACMANAGER_mp_SIMHVAC	87,434	0.0%	140,063,311	25.3%	68,533	1	8	0	0	2.04	C:\Dev\E+\2.2\HVACManager.f90
11	HVACMANAGER_mp_SIMSELECTEDEQUIPMENT	249,413	0.0%	139,021,023	25.1%	199,509	1	9	0	0	0.7	C:\Dev\E+\2.2\HVACManager.f90
12	CALCHEATBALANCEINSIDESURF	10,587,622	1.9%	82,942,741	15.0%	55,296	1	10	0.13	0.19	1.5	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
13	PLANTMANAGER_mp_MANAGEPLANTLOOPS	115,726	0.0%	79,238,593	14.3%	199,509	1	6	0	0	0.4	C:\Dev\E+\2.2\PlantManager.f90
14	HEATBALANCEINTRADEXCHANGE_mp_CALCINTERIORRADEXCHANGE	39,803,380	7.2%	67,898,185	12.3%	377,524	3	3	0.59	0.11	0.18	C:\Dev\E+\2.2\HeatBalanceIntRadExchange.f90
15	DEMANDSIDESOLVERS_mp_SIMPLANTDEMANDSIDES	2,658,361	0.5%	52,960,191	9.6%	332,515	1	7	0.05	0.01	0.16	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
16	OUTPUTREPORTTABULAR_mp_UPDATETABULARREPORTS	81,071	0.0%	49,990,833	9.0%	114,361	2	9	0	0	0.44	C:\Dev\E+\2.2\OutputReportTabular.f90
17	for_cpstr	33,656,575	6.1%	46,554,673	8.4%	463,138,684	164	1	0.72	0	0	
18	DEMANDSIDESOLVERS_mp_SIMULATEPIPES	2,666,066	0.5%	39,927,642	7.2%	4,987,725	1	2	0.07	0	0.01	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
19	PIPES_mp_SIMPIPES	14,455,702	2.6%	39,672,653	7.2%	78,358,259	3	2	0.36	0	0	C:\Dev\E+\2.2\PlantPipes.f90
20	OUTPUTPROCESSOR_mp_SETREPORTNOW	36,767,534	6.7%	36,767,534	6.6%	1,087,157,992	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
21	ZONEEQUIPMENTMANAGER_mp_MANAGEZONEEQUIPMENT	67,395	0.0%	36,385,897	6.6%	203,970	3	6	0	0	0.18	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
22	ZONEEQUIPMENTMANAGER_mp_SIMZONEEQUIPMENT	772,391	0.1%	36,017,798	6.5%	201,940	1	8	0.02	0	0.18	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
23	OUTPUTREPORTTABULAR_mp_GETINPUTTABULARMONTHLY	4,025	0.0%	31,576,706	5.7%	1	1	19	0	4.03	31576.71	C:\Dev\E+\2.2\OutputReportTabular.f90
24	__powr8i4	29,187,636	5.3%	29,187,636	5.3%	749,238,063	14	0	1	0	0	
25	HEATBALANCESURFACEMANAGER_mp_INITSURFACEHEATBALANCE	4,114,441	0.7%	28,521,921	5.2%	55,296	1	19	0.14	0.07	0.52	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
26	ZONEAIRLOOPEQUIPMENTMANAGER_mp_MANAGEZONEAIRLOOPEQUIPMENT	502,416	0.1%	26,072,835	4.7%	3,029,100	1	5	0.02	0	0.01	C:\Dev\E+\2.2\Zoneairloopequipmentmanager.f90
27	SUPPLYSIDESOLVERS_mp_MANAGEPLANTSUPPLYSIDES	77,627	0.0%	25,355,787	4.6%	146,041	1	5	0	0	0.17	C:\Dev\E+\2.2\PlantSupplySideSolvers.f90
28	SUPPLYSIDESOLVERS_mp_SIMLOOPPUMPSOLUTIONSCHEME	329,178	0.1%	25,223,126	4.6%	438,123	1	10	0.01	0	0.06	C:\Dev\E+\2.2\PlantSupplySideSolvers.f90
29	ZONEAIRLOOPEQUIPMENTMANAGER_mp_SIMZONEAIRLOOPEQUIPMENT	846,333	0.2%	25,153,089	4.5%	3,029,100	1	2	0.03	0	0.01	C:\Dev\E+\2.2\Zoneairloopequipmentmanager.f90
30	SINGLEDUCT_mp_SIMULATESINGLEDUCT	611,927	0.1%	23,518,664	4.2%	3,029,100	1	6	0.03	0	0.01	C:\Dev\E+\2.2\HVACSingleDuctSystem.f90
31	SUPPLYSIDESOLVERS_mp_LOADBASEDSOLUTION	854,795	0.2%	23,021,706	4.2%	438,123	1	9	0.04	0	0.05	C:\Dev\E+\2.2\PlantSupplySideSolvers.f90
32	SINGLEDUCT_mp_SIMVAV	1,004,170	0.2%	21,771,357	3.9%	3,029,100	1	4	0.05	0	0.01	C:\Dev\E+\2.2\HVACSingleDuctSystem.f90
33	WATERCOILS_mp_SIMULATEWATERCOILCOMPONENTS	2,315,168	0.4%	18,353,146	3.3%	12,420,340	3	8	0.13	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
34	OUTPUTREPORTTABULAR_mp_GATHERMONTHLYRESULTSFORTIMESTEP	14,083,717	2.6%	18,017,545	3.3%	114,361	1	2	0.78	0.12	0.16	C:\Dev\E+\2.2\OutputReportTabular.f90
35	CONTROLCOMPOUTPUT	2,370,056	0.4%	17,792,028	3.2%	651,273	1	3	0.13	0	0.03	C:\Dev\E+\2.2\GeneralRoutines.f90
36	GETVARIABLEKEYCOUNTANDTYPE	2,360,687	0.4%	17,523,771	3.2%	1,193	2	11	0.13	1.98	14.69	C:\Dev\E+\2.2\OutputProcessor.f90
37	SYSTEMREPORTS_mp_REPORTSYSTEMENERGYUSE	1,728,075	0.3%	16,588,960	3.0%	61,801	1	3	0.1	0.03	0.27	C:\Dev\E+\2.2\SystemReports.f90
38	for_f90_index	8,095,015	1.5%	16,129,808	2.9%	21,709,774	40	3	0.5	0	0	
39	SYSTEMREPORTS_mp_CALCSYSTEMENERGYUSE	4,381,333	0.8%	14,375,119	2.6%	4,974,785	1	1	0.3	0	0	C:\Dev\E+\2.2\SystemReports.f90
40	GETVARIABLEKEYS	1,794,903	0.3%	14,002,496	2.5%	1,193	2	9	0.13	1.5	11.74	C:\Dev\E+\2.2\OutputProcessor.f90
41	PSYCHROMETRICS_mp_PSYPSATFNTEMP	7,842,541	1.4%	13,415,880	2.4%	61,248,462	8	2	0.58	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
42	_intel_fast_memcmp	12,898,098	2.3%	12,898,098	2.3%	463,138,687	2	0	1	0	0	
43	OUTPUTPROCESSOR_mp_SETMINMAX	12,508,481	2.3%	12,508,481	2.3%	463,230,963	2	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
44	SIMAIRSERVINGZONES_mp_MANAGEAIRLOOPS	40,330	0.0%	12,236,389	2.2%	206,160	2	4	0	0	0.06	C:\Dev\E+\2.2\SimAirServingZones.f90
45	SIMAIRSERVINGZONES_mp_SIMAIRLOOPS	144,959	0.0%	11,980,170	2.2%	206,159	1	6	0.01	0	0.06	C:\Dev\E+\2.2\SimAirServingZones.f90
46	CALCHEATBALANCEOUTSIDESURF	606,696	0.1%	11,331,763	2.0%	55,296	1	3	0.05	0.01	0.2	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
47	PSYCHROMETRICS_mp_PSYCPAIRFNWTDB	7,483,944	1.4%	11,213,459	2.0%	76,720,326	22	1	0.67	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
48	SIMAIRSERVINGZONES_mp_SIMAIRLOOP	43,600	0.0%	11,078,893	2.0%	237,110	1	2	0	0	0.05	C:\Dev\E+\2.2\SimAirServingZones.f90
49	PLANTLOOPEQUIP_mp_SIMPLANTEQUIP	3,866,070	0.7%	10,449,261	1.9%	5,695,611	2	6	0.37	0	0	C:\Dev\E+\2.2\PlantLoopEquipments.f90
50	PSYCHROMETRICS_mp_PSYRHOVFNTDBRH	2,263,952	0.4%	10,106,664	1.8%	34,167,296	1	1	0.22	0	0	C:\Dev\E+\2.2\PsychRoutines.f90

Source: Lawrence Berkeley National Laboratory

Table 28. Code Profiling Results Sorted by Number of Calls for the Large Office Run

Rank	Function	Self Time	% Self Time	Total Time	% Total Time	Calls	Callers	Callees	% in function	Average Self time per call	Average Total time per call	Source File
	energyplus.exe - Total	549,553,495	100.0%	553,692,690	100.0%	4,941,074,699						
1	OUTPUTPROCESSOR_mp_SETREPORTNOW	36,767,534	6.7%	36,767,534	6.6%	1,087,157,992	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
2	__powr8i4	29,187,636	5.3%	29,187,636	5.3%	749,238,063	14	0	1	0	0	
3	OUTPUTPROCESSOR_mp_SETMINMAX	12,508,481	2.3%	12,508,481	2.3%	463,230,963	2	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
4	_intel_fast_memcmp	12,898,098	2.3%	12,898,098	2.3%	463,138,687	2	0	1	0	0	
5	for_cpstr	33,656,575	6.1%	46,554,673	8.4%	463,138,684	164	1	0.72	0	0	
6	PSYCHROMETRICS_mp_PSYHFNTDBW	4,646,743	0.8%	4,646,743	0.8%	187,063,090	20	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
7	memcpy	4,175,703	0.8%	4,175,742	0.8%	87,644,232	156	1	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\memcpy.asm
8	exp	3,135,808	0.6%	3,135,808	0.6%	81,992,221	11	0	1	0	0	
9	PIPES_mp_SIMPIPES	14,455,702	2.6%	39,672,653	7.2%	78,358,259	3	2	0.36	0	0	C:\Dev\E+\2.2\PlantPipes.f90
10	PSYCHROMETRICS_mp_PSYCPAIRFNWTDB	7,483,944	1.4%	11,213,459	2.0%	76,720,326	22	1	0.67	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
11	log	3,150,980	0.6%	3,150,980	0.6%	63,745,990	7	0	1	0	0	
12	GETINTERNALVARIABLEVALUE	3,462,663	0.6%	3,534,822	0.6%	63,734,186	2	1	0.98	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
13	PSYCHROMETRICS_mp_PSYPSATFNTEMP	7,842,541	1.4%	13,415,880	2.4%	61,248,462	8	2	0.58	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
14	_intel_fast_memcpy	1,553,211	0.3%	1,553,211	0.3%	60,884,555	16	0	1	0	0	
15	ENCODEMONDAYHRMIN	910,366	0.2%	910,366	0.2%	48,438,282	2	0	1	0	0	C:\Dev\E+\2.2\UtilityRoutines.f90
16	memmove	1,029,817	0.2%	1,040,259	0.2%	47,105,926	78	1	0.99	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\Intel\MEMCPY.ASM
17	PSYCHROMETRICS_mp_PSYRHOAIRFNPBTDBW	1,756,781	0.3%	1,756,781	0.3%	46,019,998	14	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
18	chkstk	853,913	0.2%	853,913	0.2%	41,496,718	167	0	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\chkstk.asm
19	for_trim	5,918,591	1.1%	7,020,499	1.3%	39,667,738	105	1	0.84	0	0	
20	PSYCHROMETRICS_mp_PSYRHOVFNTDBRH	2,263,952	0.4%	10,106,664	1.8%	34,167,296	1	1	0.22	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
21	PSYCHROMETRICS_mp_PSYRHOVFNTDBWPB	1,200,340	0.2%	1,200,340	0.2%	34,167,296	1	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
22	SCHEDULEMANAGER_mp_GETCURRENTSCHEDULEVALUE	2,080,664	0.4%	2,080,664	0.4%	31,681,606	20	0	1	0	0	C:\Dev\E+\2.2\ScheduleManager.f90
23	pow	1,817,894	0.3%	1,817,894	0.3%	23,632,377	13	0	1	0	0	
24	_intel_fast_memset	703,636	0.1%	703,638	0.1%	21,940,747	18	1	1	0	0	
25	for_f90_index	8,095,015	1.5%	16,129,808	2.9%	21,709,774	40	3	0.5	0	0	
26	_SEH_prolog4	631,884	0.1%	631,884	0.1%	21,637,920	18	0	1	0	0	
27	_SEH_epilog4	253,819	0.0%	253,819	0.0%	21,637,918	16	0	1	0	0	
28	free	2,198,515	0.4%	4,347,082	0.8%	21,624,864	6	3	0.51	0	0	f:\sp\vctools\crt_bld\self_x86\crt\src\free.c
29	malloc	1,092,778	0.2%	2,957,864	0.5%	21,566,456	8	1	0.37	0	0	f:\sp\vctools\crt_bld\self_x86\crt\src\malloc.c
30	GENERAL_mp_ITERATE	1,015,509	0.2%	1,015,509	0.2%	21,324,351	3	0	1	0	0	C:\Dev\E+\2.2\General.f90
31	for_cpystr	1,477,231	0.3%	2,482,170	0.4%	20,712,279	171	2	0.6	0	0	
32	for__free_vm	970,113	0.2%	5,037,022	0.9%	20,652,498	14	1	0.19	0	0	
33	for__get_vm	807,809	0.1%	3,484,470	0.6%	20,573,650	15	1	0.23	0	0	
34	for_concat	1,831,854	0.3%	2,611,907	0.5%	19,588,877	74	3	0.7	0	0	
35	PSYCHROMETRICS_mp_CPCW	254,232	0.0%	254,232	0.0%	14,853,076	17	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
36	PSYCHROMETRICS_mp_CPHW	214,334	0.0%	214,334	0.0%	12,523,552	13	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
37	WATERCOILS_mp_SIMULATEWATERCOILCOMPONENTS	2,315,168	0.4%	18,353,146	3.3%	12,420,340	3	8	0.13	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
38	WATERCOILS_mp_UPDATEWATERCOIL	1,431,608	0.3%	1,431,608	0.3%	12,420,340	1	0	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
39	WATERCOILS_mp_INITWATERCOIL	986,671	0.2%	1,004,462	0.2%	12,420,340	1	12	0.98	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
40	WATERCOILS_mp_REPORTWATERCOIL	458,867	0.1%	458,867	0.1%	12,420,340	1	0	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
41	WATERCOILS_mp_CALCSIMPLEHEATINGCOIL	3,844,343	0.7%	6,830,974	1.2%	11,885,996	2	6	0.56	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
42	OUTPUTPROCESSOR_mp_UPDATEMETERVALUES	665,760	0.1%	665,760	0.1%	10,722,240	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
43	for_f90_scan	1,056,409	0.2%	1,056,409	0.2%	8,589,673	8	0	1	0	0	
44	DATAENVIRONMENT_mp_OUTDRYBULBTEMPAT	752,748	0.1%	752,748	0.1%	7,962,624	1	0	1	0	0	C:\Dev\E+\2.2\DataEnvironment.f90
45	DATAENVIRONMENT_mp_OUTWETBULBTEMPAT	214,186	0.0%	214,186	0.0%	7,962,624	1	0	1	0	0	C:\Dev\E+\2.2\DataEnvironment.f90
46	allmul	111,678	0.0%	111,678	0.0%	7,618,369	6	0	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\llmul.asm
47	CONVECTIONCOEFFICIENTS_mp_CALCASHRAEDETAILEDINTCONVCOEFF	667,458	0.1%	1,282,496	0.2%	7,077,888	1	1	0.52	0	0	C:\Dev\E+\2.2\HeatBalanceConvectionCoeffs.f90
48	PLANTLOOPEQUIP_mp_SIMPLANTEQUIP	3,866,070	0.7%	10,449,261	1.9%	5,695,611	2	6	0.37	0	0	C:\Dev\E+\2.2\PlantLoopEquipments.f90
49	PSYCHROMETRICS_mp_RHOH2O	363,911	0.1%	586,616	0.1%	5,524,475	27	1	0.62	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
50	GETCURRENTMETERVALUE	129,639	0.0%	129,639	0.0%	5,053,008	3	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90

Source: Lawrence Berkeley National Laboratory

Table 29. Code Profiling Results Sorted by Subroutine Self Time for the Large Office w/o Reports Run

Rank	Function	Self Time	% Self Time	Total Time	% Total Time	Calls	Callers	Callees	% in function	Average Self time per call	Average Total time per call	Source File
	energyplus.exe - Total	386,832,063	100.0%	387,534,677	100.0%	4,455,752,368						
1	UPDATEDATAANDREPORT	95,117,275	24.6%	124,304,013	32.1%	114,361	2	11	0.77	0.83	1.09	C:\Dev\E+\2.2\OutputProcessor.f90
2	HEATBALANCEINTRADEXCHANGE_mp_CALCINTERIORRADEXCHANGE	32,731,554	8.5%	56,774,332	14.7%	377,524	3	3	0.58	0.09	0.15	C:\Dev\E+\2.2\HeatBalanceIntRadExchange.f90
3	for_cpstr	26,533,547	6.9%	37,001,332	9.5%	460,318,156	152	1	0.72	0	0	
4	__powr8i4	24,801,192	6.4%	24,801,192	6.4%	743,023,179	13	0	1	0	0	
5	OUTPUTPROCESSOR_mp_SETREPORTNOW	17,180,443	4.4%	17,180,443	4.4%	1,082,016,382	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
6	PIPES_mp_SIMPIPES	11,413,190	3.0%	32,876,059	8.5%	78,358,259	3	2	0.35	0	0	C:\Dev\E+\2.2\PlantPipes.f90
7	_intel_fast_memcmp	10,467,785	2.7%	10,467,785	2.7%	460,318,159	2	0	1	0	0	
8	CALCHEATBALANCEINSIDESURF	9,367,570	2.4%	68,304,073	17.6%	55,296	1	10	0.14	0.17	1.24	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
9	OUTPUTPROCESSOR_mp_SETMINMAX	8,482,054	2.2%	8,482,054	2.2%	460,865,763	2	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
10	HEATBALANCESURFACEMANAGER_mp_UPDATETHERMALHISTORIES	7,121,260	1.8%	7,121,260	1.8%	55,296	1	2	1	0.13	0.13	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
11	PSYCHROMETRICS_mp_PSYPSATFNTEMP	6,100,613	1.6%	10,213,247	2.6%	59,671,662	7	2	0.6	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
12	PSYCHROMETRICS_mp_PSYCPAIRFNWTDB	5,804,305	1.5%	8,808,935	2.3%	76,720,326	22	1	0.66	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
13	HEATBALANCESURFACEMANAGER_mp_INITSOLARHEATGAINS	4,117,616	1.1%	5,492,789	1.4%	55,296	1	2	0.75	0.07	0.1	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
14	PSYCHROMETRICS_mp_PSYHFNTDBW	3,816,964	1.0%	3,816,964	1.0%	187,063,090	20	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
15	FLOWRESOLVER_mp_REQUESTNETWORKFLOWANDSOLVE	3,809,100	1.0%	7,928,661	2.0%	1,435,668	2	2	0.48	0	0.01	C:\Dev\E+\2.2\PlantFlowResolver.f90
16	GETINSTANTMETERVALUE	3,806,502	1.0%	3,806,502	1.0%	1,596,072	2	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
17	PLANTLOOPEQUIP_mp_SIMPLANTEQUIP	3,575,392	0.9%	9,487,452	2.4%	5,695,611	2	6	0.38	0	0	C:\Dev\E+\2.2\PlantLoopEquipments.f90
18	HEATBALANCESURFACEMANAGER_mp_INITSURFACEHEATBALANCE	3,559,940	0.9%	25,431,793	6.6%	55,296	1	19	0.14	0.06	0.46	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
19	PLANTCONDLOOPOPERATION_mp_CHECKFOREMSCTRL	3,341,862	0.9%	3,341,862	0.9%	1,504,575	2	0	1	0	0	C:\Dev\E+\2.2\PlantCondLoopOperation.f90
20	SYSTEMREPORTS_mp_CALCSYSTEMENERGYUSE	3,204,851	0.8%	9,640,419	2.5%	4,974,785	1	1	0.33	0	0	C:\Dev\E+\2.2\SystemReports.f90
21	WATERCOILS_mp_CALCSIMPLEHEATINGCOIL	3,194,533	0.8%	5,781,129	1.5%	11,885,996	2	6	0.55	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
22	PLANTUTILITIES_mp_UPDATEPLANTMIXER	2,716,383	0.7%	2,716,383	0.7%	1,435,668	2	0	1	0	0	C:\Dev\E+\2.2\PlantUtilities.f90
23	OUTPUTPROCESSOR_mp_UPDATEMETERS	2,705,012	0.7%	3,976,239	1.0%	52,560	1	1	0.68	0.05	0.08	C:\Dev\E+\2.2\OutputProcessor.f90
24	exp	2,559,868	0.7%	2,559,868	0.7%	79,627,021	10	0	1	0	0	
25	DEMANDSIDESOLVERS_mp_SIMPLANTDEMANDSIDES	2,467,674	0.6%	45,131,141	11.6%	332,515	1	7	0.05	0.01	0.14	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
26	FLOWRESOLVER_mp_ENFORCESPLITTERCONTINUITY	2,417,989	0.6%	2,515,540	0.6%	1,435,668	1	1	0.96	0	0	C:\Dev\E+\2.2\PlantFlowResolver.f90
27	log	2,202,909	0.6%	2,202,909	0.6%	62,169,190	7	0	1	0	0	
28	memcpy	2,175,511	0.6%	2,175,511	0.6%	63,100,011	143	1	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\memcpy.asm
29	DEMANDSIDESOLVERS_mp_SIMULATEPIPES	1,972,950	0.5%	32,729,170	8.4%	4,987,725	1	2	0.06	0	0.01	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
30	SYSTEMREPORTS_mp_INITENERGYREPORTS	1,907,114	0.5%	2,331,013	0.6%	61,801	1	7	0.82	0.03	0.04	C:\Dev\E+\2.2\SystemReports.f90
31	PSYCHROMETRICS_mp_PSYRHOVFNTDBRH	1,862,909	0.5%	7,744,653	2.0%	34,167,296	1	1	0.24	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
32	CONTROLCOMPOUTPUT	1,859,900	0.5%	14,944,696	3.9%	651,273	1	3	0.12	0	0.02	C:\Dev\E+\2.2\GeneralRoutines.f90
33	WATERCOILS_mp_SIMULATEWATERCOILCOMPONENTS	1,717,273	0.4%	15,428,362	4.0%	12,420,340	3	8	0.11	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
34	ZONEEQUIPMENTMANAGER_mp_CALCZONELEAVINGCONDITIONS	1,699,542	0.4%	3,861,308	1.0%	203,970	2	5	0.44	0.01	0.02	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
35	SCHEDULEMANAGER_mp_GETCURRENTSCHEDULEVALUE	1,639,070	0.4%	1,639,070	0.4%	28,528,006	19	0	1	0	0	C:\Dev\E+\2.2\ScheduleManager.f90
36	INTERNALHEATGAINS_mp_INITINTERNALHEATGAINS	1,554,687	0.4%	1,824,898	0.5%	55,296	1	7	0.85	0.03	0.03	C:\Dev\E+\2.2\HeatBalanceInternalHeatGains.f90
37	PSYCHROMETRICS_mp_PSYRHOAIRFNPBTDBW	1,545,499	0.4%	1,545,499	0.4%	46,019,998	14	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
38	FLOWRESOLVER_mp_SOLVEFLOWNETWORK	1,511,671	0.4%	4,027,211	1.0%	1,435,668	1	1	0.38	0	0	C:\Dev\E+\2.2\PlantFlowResolver.f90
39	SYSTEMREPORTS_mp_REPORTSYSTEMENERGYUSE	1,495,811	0.4%	11,550,257	3.0%	61,801	1	3	0.13	0.02	0.19	C:\Dev\E+\2.2\SystemReports.f90
40	ZONETEMPPREDICTORCORRECTOR_mp_CALCZONESUMS	1,485,835	0.4%	1,737,540	0.4%	2,285,680	2	1	0.86	0	0	C:\Dev\E+\2.2\ZoneTempPredictorCorrector.f90
41	WATERCOILS_mp_UPDATEWATERCOIL	1,410,904	0.4%	1,410,904	0.4%	12,420,340	1	0	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
42	pow	1,371,104	0.4%	1,371,104	0.4%	19,782,658	12	0	1	0	0	
43	PSYCHROMETRICS_mp_PSYTSATFNPB	1,358,160	0.4%	5,949,482	1.5%	1,534,809	2	2	0.23	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
44	PLANTCONDLOOPOPERATION_mp_DISTRIBUTEPLANTLOAD	1,249,264	0.3%	2,285,971	0.6%	1,314,367	1	4	0.55	0	0	C:\Dev\E+\2.2\PlantCondLoopOperation.f90
45	NODEINPUTMANAGER_mp_CALCMORENODEINFO	1,055,725	0.3%	1,435,265	0.4%	114,361	2	5	0.74	0.01	0.01	C:\Dev\E+\2.2\NodeInputManager.f90
46	PSYCHROMETRICS_mp_PSYRHOVFNTDBWPB	1,005,857	0.3%	1,005,857	0.3%	34,167,296	1	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
47	GENERAL_mp_ITERATE	993,436	0.3%	993,436	0.3%	21,324,351	3	0	1	0	0	C:\Dev\E+\2.2\General.f90
48	for_cpystr	964,648	0.2%	1,749,154	0.5%	19,608,007	156	2	0.55	0	0	
49	PLANTUTILITIES_mp_UPDATEPLANTSPLITTER	955,124	0.2%	955,124	0.2%	3,188,160	2	0	1	0	0	C:\Dev\E+\2.2\PlantUtilities.f90
50	HEATBALANCESURFACEMANAGER_mp_COMPUTEINTTHERMALABSORPFACTORS	935,395	0.2%	935,395	0.2%	55,296	1	2	1	0.02	0.02	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90

Source: Lawrence Berkeley National Laboratory

Table 30. Code Profiling Results Sorted by Subroutine Total Time for the Large Office w/o Reports Run

Rank	Function	Self Time	% Self Time	Total Time	% Total Time	Calls	Callers	Callees	% in function	Average Self time per call	Average Total time per call	Source File
	energyplus.exe - Total	386,832,063	100.0%	387,534,677	100.0%	4,455,752,368						
1	ENERGYPLUS	8	0.0%	387,534,472	100.0%	1	1	20	0	0.01	387534.47	C:\Dev\E+\2.2\EnergyPlus.f90
2	SIMULATIONMANAGER_mp_MANAGESIMULATION	60,404	0.0%	385,023,594	99.4%	1	1	30	0	60.4	385023.59	C:\Dev\E+\2.2\SimulationManager.f90
3	HEATBALANCEMANAGER_mp_MANAGEHEATBALANCE	52,839	0.0%	382,921,342	98.8%	55,296	2	7	0	0	6.92	C:\Dev\E+\2.2\HeatBalanceManager.f90
4	HEATBALANCESURFACEMANAGER_mp_MANAGESURFACEHEATBALANCE	55,404	0.0%	295,470,867	76.2%	55,296	1	9	0	0	5.34	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
5	HEATBALANCEAIRMANAGER_mp_MANAGEAIRHEATBALANCE	19,626	0.0%	184,062,278	47.5%	55,296	1	4	0	0	3.33	C:\Dev\E+\2.2\HeatBalanceAirManager.f90
6	HEATBALANCEAIRMANAGER_mp_CALCHEATBALANCEAIR	33,782	0.0%	183,975,576	47.5%	55,296	1	1	0	0	3.33	C:\Dev\E+\2.2\HeatBalanceAirManager.f90
7	HVACMANAGER_mp_MANAGEHVAC	330,202	0.1%	183,941,794	47.5%	55,296	1	44	0	0.01	3.33	C:\Dev\E+\2.2\HVACManager.f90
8	UPDATEDATAANDREPORT	95,117,275	24.6%	124,304,013	32.1%	114,361	2	11	0.77	0.83	1.09	C:\Dev\E+\2.2\OutputProcessor.f90
9	HVACMANAGER_mp_SIMHVAC	78,815	0.0%	119,367,875	30.8%	68,533	1	8	0	0	1.74	C:\Dev\E+\2.2\HVACManager.f90
10	HVACMANAGER_mp_SIMSELECTEDEQUIPMENT	211,590	0.1%	118,678,079	30.6%	199,509	1	9	0	0	0.59	C:\Dev\E+\2.2\HVACManager.f90
11	HEATBALANCEMANAGER_mp_REPORTHEATBALANCE	60,283	0.0%	85,577,839	22.1%	55,296	1	5	0	0	1.55	C:\Dev\E+\2.2\HeatBalanceManager.f90
12	PLANTMANAGER_mp_MANAGEPLANTLOOPS	89,947	0.0%	68,675,578	17.7%	199,509	1	6	0	0	0.34	C:\Dev\E+\2.2\PlantManager.f90
13	CALCHEATBALANCEINSIDESURF	9,367,570	2.4%	68,304,073	17.6%	55,296	1	10	0.14	0.17	1.24	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
14	HEATBALANCEINTRADEXCHANGE_mp_CALCINTERIORRADEXCHANGE	32,731,554	8.5%	56,774,332	14.7%	377,524	3	3	0.58	0.09	0.15	C:\Dev\E+\2.2\HeatBalanceIntRadExchange.f90
15	DEMANDSIDESOLVERS_mp_SIMPLANTDEMANDSIDES	2,467,674	0.6%	45,131,141	11.6%	332,515	1	7	0.05	0.01	0.14	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
16	for_cpstr	26,533,547	6.9%	37,001,332	9.5%	460,318,156	152	1	0.72	0	0	
17	PIPES_mp_SIMPIPES	11,413,190	3.0%	32,876,059	8.5%	78,358,259	3	2	0.35	0	0	C:\Dev\E+\2.2\PlantPipes.f90
18	DEMANDSIDESOLVERS_mp_SIMULATEPIPES	1,972,950	0.5%	32,729,170	8.4%	4,987,725	1	2	0.06	0	0.01	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
19	ZONEEQUIPMENTMANAGER_mp_MANAGEZONEEQUIPMENT	49,420	0.0%	30,195,977	7.8%	203,970	3	6	0	0	0.15	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
20	ZONEEQUIPMENTMANAGER_mp_SIMZONEEQUIPMENT	792,810	0.2%	29,911,612	7.7%	201,940	1	8	0.03	0	0.15	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
21	HEATBALANCESURFACEMANAGER_mp_INITSURFACEHEATBALANCE	3,559,940	0.9%	25,431,793	6.6%	55,296	1	19	0.14	0.06	0.46	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
22	__powr8i4	24,801,192	6.4%	24,801,192	6.4%	743,023,179	13	0	1	0	0	
23	SUPPLYSIDESOLVERS_mp_MANAGEPLANTSUPPLYSIDES	69,584	0.0%	22,791,088	5.9%	146,041	1	5	0	0	0.16	C:\Dev\E+\2.2\PlantSupplySideSolvers.f90
24	SUPPLYSIDESOLVERS_mp_SIMLOOPPUMPSOLUTIONSCHEME	275,032	0.1%	22,715,104	5.9%	438,123	1	10	0.01	0	0.05	C:\Dev\E+\2.2\PlantSupplySideSolvers.f90
25	ZONEAIRLOOPEQUIPMENTMANAGER_mp_MANAGEZONEAIRLOOPEQUIPMENT	361,120	0.1%	21,696,301	5.6%	3,029,100	1	5	0.02	0	0.01	C:\Dev\E+\2.2\Zoneairloopequipmentmanager.f90
26	ZONEAIRLOOPEQUIPMENTMANAGER_mp_SIMZONEAIRLOOPEQUIPMENT	683,275	0.2%	20,942,697	5.4%	3,029,100	1	2	0.03	0	0.01	C:\Dev\E+\2.2\Zoneairloopequipmentmanager.f90
27	SUPPLYSIDESOLVERS_mp_LOADBASEDSOLUTION	746,480	0.2%	20,850,601	5.4%	438,123	1	9	0.04	0	0.05	C:\Dev\E+\2.2\PlantSupplySideSolvers.f90
28	SINGLEDUCT_mp_SIMULATESINGLEDUCT	454,026	0.1%	19,643,918	5.1%	3,029,100	1	6	0.02	0	0.01	C:\Dev\E+\2.2\HVACSingleDuctSystem.f90
29	SINGLEDUCT_mp_SIMVAV	859,463	0.2%	18,317,897	4.7%	3,029,100	1	4	0.05	0	0.01	C:\Dev\E+\2.2\HVACSingleDuctSystem.f90
30	OUTPUTPROCESSOR_mp_SETREPORTNOW	17,180,443	4.4%	17,180,443	4.4%	1,082,016,382	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
31	WATERCOILS_mp_SIMULATEWATERCOILCOMPONENTS	1,717,273	0.4%	15,428,362	4.0%	12,420,340	3	8	0.11	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
32	CONTROLCOMPOUTPUT	1,859,900	0.5%	14,944,696	3.9%	651,273	1	3	0.12	0	0.02	C:\Dev\E+\2.2\GeneralRoutines.f90
33	SYSTEMREPORTS_mp_REPORTSYSTEMENERGYUSE	1,495,811	0.4%	11,550,257	3.0%	61,801	1	3	0.13	0.02	0.19	C:\Dev\E+\2.2\SystemReports.f90
34	_intel_fast_memcmp	10,467,785	2.7%	10,467,785	2.7%	460,318,159	2	0	1	0	0	
35	PSYCHROMETRICS_mp_PSYPSATFNTEMP	6,100,613	1.6%	10,213,247	2.6%	59,671,662	7	2	0.6	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
36	SIMAIRSERVINGZONES_mp_MANAGEAIRLOOPS	29,203	0.0%	10,205,239	2.6%	206,160	2	4	0	0	0.05	C:\Dev\E+\2.2\SimAirServingZones.f90
37	SIMAIRSERVINGZONES_mp_SIMAIRLOOPS	120,966	0.0%	10,024,909	2.6%	206,159	1	6	0.01	0	0.05	C:\Dev\E+\2.2\SimAirServingZones.f90
38	CALCHEATBALANCEOUTSIDESURF	530,451	0.1%	9,825,231	2.5%	55,296	1	3	0.05	0.01	0.18	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
39	SYSTEMREPORTS_mp_CALCSYSTEMENERGYUSE	3,204,851	0.8%	9,640,419	2.5%	4,974,785	1	1	0.33	0	0	C:\Dev\E+\2.2\SystemReports.f90
40	PLANTLOOPEQUIP_mp_SIMPLANTEQUIP	3,575,392	0.9%	9,487,452	2.4%	5,695,611	2	6	0.38	0	0	C:\Dev\E+\2.2\PlantLoopEquipments.f90
41	SIMAIRSERVINGZONES_mp_SIMAIRLOOP	39,073	0.0%	9,252,184	2.4%	237,110	1	2	0	0	0.04	C:\Dev\E+\2.2\SimAirServingZones.f90
42	PSYCHROMETRICS_mp_PSYCPAIRFNWTDB	5,804,305	1.5%	8,808,935	2.3%	76,720,326	22	1	0.66	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
43	OUTPUTPROCESSOR_mp_SETMINMAX	8,482,054	2.2%	8,482,054	2.2%	460,865,763	2	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
44	FLOWRESOLVER_mp_REQUESTNETWORKFLOWANDSOLVE	3,809,100	1.0%	7,928,661	2.0%	1,435,668	2	2	0.48	0	0.01	C:\Dev\E+\2.2\PlantFlowResolver.f90
45	PSYCHROMETRICS_mp_PSYRHOVFNTDBRH	1,862,909	0.5%	7,744,653	2.0%	34,167,296	1	1	0.24	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
46	SIMAIRSERVINGZONES_mp_SOLVEAIRLOOPCONTROLLERS	138,277	0.0%	7,615,330	2.0%	140,848	1	2	0.02	0	0.05	C:\Dev\E+\2.2\SimAirServingZones.f90
47	SIMAIRSERVINGZONES_mp_SIMAIRLOOPCOMPONENTS	303,885	0.1%	7,438,935	1.9%	534,591	2	3	0.04	0	0.01	C:\Dev\E+\2.2\SimAirServingZones.f90
48	HEATBALANCESURFACEMANAGER_mp_UPDATETHERMALHISTORIES	7,121,260	1.8%	7,121,260	1.8%	55,296	1	2	1	0.13	0.13	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
49	SIMAIRSERVINGZONES_mp_SIMAIRLOOPCOMPONENT	181,878	0.0%	6,920,568	1.8%	2,138,364	1	3	0.03	0	0	C:\Dev\E+\2.2\SimAirServingZones.f90
50	ZONETEMPPREDICTORCORRECTOR_mp_MANAGEZONEAIRUPDATES	46,241	0.0%	6,385,020	1.6%	198,151	1	5	0.01	0	0.03	C:\Dev\E+\2.2\ZoneTempPredictorCorrector.f90

Source: Lawrence Berkeley National Laboratory

Table 31. Code Profiling Results Sorted by Number of Calls for the Large Office w/o Reports Run

Rank	Function	Self Time	% Self Time	Total Time	% Total Time	Calls	Callers	Callees	% in function	Average Self time per call	Average Total time per call	Source File
	energyplus.exe - Total	386,832,063	100.0%	387,534,677	100.0%	4,455,752,368						
1	OUTPUTPROCESSOR_mp_SETREPORTNOW	17,180,443	4.4%	17,180,443	4.4%	1,082,016,382	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
2	__powr8i4	24,801,192	6.4%	24,801,192	6.4%	743,023,179	13	0	1	0	0	
3	OUTPUTPROCESSOR_mp_SETMINMAX	8,482,054	2.2%	8,482,054	2.2%	460,865,763	2	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
4	_intel_fast_memcmp	10,467,785	2.7%	10,467,785	2.7%	460,318,159	2	0	1	0	0	
5	for_cpstr	26,533,547	6.9%	37,001,332	9.5%	460,318,156	152	1	0.72	0	0	
6	PSYCHROMETRICS_mp_PSYHFNTDBW	3,816,964	1.0%	3,816,964	1.0%	187,063,090	20	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
7	exp	2,559,868	0.7%	2,559,868	0.7%	79,627,021	10	0	1	0	0	
8	PIPES_mp_SIMPIPES	11,413,190	3.0%	32,876,059	8.5%	78,358,259	3	2	0.35	0	0	C:\Dev\E+\2.2\PlantPipes.f90
9	PSYCHROMETRICS_mp_PSYCPAIRFNWTDB	5,804,305	1.5%	8,808,935	2.3%	76,720,326	22	1	0.66	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
10	memcpy	2,175,511	0.6%	2,175,511	0.6%	63,100,011	143	1	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\memcpy.asm
11	log	2,202,909	0.6%	2,202,909	0.6%	62,169,190	7	0	1	0	0	
12	PSYCHROMETRICS_mp_PSYPSATFNTEMP	6,100,613	1.6%	10,213,247	2.6%	59,671,662	7	2	0.6	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
13	PSYCHROMETRICS_mp_PSYRHOAIRFNPBTDBW	1,545,499	0.4%	1,545,499	0.4%	46,019,998	14	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
14	PSYCHROMETRICS_mp_PSYRHOVFNTDBRH	1,862,909	0.5%	7,744,653	2.0%	34,167,296	1	1	0.24	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
15	PSYCHROMETRICS_mp_PSYRHOVFNTDBWPB	1,005,857	0.3%	1,005,857	0.3%	34,167,296	1	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
16	SCHEDULEMANAGER_mp_GETCURRENTSCHEDULEVALUE	1,639,070	0.4%	1,639,070	0.4%	28,528,006	19	0	1	0	0	C:\Dev\E+\2.2\ScheduleManager.f90
17	memmove	401,817	0.1%	412,355	0.1%	23,007,538	69	1	0.97	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\Intel\MEMCPY.ASM
18	chkstk	400,349	0.1%	400,349	0.1%	21,769,667	155	0	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\chkstk.asm
19	GENERAL_mp_ITERATE	993,436	0.3%	993,436	0.3%	21,324,351	3	0	1	0	0	C:\Dev\E+\2.2\General.f90
20	_intel_fast_memset	550,465	0.1%	550,466	0.1%	20,018,600	18	1	1	0	0	
21	pow	1,371,104	0.4%	1,371,104	0.4%	19,782,658	12	0	1	0	0	
22	for_cpystr	964,648	0.2%	1,749,154	0.5%	19,608,007	156	2	0.55	0	0	
23	PSYCHROMETRICS_mp_CPCW	235,185	0.1%	235,185	0.1%	14,853,076	17	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
24	PSYCHROMETRICS_mp_CPHW	176,169	0.0%	176,169	0.0%	12,523,552	13	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
25	WATERCOILS_mp_SIMULATEWATERCOILCOMPONENTS	1,717,273	0.4%	15,428,362	4.0%	12,420,340	3	8	0.11	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
26	WATERCOILS_mp_UPDATEWATERCOIL	1,410,904	0.4%	1,410,904	0.4%	12,420,340	1	0	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
27	WATERCOILS_mp_INITWATERCOIL	894,048	0.2%	894,806	0.2%	12,420,340	1	12	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
28	WATERCOILS_mp_REPORTWATERCOIL	469,761	0.1%	469,761	0.1%	12,420,340	1	0	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
29	WATERCOILS_mp_CALCSIMPLEHEATINGCOIL	3,194,533	0.8%	5,781,129	1.5%	11,885,996	2	6	0.55	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
30	OUTPUTPROCESSOR_mp_UPDATEMETERVALUES	512,694	0.1%	512,694	0.1%	10,722,240	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
31	DATAENVIRONMENT_mp_OUTDRYBULBTEMPAT	656,664	0.2%	656,664	0.2%	7,962,624	1	0	1	0	0	C:\Dev\E+\2.2\DataEnvironment.f90
32	DATAENVIRONMENT_mp_OUTWETBULBTEMPAT	168,781	0.0%	168,781	0.0%	7,962,624	1	0	1	0	0	C:\Dev\E+\2.2\DataEnvironment.f90
33	allmul	94,651	0.0%	94,651	0.0%	7,613,886	6	0	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\llmul.asm
34	CONVECTIONCOEFFICIENTS_mp_CALCASHRAEDETAILEDINTCONVCOEFF	575,380	0.1%	1,223,645	0.3%	7,077,888	1	1	0.47	0	0	C:\Dev\E+\2.2\HeatBalanceConvectionCoeffs.f90
35	GETINTERNALVARIABLEVALUE	416,811	0.1%	416,811	0.1%	6,365,503	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
36	PLANTLOOPEQUIP_mp_SIMPLANTEQUIP	3,575,392	0.9%	9,487,452	2.4%	5,695,611	2	6	0.38	0	0	C:\Dev\E+\2.2\PlantLoopEquipments.f90
37	PSYCHROMETRICS_mp_RHOH2O	279,089	0.1%	481,513	0.1%	5,524,475	27	1	0.58	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
38	DEMANDSIDESOLVERS_mp_SIMULATEPIPES	1,972,950	0.5%	32,729,170	8.4%	4,987,725	1	2	0.06	0	0.01	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
39	SYSTEMREPORTS_mp_CALCSYSTEMENERGYUSE	3,204,851	0.8%	9,640,419	2.5%	4,974,785	1	1	0.33	0	0	C:\Dev\E+\2.2\SystemReports.f90
40	PSYCHROMETRICS_mp_PSYHGAIRFNWTDB	51,944	0.0%	51,944	0.0%	4,853,319	3	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
41	for_f90_scan	427,323	0.1%	427,323	0.1%	3,567,355	8	0	1	0	0	
42	PLANTUTILITIES_mp_UPDATEPLANTSPLITTER	955,124	0.2%	955,124	0.2%	3,188,160	2	0	1	0	0	C:\Dev\E+\2.2\PlantUtilities.f90
43	SINGLEDUCT_mp_UPDATESYS	196,862	0.1%	196,862	0.1%	3,078,165	1	0	1	0	0	C:\Dev\E+\2.2\HVACSingleDuctSystem.f90
44	ZONEEQUIPMENTMANAGER_mp_INITSYSTEMOUTPUTREQUIRED	134,917	0.0%	134,917	0.0%	3,059,550	2	0	1	0	0	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
45	ZONEEQUIPMENTMANAGER_mp_UPDATESYSTEMOUTPUTREQUIRED	104,528	0.0%	104,528	0.0%	3,059,550	2	0	1	0	0	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
46	ZONEAIRLOOPEQUIPMENTMANAGER_mp_MANAGEZONEAIRLOOPEQUIPMENT	361,120	0.1%	21,696,301	5.6%	3,029,100	1	5	0.02	0	0.01	C:\Dev\E+\2.2\Zoneairloopequipmentmanager.f90
47	ZONEAIRLOOPEQUIPMENTMANAGER_mp_SIMZONEAIRLOOPEQUIPMENT	683,275	0.2%	20,942,697	5.4%	3,029,100	1	2	0.03	0	0.01	C:\Dev\E+\2.2\Zoneairloopequipmentmanager.f90
48	SINGLEDUCT_mp_SIMULATESINGLEDUCT	454,026	0.1%	19,643,918	5.1%	3,029,100	1	6	0.02	0	0.01	C:\Dev\E+\2.2\HVACSingleDuctSystem.f90
49	SINGLEDUCT_mp_SIMVAV	859,463	0.2%	18,317,897	4.7%	3,029,100	1	4	0.05	0	0.01	C:\Dev\E+\2.2\HVACSingleDuctSystem.f90
50	ZONEEQUIPMENTMANAGER_mp_SETZONEEQUIPSIMORDER	707,650	0.2%	1,645,632	0.4%	3,029,100	1	2	0.43	0	0	C:\Dev\E+\2.2\Zoneequipmentmanager.f90

Source: Lawrence Berkeley National Laboratory

Table 32. Code Profiling Results Sorted by Subroutine Self Time for the Elementary School Run

Rank	Function	Self Time	% Self Time	Total Time	% Total Time	Calls	Callers	Callees	% in function	Average Self time per call	Average Total time per call	Source File
1	energyplus.exe - Total	1,231,866,928	100.0%	1,238,262,060	100.0%	18,987,485,930						
2	UPDATEDATAANDREPORT	386,555,724	31.4%	430,745,364	34.8%	303,793	2	14	0.9	1.27	1.42	C:\Dev\E+\2.2\OutputProcessor.f90
3	HEATBALANCEINTRADEXCHANGE_mp_CALCINTERIORRADEXCHANGE	61,084,764	5.0%	88,389,891	7.1%	415,909	3	3	0.69	0.15	0.21	C:\Dev\E+\2.2\HeatBalanceIntRadExchange.f90
4	OUTPUTREPORTTABULAR_mp_GATHERMONTHLYRESULTSFORTIMESTEP	44,912,801	3.6%	53,157,841	4.3%	303,793	1	2	0.84	0.15	0.17	C:\Dev\E+\2.2\OutputReportTabular.f90
5	OUTPUTPROCESSOR_mp_SETREPORTNOW	39,094,969	3.2%	39,094,969	3.2%	3,069,675,512	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
6	GETINSTANTMETERVALUE	34,402,911	2.8%	34,402,911	2.8%	12,799,872	3	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
7	for_cpstr	31,046,925	2.5%	48,237,833	3.9%	1,877,899,149	168	1	0.64	0	0	
8	PLANTUTILITIES_mp_UPDATEPLANTMIXER	29,911,685	2.4%	29,911,685	2.4%	4,024,746	2	0	1	0.01	0.01	C:\Dev\E+\2.2\PlantUtilities.f90
9	__powr8i4	28,633,740	2.3%	28,633,740	2.3%	2,036,578,240	14	0	1	0	0	
10	ZONETEMPPREDICTORCORRECTOR_mp_CALCZONESUMS	18,009,324	1.5%	18,455,713	1.5%	16,527,825	2	1	0.98	0	0	C:\Dev\E+\2.2\ZoneTempPredictorCorrector.f90
11	for_f90_index	17,973,880	1.5%	22,974,756	1.9%	56,179,779	40	3	0.78	0	0	
12	FLOWRESOLVER_mp_REQUESTNETWORKFLOWANDSOLVE	17,529,566	1.4%	34,898,721	2.8%	4,024,746	2	2	0.5	0	0.01	C:\Dev\E+\2.2\PlantFlowResolver.f90
13	_intel_fast_memcmp	17,190,908	1.4%	17,190,908	1.4%	1,877,899,152	2	0	1	0	0	
14	PSYCHROMETRICS_mp_PSYPSATFNTEMP	16,162,946	1.3%	29,426,712	2.4%	576,066,644	8	2	0.55	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
15	CALCHEATBALANCEINSIDESURF	15,968,753	1.3%	103,838,310	8.4%	54,144	1	10	0.15	0.29	1.92	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
16	PIPES_mp_SIMPIPES	13,165,143	1.1%	33,585,283	2.7%	149,474,936	2	1	0.39	0	0	C:\Dev\E+\2.2\PlantPipes.f90
17	HEATBALANCESURFACEMANAGER_mp_UPDATETHERMALHISTORIES	13,120,910	1.1%	13,120,910	1.1%	54,144	1	2	1	0.24	0.24	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
18	PSYCHROMETRICS_mp_PSYTWBFNTDBWPB	13,037,782	1.1%	45,859,462	3.7%	34,505,123	6	3	0.28	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
19	ZONEEQUIPMENTMANAGER_mp_CALCZONELEAVINGCONDITIONS	11,324,845	0.9%	18,247,315	1.5%	897,585	2	5	0.62	0.01	0.02	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
20	SYSTEMREPORTS_mp_INITENERGYREPORTS	11,286,943	0.9%	13,699,329	1.1%	251,233	1	7	0.82	0.04	0.05	C:\Dev\E+\2.2\SystemReports.f90
21	DEMANDSIDESOLVERS_mp_SIMPLANTDEMANDSIDES	11,259,757	0.9%	107,419,847	8.7%	1,410,485	1	7	0.1	0.01	0.08	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
22	GETINTERNALVARIABLEVALUE	10,650,048	0.9%	10,652,687	0.9%	207,959,818	2	1	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
23	FLOWRESOLVER_mp_ENFORCESPLITTERCONTINUITY	10,409,862	0.8%	10,454,957	0.8%	4,024,746	1	1	1	0	0	C:\Dev\E+\2.2\PlantFlowResolver.f90
24	GENERAL_mp_ITERATE	10,221,761	0.8%	10,221,761	0.8%	468,904,498	2	0	1	0	0	C:\Dev\E+\2.2\General.f90
25	for_trim	10,152,577	0.8%	10,976,965	0.9%	102,647,627	112	1	0.92	0	0	
26	WATERCOILS_mp_CALCSIMPLEHEATINGCOIL	9,825,382	0.8%	13,870,412	1.1%	63,931,638	2	6	0.71	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
27	memcpy	9,712,569	0.8%	9,712,610	0.8%	340,233,818	153	1	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\memcpy.asm
28	SYSTEMREPORTS_mp_REPORTSYSTEMENERGYUSE	8,946,579	0.7%	23,299,421	1.9%	251,233	1	3	0.38	0.04	0.09	C:\Dev\E+\2.2\SystemReports.f90
29	SYSTEMREPORTS_mp_CALCSYSTEMENERGYUSE	8,625,366	0.7%	12,777,959	1.0%	32,864,100	1	1	0.68	0	0	C:\Dev\E+\2.2\SystemReports.f90
30	PLANTLOOPEQUIP_mp_SIMPLANTEQUIP	8,494,292	0.7%	18,345,336	1.5%	15,649,096	2	5	0.46	0	0	C:\Dev\E+\2.2\PlantLoopEquipments.f90
31	log	8,213,092	0.7%	8,213,092	0.7%	597,945,547	8	0	1	0	0	
32	HEATBALANCESURFACEMANAGER_mp_INITSOLARHEATGAINS	8,191,401	0.7%	11,601,764	0.9%	54,144	1	2	0.71	0.15	0.21	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
33	PSYCHROMETRICS_mp_PSYCPAIRFNWTDB	7,261,179	0.6%	9,439,976	0.8%	332,383,557	22	1	0.77	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
34	PLANTCONDLOOPOPERATION_mp_CHECKFOREMSCTRL	7,176,500	0.6%	7,176,500	0.6%	3,611,328	1	0	1	0	0	C:\Dev\E+\2.2\PlantCondLoopOperation.f90
35	SCHEDULEMANAGER_mp_GETCURRENTSCHEDULEVALUE	6,901,360	0.6%	6,901,360	0.6%	189,291,210	32	0	1	0	0	C:\Dev\E+\2.2\ScheduleManager.f90
36	FLOWRESOLVER_mp_SOLVEFLOWNETWORK	6,892,198	0.6%	17,347,155	1.4%	4,024,746	1	1	0.4	0	0	C:\Dev\E+\2.2\PlantFlowResolver.f90
37	HEATBALANCESURFACEMANAGER_mp_INITSURFACEHEATBALANCE	6,830,789	0.6%	43,804,374	3.5%	54,144	1	19	0.16	0.13	0.81	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
38	WATERCOILS_mp_UPDATEWATERCOIL	6,266,808	0.5%	6,266,808	0.5%	63,931,221	1	0	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
39	exp	5,933,481	0.5%	5,933,481	0.5%	666,174,566	10	0	1	0	0	
40	DXCOILS_mp_CALCMULTISPEEDDXCOIL	5,695,668	0.5%	58,750,150	4.7%	15,961,724	3	11	0.1	0	0	C:\Dev\E+\2.2\DXCoil.f90
41	PSYCHROMETRICS_mp_PSYTSATFNPB	5,430,294	0.4%	24,364,689	2.0%	36,888,040	2	2	0.22	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
42	ZONEEQUIPMENTMANAGER_mp_SIMZONEEQUIPMENT	5,040,758	0.4%	103,881,227	8.4%	896,532	1	10	0.05	0.01	0.12	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
43	ZONETEMPPREDICTORCORRECTOR_mp_CALCZONECOMPONENTLOADSUMS	4,861,856	0.4%	5,474,945	0.4%	9,449,375	1	2	0.89	0	0	C:\Dev\E+\2.2\ZoneTempPredictorCorrector.f90
44	ZONETEMPPREDICTORCORRECTOR_mp_CORRECTZONEAIRTEMP	4,558,471	0.4%	24,745,066	2.0%	377,975	1	7	0.18	0.01	0.07	C:\Dev\E+\2.2\ZoneTempPredictorCorrector.f90
45	SINGLEDUCT_mp_SIMVAV	4,528,763	0.4%	45,687,961	3.7%	21,516,768	1	4	0.1	0	0	C:\Dev\E+\2.2\HVACSingleDuctSystem.f90
46	CONTROLCOMPOUTPUT	4,197,958	0.3%	29,856,727	2.4%	2,654,610	1	3	0.14	0	0.01	C:\Dev\E+\2.2\GeneralRoutines.f90
47	ZONEEQUIPMENTMANAGER_mp_SETZONEEQUIPSIMORDER	4,143,036	0.3%	7,093,751	0.6%	22,413,300	1	2	0.58	0	0	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
48	WATERCOILS_mp_INITWATERCOIL	4,141,688	0.3%	4,142,729	0.3%	63,931,221	1	6	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
49	PLANTUTILITIES_mp_UPDATEPLANTSPLITTER	3,765,211	0.3%	3,765,211	0.3%	8,839,850	2	0	1	0	0	C:\Dev\E+\2.2\PlantUtilities.f90
50	ZONEAIRLOOPEQUIPMENTMANAGER_mp_SIMZONEAIRLOOPEQUIPMENT	3,696,622	0.3%	55,890,769	4.5%	21,516,768	1	2	0.07	0	0	C:\Dev\E+\2.2\Zoneairloopequipmentmanager.f90

Source: Lawrence Berkeley National Laboratory

Table 33. Code Profiling Results Sorted by Subroutine Total Time for the Elementary School Run

Rank	Function	Self Time	% Self Time	Total Time	% Total Time	Calls	Callers	Callees	% in function	Average Self time per call	Average Total time per call	Source File
1	energyplus.exe - Total	1,231,866,928	100.0%	1,238,262,060	100.0%	18,987,485,930						
2	ENERGYPLUS	9	0.0%	1,238,261,800	100.0%	1	1	20	0	0.01	1238261.8	C:\Dev\E+\2.2\EnergyPlus.f90
3	SIMULATIONMANAGER_mp_MANAGESIMULATION	78,895	0.0%	1,237,064,616	99.9%	1	1	30	0	78.9	1237064.62	C:\Dev\E+\2.2\SimulationManager.f90
4	HEATBALANCEMANAGER_mp_MANAGEHEATBALANCE	97,799	0.0%	1,234,632,986	99.7%	54,144	2	7	0	0	22.8	C:\Dev\E+\2.2\HeatBalanceManager.f90
5	HEATBALANCESURFACEMANAGER_mp_MANAGESURFACEHEATBALANCE	84,120	0.0%	1,013,464,193	81.8%	54,144	1	9	0	0	18.72	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
6	HEATBALANCEAIRMANAGER_mp_MANAGEAIRHEATBALANCE	24,887	0.0%	836,108,257	67.5%	54,144	1	4	0	0	15.44	C:\Dev\E+\2.2\HeatBalanceAirManager.f90
7	HEATBALANCEAIRMANAGER_mp_CALCHEATBALANCEAIR	56,164	0.0%	835,917,776	67.5%	54,144	1	1	0	0	15.44	C:\Dev\E+\2.2\HeatBalanceAirManager.f90
8	HVACMANAGER_mp_MANAGEHVAC	1,384,341	0.1%	835,861,612	67.5%	54,144	1	44	0	0.03	15.44	C:\Dev\E+\2.2\HVACManager.f90
9	UPDATEDATAANDREPORT	386,555,724	31.4%	430,745,364	34.8%	303,793	2	14	0.9	1.27	1.42	C:\Dev\E+\2.2\OutputProcessor.f90
10	HVACMANAGER_mp_SIMHVAC	370,148	0.0%	424,623,020	34.3%	283,138	1	8	0	0	1.5	C:\Dev\E+\2.2\HVACManager.f90
11	HVACMANAGER_mp_SIMSELECTEDEQUIPMENT	813,404	0.1%	420,593,446	34.0%	846,285	1	9	0	0	0.5	C:\Dev\E+\2.2\HVACManager.f90
12	HEATBALANCEMANAGER_mp_REPORTHEATBALANCE	107,315	0.0%	218,812,654	17.7%	54,144	1	5	0	0	4.04	C:\Dev\E+\2.2\HeatBalanceManager.f90
13	PLANTMANAGER_mp_MANAGEPLANTLOOPS	380,741	0.0%	158,901,111	12.8%	846,285	1	6	0	0	0.19	C:\Dev\E+\2.2\PlantManager.f90
14	SIMAIRSERVINGZONES_mp_MANAGEAIRLOOPS	117,801	0.0%	121,259,988	9.8%	901,376	2	4	0	0	0.13	C:\Dev\E+\2.2\SimAirServingZones.f90
15	SIMAIRSERVINGZONES_mp_SIMAIRLOOPS	1,117,791	0.1%	118,930,471	9.6%	901,375	1	6	0.01	0	0.13	C:\Dev\E+\2.2\SimAirServingZones.f90
16	SIMAIRSERVINGZONES_mp_SIMAIRLOOP	521,646	0.0%	111,175,241	9.0%	6,422,836	1	2	0	0	0.02	C:\Dev\E+\2.2\SimAirServingZones.f90
17	DEMANDSIDESOLVERS_mp_SIMPLANTDEMANDSIDES	11,259,757	0.9%	107,419,847	8.7%	1,410,485	1	7	0.1	0.01	0.08	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
18	ZONEEQUIPMENTMANAGER_mp_MANAGEZONEEQUIPMENT	161,426	0.0%	105,504,242	8.5%	897,585	3	6	0	0	0.12	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
19	ZONEEQUIPMENTMANAGER_mp_SIMZONEEQUIPMENT	5,040,758	0.4%	103,881,227	8.4%	896,532	1	10	0.05	0.01	0.12	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
20	CALCHEATBALANCEINSIDESURF	15,968,753	1.3%	103,838,310	8.4%	54,144	1	10	0.15	0.29	1.92	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
21	SIMAIRSERVINGZONES_mp_SIMAIRLOOPCOMPONENTS	2,031,216	0.2%	102,991,761	8.3%	7,257,471	2	3	0.02	0	0.01	C:\Dev\E+\2.2\SimAirServingZones.f90
22	SIMAIRSERVINGZONES_mp_SIMAIRLOOPCOMPONENT	1,599,746	0.1%	99,438,973	8.0%	25,424,384	1	5	0.02	0	0	C:\Dev\E+\2.2\SimAirServingZones.f90
23	OUTPUTREPORTTABULAR_mp_UPDATETABULARREPORTS	225,956	0.0%	94,187,361	7.6%	303,793	2	9	0	0	0.31	C:\Dev\E+\2.2\OutputReportTabular.f90
24	HEATBALANCEINTRADEXCHANGE_mp_CALCINTERIORRADEXCHANGE	61,084,764	5.0%	88,389,891	7.1%	415,909	3	3	0.69	0.15	0.21	C:\Dev\E+\2.2\HeatBalanceIntRadExchange.f90
25	SIMAIRSERVINGZONES_mp_SOLVEAIRLOOPCONTROLLERS	1,000,637	0.1%	80,411,014	6.5%	4,027,830	1	2	0.01	0	0.02	C:\Dev\E+\2.2\SimAirServingZones.f90
26	HVACDXSYSTEM_mp_SIMDXCOOLINGSYSTEM	1,097,303	0.1%	66,704,417	5.4%	5,454,721	1	7	0.02	0	0.01	C:\Dev\E+\2.2\HVACDXSystem.f90
27	DXCOILS_mp_CALCMULTISPEEDDXCOIL	5,695,668	0.5%	58,750,150	4.7%	15,961,724	3	11	0.1	0	0	C:\Dev\E+\2.2\DXCoil.f90
28	ZONEAIRLOOPEQUIPMENTMANAGER_mp_MANAGEZONEAIRLOOPEQUIPMENT	1,156,083	0.1%	57,982,501	4.7%	21,516,768	1	5	0.02	0	0	C:\Dev\E+\2.2\Zoneairloopequipmentmanager.f90
29	ZONEAIRLOOPEQUIPMENTMANAGER_mp_SIMZONEAIRLOOPEQUIPMENT	3,696,622	0.3%	55,890,769	4.5%	21,516,768	1	2	0.07	0	0	C:\Dev\E+\2.2\Zoneairloopequipmentmanager.f90
30	OUTPUTREPORTTABULAR_mp_GATHERMONTHLYRESULTSFORTIMESTEP	44,912,801	3.6%	53,157,841	4.3%	303,793	1	2	0.84	0.15	0.17	C:\Dev\E+\2.2\OutputReportTabular.f90
31	SINGLEDUCT_mp_SIMULATESINGLEDUCT	1,537,295	0.1%	51,636,508	4.2%	21,516,768	1	6	0.03	0	0	C:\Dev\E+\2.2\HVACSingleDuctSystem.f90
32	SUPPLYSIDESOLVERS_mp_MANAGEPLANTSUPPLYSIDES	268,436	0.0%	48,824,473	3.9%	601,888	1	5	0.01	0	0.08	C:\Dev\E+\2.2\PlantSupplySideSolvers.f90
33	SUPPLYSIDESOLVERS_mp_SIMLOOPPUMPSOLUTIONSCHEME	636,862	0.1%	48,541,751	3.9%	1,203,776	1	10	0.01	0	0.04	C:\Dev\E+\2.2\PlantSupplySideSolvers.f90
34	for_cpstr	31,046,925	2.5%	48,237,833	3.9%	1,877,899,149	168	1	0.64	0	0	
35	PSYCHROMETRICS_mp_PSYTWBFNTDBWPB	13,037,782	1.1%	45,859,462	3.7%	34,505,123	6	3	0.28	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
36	SINGLEDUCT_mp_SIMVAV	4,528,763	0.4%	45,687,961	3.7%	21,516,768	1	4	0.1	0	0	C:\Dev\E+\2.2\HVACSingleDuctSystem.f90
37	SUPPLYSIDESOLVERS_mp_LOADBASEDSOLUTION	1,596,775	0.1%	44,101,075	3.6%	1,203,776	1	9	0.04	0	0.04	C:\Dev\E+\2.2\PlantSupplySideSolvers.f90
38	HEATBALANCESURFACEMANAGER_mp_INITSURFACEHEATBALANCE	6,830,789	0.6%	43,804,374	3.5%	54,144	1	19	0.16	0.13	0.81	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
39	HVACDXSYSTEM_mp_CONTROLDXSYSTEM	1,199,136	0.1%	42,810,250	3.5%	5,454,721	1	5	0.03	0	0.01	C:\Dev\E+\2.2\HVACDXSystem.f90
40	ZONETEMPPREDICTORCORRECTOR_mp_MANAGEZONEAIRUPDATES	200,952	0.0%	40,894,284	3.3%	715,257	1	5	0	0	0.06	C:\Dev\E+\2.2\ZoneTempPredictorCorrector.f90
41	OUTPUTREPORTTABULAR_mp_GETINPUTTABULARMONTHLY	5,649	0.0%	40,514,017	3.3%	1	1	19	0	5.65	40514.02	C:\Dev\E+\2.2\OutputReportTabular.f90
42	OUTPUTPROCESSOR_mp_SETREPORTNOW	39,094,969	3.2%	39,094,969	3.2%	3,069,675,512	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
43	DXCOILS_mp_SIMDXCOILMULTISPEED	913,552	0.1%	36,633,176	3.0%	8,327,093	2	6	0.02	0	0	C:\Dev\E+\2.2\DXCoil.f90
44	FLOWRESOLVER_mp_REQUESTNETWORKFLOWANDSOLVE	17,529,566	1.4%	34,898,721	2.8%	4,024,746	2	2	0.5	0	0.01	C:\Dev\E+\2.2\PlantFlowResolver.f90
45	GETINSTANTMETERVALUE	34,402,911	2.8%	34,402,911	2.8%	12,799,872	3	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
46	PIPES_mp_SIMPIPES	13,165,143	1.1%	33,585,283	2.7%	149,474,936	2	1	0.39	0	0	C:\Dev\E+\2.2\PlantPipes.f90
47	GENERAL_mp_SOLVEREGULAFALSI	769,391	0.1%	33,219,298	2.7%	3,598,757	4	5	0.02	0	0.01	C:\Dev\E+\2.2\General.f90
48	DEMANDSIDESOLVERS_mp_SIMULATEPIPES	1,644,265	0.1%	31,986,201	2.6%	14,104,850	1	2	0.05	0	0	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
49	WATERCOILS_mp_SIMULATEWATERCOILCOMPONENTS	2,581,652	0.2%	30,473,529	2.5%	63,931,221	3	7	0.08	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
50	SIMAIRSERVINGZONES_mp_RESOLVEAIRLOOPCONTROLLERS	439,852	0.0%	30,242,581	2.4%	2,477,160	1	2	0.01	0	0.01	C:\Dev\E+\2.2\SimAirServingZones.f90

Source: Lawrence Berkeley National Laboratory

Table 34. Code Profiling Results Sorted by Number of Calls for the Elementary School Run

Rank	Function	Self Time	% Self Time	Total Time	% Total Time	Calls	Callers	Callees	% in function	Average Self time per call	Average Total time per call	Source File
1	energyplus.exe - Total	1,231,866,928	100.0%	1,238,262,060	100.0%	18,987,485,930						
2	OUTPUTPROCESSOR_mp_SETREPORTNOW	39,094,969	3.2%	39,094,969	3.2%	3,069,675,512	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
3	__powr8i4	28,633,740	2.3%	28,633,740	2.3%	2,036,578,240	14	0	1	0	0	
4	_intel_fast_memcmp	17,190,908	1.4%	17,190,908	1.4%	1,877,899,152	2	0	1	0	0	
5	for_cpstr	31,046,925	2.5%	48,237,833	3.9%	1,877,899,149	168	1	0.64	0	0	
6	OUTPUTPROCESSOR_mp_SETMINMAX	351,707	0.0%	351,707	0.0%	1,749,210,087	2	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
7	PSYCHROMETRICS_mp_PSYHFNTDBW	3,166,717	0.3%	3,166,717	0.3%	927,522,371	23	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
8	exp	5,933,481	0.5%	5,933,481	0.5%	666,174,566	10	0	1	0	0	
9	log	8,213,092	0.7%	8,213,092	0.7%	597,945,547	8	0	1	0	0	
10	PSYCHROMETRICS_mp_PSYPSATFNTEMP	16,162,946	1.3%	29,426,712	2.4%	576,066,644	8	2	0.55	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
11	GENERAL_mp_ITERATE	10,221,761	0.8%	10,221,761	0.8%	468,904,498	2	0	1	0	0	C:\Dev\E+\2.2\General.f90
12	memcpy	9,712,569	0.8%	9,712,610	0.8%	340,233,818	153	1	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\memcpy.asm
13	PSYCHROMETRICS_mp_PSYCPAIRFNWTDB	7,261,179	0.6%	9,439,976	0.8%	332,383,557	22	1	0.77	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
14	GETINTERNALVARIABLEVALUE	10,650,048	0.9%	10,652,687	0.9%	207,959,818	2	1	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
15	SCHEDULEMANAGER_mp_GETCURRENTSCHEDULEVALUE	6,901,360	0.6%	6,901,360	0.6%	189,291,210	32	0	1	0	0	C:\Dev\E+\2.2\ScheduleManager.f90
16	memmove	205,962	0.0%	217,216	0.0%	168,170,301	78	1	0.95	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\Intel\MEMCPY.ASM
17	PSYCHROMETRICS_mp_PSYRHOAIRFNPBTDBW	2,716,969	0.2%	2,716,969	0.2%	167,194,099	16	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
18	ENCODEMONDAYHRMIN	2,778	0.0%	2,778	0.0%	163,648,013	2	0	1	0	0	C:\Dev\E+\2.2\UtilityRoutines.f90
19	_intel_fast_memcpy	877,305	0.1%	877,305	0.1%	155,529,341	16	0	1	0	0	
20	PIPES_mp_SIMPIPES	13,165,143	1.1%	33,585,283	2.7%	149,474,936	2	1	0.39	0	0	C:\Dev\E+\2.2\PlantPipes.f90
21	chkstk	497,760	0.0%	497,760	0.0%	135,300,184	175	0	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\chkstk.asm
22	_intel_fast_memset	1,431,161	0.1%	1,431,163	0.1%	108,057,188	18	1	1	0	0	
23	for_cpystr	95,229	0.0%	1,498,720	0.1%	106,680,385	172	2	0.06	0	0	
24	for_trim	10,152,577	0.8%	10,976,965	0.9%	102,647,627	112	1	0.92	0	0	
25	CURVEMANAGER_mp_CURVEVALUE	3,338,812	0.3%	3,338,812	0.3%	76,510,263	6	0	1	0	0	C:\Dev\E+\2.2\CurveManager.f90
26	PSYCHROMETRICS_mp_PSYRHOVFNTDBRH	1,255,797	0.1%	7,586,526	0.6%	73,213,798	1	1	0.17	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
27	PSYCHROMETRICS_mp_PSYRHOVFNTDBWPB	865,013	0.1%	865,013	0.1%	73,213,798	1	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
28	pow	3,045,917	0.2%	3,045,917	0.2%	69,673,240	12	0	1	0	0	
29	WATERCOILS_mp_CALCSIMPLEHEATINGCOIL	9,825,382	0.8%	13,870,412	1.1%	63,931,638	2	6	0.71	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
30	WATERCOILS_mp_SIMULATEWATERCOILCOMPONENTS	2,581,652	0.2%	30,473,529	2.5%	63,931,221	3	7	0.08	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
31	WATERCOILS_mp_UPDATEWATERCOIL	6,266,808	0.5%	6,266,808	0.5%	63,931,221	1	0	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
32	WATERCOILS_mp_INITWATERCOIL	4,141,688	0.3%	4,142,729	0.3%	63,931,221	1	6	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
33	WATERCOILS_mp_REPORTWATERCOIL	1,086,732	0.1%	1,086,732	0.1%	63,931,221	1	0	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
34	for_f90_index	17,973,880	1.5%	22,974,756	1.9%	56,179,779	40	3	0.78	0	0	
35	_SEH_prolog4	305,036	0.0%	305,036	0.0%	54,889,223	19	0	1	0	0	
36	_SEH_epilog4	921	0.0%	921	0.0%	54,889,221	17	0	1	0	0	
37	free	215,856	0.0%	2,543,678	0.2%	54,876,165	6	3	0.08	0	0	f:\sp\vctools\crt_bld\self_x86\crt\src\free.c
38	malloc	237,364	0.0%	3,782,117	0.3%	54,828,906	8	1	0.06	0	0	f:\sp\vctools\crt_bld\self_x86\crt\src\malloc.c
39	for__free_vm	11,655	0.0%	2,063,981	0.2%	52,145,675	14	1	0.01	0	0	
40	for__get_vm	17,902	0.0%	2,945,208	0.2%	52,066,827	15	1	0.01	0	0	
41	for_concat	738,323	0.1%	745,473	0.1%	51,032,579	78	3	0.99	0	0	
42	PSYCHROMETRICS_mp_CPHW	256	0.0%	256	0.0%	50,315,411	11	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
43	PSYCHROMETRICS_mp_PSYTSATFNHPB	1,686,466	0.1%	2,649,407	0.2%	47,337,655	3	3	0.64	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
44	PSYTSATFNHPB_ip_F6	446,661	0.0%	446,661	0.0%	47,337,655	1	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
45	PSYCHROMETRICS_mp_PSYWFNTDBH	664,361	0.1%	664,361	0.1%	45,728,851	4	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
46	PSYCHROMETRICS_mp_PSYTSATFNPB	5,430,294	0.4%	24,364,689	2.0%	36,888,040	2	2	0.22	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
47	PSYCHROMETRICS_mp_PSYTWBFNTDBWPB	13,037,782	1.1%	45,859,462	3.7%	34,505,123	6	3	0.28	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
48	PSYCHROMETRICS_mp_PSYHGAIRFNWTDB	14,894	0.0%	14,894	0.0%	33,583,676	3	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
49	PSYCHROMETRICS_mp_PSYTDBFNHW	355,240	0.0%	355,240	0.0%	33,272,496	9	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
50	SYSTEMREPORTS_mp_CALCSYSTEMENERGYUSE	8,625,366	0.7%	12,777,959	1.0%	32,864,100	1	1	0.68	0	0	C:\Dev\E+\2.2\SystemReports.f90

Source: Lawrence Berkeley National Laboratory

Table 35. Code Profiling Results Sorted by Subroutine Self Time for the High School Run

Rank	Function	Self Time	% Self Time	Total Time	% Total Time	Calls	Callers	Callees	% in function	Average Self time per call	Average Total time per call	Source File
1	energyplus.exe - Total	4,617,448,688	100.0%	4,644,392,874	100.0%	44,102,657,041						
2	UPDATEDATAANDREPORT	1,270,276,031	27.5%	1,516,506,012	32.7%	357,703	2	14	0.84	3.55	4.24	C:\Dev\E+\2.2\OutputProcessor.f90
3	HEATBALANCEINTRADEXCHANGE_mp_CALCINTERIORRADEXCHANGE	519,922,955	11.3%	887,220,725	19.1%	418,724	3	3	0.59	1.24	2.12	C:\Dev\E+\2.2\HeatBalanceIntRadExchange.f90
4	__powr8i4	374,226,689	8.1%	374,226,689	8.1%	11,542,347,970	14	0	1	0	0	
5	for_cpstr	189,441,527	4.1%	297,672,191	6.4%	4,123,795,906	173	1	0.64	0	0	
6	OUTPUTPROCESSOR_mp_SETREPORTNOW	179,356,535	3.9%	179,356,535	3.9%	6,624,892,371	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
7	OUTPUTREPORTTABULAR_mp_GATHERMONTHLYRESULTSFORTIMESTEP	108,729,787	2.4%	148,445,434	3.2%	357,703	1	2	0.73	0.3	0.41	C:\Dev\E+\2.2\OutputReportTabular.f90
8	_intel_fast_memcmp	108,230,664	2.3%	108,230,664	2.3%	4,123,795,909	2	0	1	0	0	
9	PLANTUTILITIES_mp_UPDATEPLANTMIXER	89,372,849	1.9%	89,372,849	1.9%	7,228,452	2	0	1	0.01	0.01	C:\Dev\E+\2.2\PlantUtilities.f90
10	for_f90_index	78,707,293	1.7%	142,539,863	3.1%	203,836,952	41	3	0.55	0	0	
11	GETINSTANTMETERVALUE	69,314,123	1.5%	69,314,123	1.5%	15,443,240	3	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
12	ZONETEMPPREDICTORCORRECTOR_mp_CALCZONESUMS	61,042,506	1.3%	65,244,195	1.4%	36,514,754	2	1	0.94	0	0	C:\Dev\E+\2.2\ZoneTempPredictorCorrector.f90
13	OUTPUTPROCESSOR_mp_SETMINMAX	58,312,283	1.3%	58,312,283	1.3%	3,737,202,766	2	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
14	PIPES_mp_SIMPIPES	53,754,293	1.2%	157,513,350	3.4%	397,962,978	3	2	0.34	0	0	C:\Dev\E+\2.2\PlantPipes.f90
15	for_trim	51,396,149	1.1%	63,035,471	1.4%	372,800,040	113	1	0.82	0	0	
16	CALCHEATBALANCEINSIDESURF	49,390,648	1.1%	846,782,515	18.2%	54,432	1	10	0.06	0.91	15.56	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
17	PSYCHROMETRICS_mp_PSYCPAIRFNWTDB	46,989,976	1.0%	75,345,286	1.6%	661,782,330	26	1	0.62	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
18	GETINTERNALVARIABLEVALUE	44,292,672	1.0%	44,382,317	1.0%	431,539,936	2	1	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
19	SYSTEMREPORTS_mp_CALCSYSTEMENERGYUSE	43,094,033	0.9%	128,957,190	2.8%	69,915,462	1	1	0.33	0	0	C:\Dev\E+\2.2\SystemReports.f90
20	PSYCHROMETRICS_mp_PSYPSATFNTEMP	40,885,898	0.9%	69,941,607	1.5%	436,918,901	8	2	0.58	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
21	memcpy	40,368,899	0.9%	40,368,971	0.9%	719,055,814	165	1	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\memcpy.asm
22	ZONEEQUIPMENTMANAGER_mp_CALCZONELEAVINGCONDITIONS	39,379,011	0.9%	94,322,721	2.0%	1,024,134	2	5	0.42	0.04	0.09	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
23	FLOWRESOLVER_mp_REQUESTNETWORKFLOWANDSOLVE	38,067,247	0.8%	76,496,851	1.6%	7,228,452	2	2	0.5	0.01	0.01	C:\Dev\E+\2.2\PlantFlowResolver.f90
24	PSYCHROMETRICS_mp_PSYHFNTDBW	37,452,381	0.8%	37,452,381	0.8%	1,715,450,269	26	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
25	PLANTCONDLOOPOPERATION_mp_CHECKFOREMSCTRL	26,425,203	0.6%	26,425,203	0.6%	7,368,838	2	0	1	0	0	C:\Dev\E+\2.2\PlantCondLoopOperation.f90
26	HEATBALANCESURFACEMANAGER_mp_UPDATETHERMALHISTORIES	25,916,924	0.6%	25,916,925	0.6%	54,432	1	2	1	0.48	0.48	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
27	SYSTEMREPORTS_mp_INITENERGYREPORTS	25,773,735	0.6%	34,003,805	0.7%	305,143	1	7	0.76	0.08	0.11	C:\Dev\E+\2.2\SystemReports.f90
28	DEMANDSIDESOLVERS_mp_SIMPLANTDEMANDSIDES	23,474,700	0.5%	344,821,179	7.4%	1,691,634	1	7	0.07	0.01	0.2	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
29	WATERCOILS_mp_CALCSIMPLEHEATINGCOIL	23,463,078	0.5%	40,895,026	0.9%	104,986,697	2	6	0.57	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
30	FLOWRESOLVER_mp_ENFORCESPLITTERCONTINUITY	22,733,179	0.5%	23,294,600	0.5%	7,228,452	1	1	0.98	0	0	C:\Dev\E+\2.2\PlantFlowResolver.f90
31	SYSTEMREPORTS_mp_REPORTSYSTEMENERGYUSE	21,688,089	0.5%	156,807,720	3.4%	305,143	1	3	0.14	0.07	0.51	C:\Dev\E+\2.2\SystemReports.f90
32	HEATBALANCESURFACEMANAGER_mp_INITSOLARHEATGAINS	20,162,544	0.4%	35,318,156	0.8%	54,432	1	2	0.57	0.37	0.65	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
33	PLANTLOOPEQUIP_mp_SIMPLANTEQUIP	17,680,851	0.4%	42,013,346	0.9%	27,996,162	2	6	0.42	0	0	C:\Dev\E+\2.2\PlantLoopEquipments.f90
34	exp	16,898,387	0.4%	16,898,387	0.4%	546,881,711	12	0	1	0	0	
35	GETVARIABLEKEYCOUNTANDTYPE	16,029,874	0.3%	144,485,059	3.1%	2,785	2	11	0.11	5.76	51.88	C:\Dev\E+\2.2\OutputProcessor.f90
36	_intel_fast_memcpy	15,739,930	0.3%	15,739,930	0.3%	561,056,522	16	0	1	0	0	
37	SCHEDULEMANAGER_mp_GETCURRENTSCHEDULEVALUE	15,402,552	0.3%	15,402,552	0.3%	273,807,707	29	0	1	0	0	C:\Dev\E+\2.2\ScheduleManager.f90
38	log	15,201,984	0.3%	15,201,984	0.3%	440,440,464	8	0	1	0	0	
39	WATERCOILS_mp_SIMULATEWATERCOILCOMPONENTS	14,632,573	0.3%	117,961,443	2.5%	112,134,654	3	8	0.12	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
40	free	14,559,638	0.3%	32,317,247	0.7%	191,870,805	6	3	0.45	0	0	f:\sp\vctools\crt_bld\self_x86\crt\src\free.c
41	FLOWRESOLVER_mp_SOLVEFLOWNETWORK	14,503,090	0.3%	37,797,690	0.8%	7,228,452	1	1	0.38	0	0.01	C:\Dev\E+\2.2\PlantFlowResolver.f90
42	HEATBALANCESURFACEMANAGER_mp_INITSURFACEHEATBALANCE	14,427,349	0.3%	194,965,132	4.2%	54,432	1	19	0.07	0.27	3.58	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
43	ZONETEMPPREDICTORCORRECTOR_mp_CALCZONECOMPONENTLOADSUMS	14,204,991	0.3%	19,304,818	0.4%	20,903,734	1	2	0.74	0	0	C:\Dev\E+\2.2\ZoneTempPredictorCorrector.f90
44	GETVARIABLEKEYS	13,801,703	0.3%	130,663,026	2.8%	2,785	2	9	0.11	4.96	46.92	C:\Dev\E+\2.2\OutputProcessor.f90
45	WATERCOILS_mp_UPDATEWATERCOIL	13,293,440	0.3%	13,293,440	0.3%	112,134,654	1	0	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
46	ZONEEQUIPMENTMANAGER_mp_SETZONEEQUIPSIMORDER	13,280,063	0.3%	35,161,586	0.8%	47,061,772	1	2	0.38	0	0	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
47	for_concat	12,956,489	0.3%	20,574,851	0.4%	185,906,306	79	3	0.63	0	0	
48	ZONEEQUIPMENTMANAGER_mp_SIMZONEEQUIPMENT	12,329,413	0.3%	371,192,860	8.0%	1,023,082	1	10	0.03	0.01	0.36	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
49	ZONETEMPPREDICTORCORRECTOR_mp_CORRECTZONEAIRTEMP	12,229,973	0.3%	87,781,937	1.9%	454,429	1	7	0.14	0.03	0.19	C:\Dev\E+\2.2\ZoneTempPredictorCorrector.f90
50	PSYCHROMETRICS_mp_PSYTSATFNPB	12,133,284	0.3%	51,788,087	1.1%	15,520,531	2	2	0.23	0	0	C:\Dev\E+\2.2\PsychRoutines.f90

Source: Lawrence Berkeley National Laboratory

Table 36. Code Profiling Results Sorted by Subroutine Total Time for the High School Run

Rank	Function	Self Time	% Self Time	Total Time	% Total Time	Calls	Callers	Callees	% in function	Average Self time per call	Average Total time per call	Source File
1	energyplus.exe - Total	4,617,448,688	100.0%	4,644,392,874	100.0%	44,102,657,041						
2	ENERGYPLUS	12	0.0%	4,644,392,680	100.0%	1	1	20	0	0.01	4644392.68	C:\Dev\E+\2.2\EnergyPlus.f90
3	SIMULATIONMANAGER_mp_MANAGESIMULATION	81,322	0.0%	4,640,748,708	99.9%	1	1	30	0	81.32	4640748.71	C:\Dev\E+\2.2\SimulationManager.f90
4	HEATBALANCEMANAGER_mp_MANAGEHEATBALANCE	110,390	0.0%	4,635,790,335	99.8%	54,432	2	7	0	0	85.17	C:\Dev\E+\2.2\HeatBalanceManager.f90
5	HEATBALANCESURFACEMANAGER_mp_MANAGESURFACEHEATBALANCE	113,392	0.0%	3,824,420,938	82.3%	54,432	1	9	0	0	70.26	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
6	HEATBALANCEAIRMANAGER_mp_MANAGEAIRHEATBALANCE	30,935	0.0%	2,633,606,160	56.7%	54,432	1	4	0	0	48.38	C:\Dev\E+\2.2\HeatBalanceAirManager.f90
7	HEATBALANCEAIRMANAGER_mp_CALCHEATBALANCEAIR	79,303	0.0%	2,633,289,638	56.7%	54,432	1	1	0	0	48.38	C:\Dev\E+\2.2\HeatBalanceAirManager.f90
8	HVACMANAGER_mp_MANAGEHVAC	2,218,847	0.0%	2,633,210,335	56.7%	54,432	1	44	0	0.04	48.38	C:\Dev\E+\2.2\HVACManager.f90
9	UPDATEDATAANDREPORT	1,270,276,031	27.5%	1,516,506,012	32.7%	357,703	2	14	0.84	3.55	4.24	C:\Dev\E+\2.2\OutputProcessor.f90
10	HVACMANAGER_mp_SIMHVAC	590,897	0.0%	1,091,193,437	23.5%	339,370	1	8	0	0	3.22	C:\Dev\E+\2.2\HVACManager.f90
11	HVACMANAGER_mp_SIMSELECTEDEQUIPMENT	1,239,262	0.0%	1,082,257,161	23.3%	1,014,976	1	9	0	0	1.07	C:\Dev\E+\2.2\HVACManager.f90
12	HEATBALANCEINTRADEXCHANGE_mp_CALCINTERIORRADEXCHANGE	519,922,955	11.3%	887,220,725	19.1%	418,724	3	3	0.59	1.24	2.12	C:\Dev\E+\2.2\HeatBalanceIntRadExchange.f90
13	CALCHEATBALANCEINSIDESURF	49,390,648	1.1%	846,782,515	18.2%	54,432	1	10	0.06	0.91	15.56	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
14	HEATBALANCEMANAGER_mp_REPORTHEATBALANCE	127,508	0.0%	802,580,426	17.3%	54,432	1	5	0	0	14.74	C:\Dev\E+\2.2\HeatBalanceManager.f90
15	PLANTMANAGER_mp_MANAGEPLANTLOOPS	564,906	0.0%	468,519,795	10.1%	1,014,976	1	6	0	0	0.46	C:\Dev\E+\2.2\PlantManager.f90
16	OUTPUTREPORTTABULAR_mp_UPDATETABULARREPORTS	327,751	0.0%	424,479,165	9.1%	357,703	2	9	0	0	1.19	C:\Dev\E+\2.2\OutputReportTabular.f90
17	ZONEEQUIPMENTMANAGER_mp_MANAGEZONEEQUIPMENT	337,806	0.0%	375,058,595	8.1%	1,024,134	3	6	0	0	0.37	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
18	__powr8i4	374,226,689	8.1%	374,226,689	8.1%	11,542,347,970	14	0	1	0	0	
19	ZONEEQUIPMENTMANAGER_mp_SIMZONEEQUIPMENT	12,329,413	0.3%	371,192,860	8.0%	1,023,082	1	10	0.03	0.01	0.36	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
20	DEMANDSIDESOLVERS_mp_SIMPLANTDEMANDSIDES	23,474,700	0.5%	344,821,179	7.4%	1,691,634	1	7	0.07	0.01	0.2	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
21	for_cpstr	189,441,527	4.1%	297,672,191	6.4%	4,123,795,906	173	1	0.64	0	0	
22	OUTPUTREPORTTABULAR_mp_GETINPUTTABULARMONTHLY	14,800	0.0%	275,253,836	5.9%	1	1	19	0	14.8	275253.84	C:\Dev\E+\2.2\OutputReportTabular.f90
23	HEATBALANCESURFACEMANAGER_mp_INITSURFACEHEATBALANCE	14,427,349	0.3%	194,965,132	4.2%	54,432	1	19	0.07	0.27	3.58	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
24	ZONEAIRLOOPEQUIPMENTMANAGER_mp_MANAGEZONEAIRLOOPEQUIPMENT	4,959,356	0.1%	192,301,052	4.1%	43,992,526	1	5	0.03	0	0	C:\Dev\E+\2.2\Zoneairloopequipmentmanager.f90
25	ZONEAIRLOOPEQUIPMENTMANAGER_mp_SIMZONEAIRLOOPEQUIPMENT	10,233,113	0.2%	182,286,105	3.9%	43,992,526	1	2	0.06	0	0	C:\Dev\E+\2.2\Zoneairloopequipmentmanager.f90
26	OUTPUTPROCESSOR_mp_SETREPORTNOW	179,356,535	3.9%	179,356,535	3.9%	6,624,892,371	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
27	SINGLEDUCT_mp_SIMULATESINGLEDUCT	6,449,051	0.1%	163,719,197	3.5%	43,992,526	1	6	0.04	0	0	C:\Dev\E+\2.2\HVACSingleDuctSystem.f90
28	PIPES_mp_SIMPIPES	53,754,293	1.2%	157,513,350	3.4%	397,962,978	3	2	0.34	0	0	C:\Dev\E+\2.2\PlantPipes.f90
29	DEMANDSIDESOLVERS_mp_SIMULATEPIPES	9,651,120	0.2%	156,808,499	3.4%	25,374,510	1	2	0.06	0	0.01	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
30	SYSTEMREPORTS_mp_REPORTSYSTEMENERGYUSE	21,688,089	0.5%	156,807,720	3.4%	305,143	1	3	0.14	0.07	0.51	C:\Dev\E+\2.2\SystemReports.f90
31	OUTPUTREPORTTABULAR_mp_GATHERMONTHLYRESULTSFORTIMESTEP	108,729,787	2.4%	148,445,434	3.2%	357,703	1	2	0.73	0.3	0.41	C:\Dev\E+\2.2\OutputReportTabular.f90
32	SIMAIRSERVINGZONES_mp_MANAGEAIRLOOPS	215,300	0.0%	147,891,060	3.2%	1,030,038	2	4	0	0	0.14	C:\Dev\E+\2.2\SimAirServingZones.f90
33	GETVARIABLEKEYCOUNTANDTYPE	16,029,874	0.3%	144,485,059	3.1%	2,785	2	11	0.11	5.76	51.88	C:\Dev\E+\2.2\OutputProcessor.f90
34	SIMAIRSERVINGZONES_mp_SIMAIRLOOPS	2,070,530	0.0%	143,740,694	3.1%	1,030,037	1	6	0.01	0	0.14	C:\Dev\E+\2.2\SimAirServingZones.f90
35	SINGLEDUCT_mp_SIMVAV	11,892,928	0.3%	143,121,755	3.1%	43,992,526	1	4	0.08	0	0	C:\Dev\E+\2.2\HVACSingleDuctSystem.f90
36	for_f90_index	78,707,293	1.7%	142,539,863	3.1%	203,836,952	41	3	0.55	0	0	
37	ZONETEMPPREDICTORCORRECTOR_mp_MANAGEZONEAIRUPDATES	254,892	0.0%	140,451,440	3.0%	848,231	1	5	0	0	0.17	C:\Dev\E+\2.2\ZoneTempPredictorCorrector.f90
38	GETVARIABLEKEYS	13,801,703	0.3%	130,663,026	2.8%	2,785	2	9	0.11	4.96	46.92	C:\Dev\E+\2.2\OutputProcessor.f90
39	SIMAIRSERVINGZONES_mp_SIMAIRLOOP	1,067,231	0.0%	129,581,255	2.8%	9,328,518	1	2	0.01	0	0.01	C:\Dev\E+\2.2\SimAirServingZones.f90
40	SYSTEMREPORTS_mp_CALCSYSTEMENERGYUSE	43,094,033	0.9%	128,957,190	2.8%	69,915,462	1	1	0.33	0	0	C:\Dev\E+\2.2\SystemReports.f90
41	SUPPLYSIDESOLVERS_mp_MANAGEPLANTSUPPLYSIDES	379,638	0.0%	119,095,081	2.6%	717,850	1	5	0	0	0.17	C:\Dev\E+\2.2\PlantSupplySideSolvers.f90
42	SUPPLYSIDESOLVERS_mp_SIMLOOPPUMPSOLUTIONSCHEME	1,270,078	0.0%	118,673,287	2.6%	2,153,550	1	10	0.01	0	0.06	C:\Dev\E+\2.2\PlantSupplySideSolvers.f90
43	WATERCOILS_mp_SIMULATEWATERCOILCOMPONENTS	14,632,573	0.3%	117,961,443	2.5%	112,134,654	3	8	0.12	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
44	CALCHEATBALANCEOUTSIDESURF	2,598,713	0.1%	116,000,968	2.5%	54,432	1	3	0.02	0.05	2.13	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
45	SUPPLYSIDESOLVERS_mp_LOADBASEDSOLUTION	3,646,216	0.1%	109,240,640	2.4%	2,153,550	1	9	0.03	0	0.05	C:\Dev\E+\2.2\PlantSupplySideSolvers.f90
46	_intel_fast_memcmp	108,230,664	2.3%	108,230,664	2.3%	4,123,795,909	2	0	1	0	0	
47	SIMAIRSERVINGZONES_mp_SIMAIRLOOPCOMPONENTS	5,736,241	0.1%	107,008,088	2.3%	11,141,877	2	3	0.05	0	0.01	C:\Dev\E+\2.2\SimAirServingZones.f90
48	SIMAIRSERVINGZONES_mp_SOLVEAIRLOOPCONTROLLERS	2,198,863	0.0%	104,915,495	2.3%	6,831,078	1	2	0.02	0	0.02	C:\Dev\E+\2.2\SimAirServingZones.f90
49	SIMAIRSERVINGZONES_mp_SIMAIRLOOPCOMPONENT	3,452,363	0.1%	96,048,579	2.1%	44,567,508	1	5	0.04	0	0	C:\Dev\E+\2.2\SimAirServingZones.f90
50	ZONEEQUIPMENTMANAGER_mp_CALCZONELEAVINGCONDITIONS	39,379,011	0.9%	94,322,721	2.0%	1,024,134	2	5	0.42	0.04	0.09	C:\Dev\E+\2.2\Zoneequipmentmanager.f90

Source: Lawrence Berkeley National Laboratory

Table 37. Code Profiling Results Sorted by Number of Calls for the High School Run

Rank	Function	Self Time	% Self Time	Total Time	% Total Time	Calls	Callers	Callees	% in function	Average Self time per call	Average Total time per call	Source File
1	energyplus.exe - Total	4,617,448,688	100.0%	4,644,392,874	100.0%	44,102,657,041						
2	__powr8i4	374,226,689	8.1%	374,226,689	8.1%	11,542,347,970	14	0	1	0	0	
3	OUTPUTPROCESSOR_mp_SETREPORTNOW	179,356,535	3.9%	179,356,535	3.9%	6,624,892,371	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
4	_intel_fast_memcmp	108,230,664	2.3%	108,230,664	2.3%	4,123,795,909	2	0	1	0	0	
5	for_cpstr	189,441,527	4.1%	297,672,191	6.4%	4,123,795,906	173	1	0.64	0	0	
6	OUTPUTPROCESSOR_mp_SETMINMAX	58,312,283	1.3%	58,312,283	1.3%	3,737,202,766	2	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
7	PSYCHROMETRICS_mp_PSYHFNTDBW	37,452,381	0.8%	37,452,381	0.8%	1,715,450,269	26	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
8	memcpy	40,368,899	0.9%	40,368,971	0.9%	719,055,814	165	1	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\memcpy.asm
9	PSYCHROMETRICS_mp_PSYCPAIRFNWTDB	46,989,976	1.0%	75,345,286	1.6%	661,782,330	26	1	0.62	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
10	_intel_fast_memcpy	15,739,930	0.3%	15,739,930	0.3%	561,056,522	16	0	1	0	0	
11	exp	16,898,387	0.4%	16,898,387	0.4%	546,881,711	12	0	1	0	0	
12	log	15,201,984	0.3%	15,201,984	0.3%	440,440,464	8	0	1	0	0	
13	PSYCHROMETRICS_mp_PSYPSATFNTEMP	40,885,898	0.9%	69,941,607	1.5%	436,918,901	8	2	0.58	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
14	GETINTERNALVARIABLEVALUE	44,292,672	1.0%	44,382,317	1.0%	431,539,936	2	1	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
15	memmove	7,150,813	0.2%	7,162,256	0.2%	413,334,811	80	1	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\Intel\MEMCPY.ASM
16	PIPES_mp_SIMPIPES	53,754,293	1.2%	157,513,350	3.4%	397,962,978	3	2	0.34	0	0	C:\Dev\E+\2.2\PlantPipes.f90
17	for_trim	51,396,149	1.1%	63,035,471	1.4%	372,800,040	113	1	0.82	0	0	
18	ENCODEMONDAYHRMIN	3,533,082	0.1%	3,533,082	0.1%	342,540,429	2	0	1	0	0	C:\Dev\E+\2.2\UtilityRoutines.f90
19	PSYCHROMETRICS_mp_PSYRHOAIRFNPBTDBW	10,645,201	0.2%	10,645,201	0.2%	341,611,225	17	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
20	chkstk	6,827,440	0.1%	6,827,440	0.1%	309,884,048	177	0	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\chkstk.asm
21	SCHEDULEMANAGER_mp_GETCURRENTSCHEDULEVALUE	15,402,552	0.3%	15,402,552	0.3%	273,807,707	29	0	1	0	0	C:\Dev\E+\2.2\ScheduleManager.f90
22	GENERAL_mp_ITERATE	8,521,893	0.2%	8,521,893	0.2%	214,143,267	3	0	1	0	0	C:\Dev\E+\2.2\General.f90
23	_intel_fast_memset	6,960,658	0.2%	6,960,659	0.1%	212,331,526	18	1	1	0	0	
24	for_cpystr	8,306,023	0.2%	18,047,821	0.4%	210,613,454	178	2	0.46	0	0	
25	for_f90_index	78,707,293	1.7%	142,539,863	3.1%	203,836,952	41	3	0.55	0	0	
26	_SEH_prolog4	5,010,801	0.1%	5,010,801	0.1%	191,883,868	19	0	1	0	0	
27	_SEH_epilog4	1,834,120	0.0%	1,834,120	0.0%	191,883,866	17	0	1	0	0	
28	free	14,559,638	0.3%	32,317,247	0.7%	191,870,805	6	3	0.45	0	0	f:\sp\vctools\crt_bld\self_x86\crt\src\free.c
29	malloc	7,694,916	0.2%	22,557,954	0.5%	191,851,568	8	1	0.34	0	0	f:\sp\vctools\crt_bld\self_x86\crt\src\malloc.c
30	for__free_vm	5,694,776	0.1%	36,608,499	0.8%	187,161,859	14	1	0.16	0	0	
31	for__get_vm	5,324,682	0.1%	26,177,392	0.6%	187,083,011	15	1	0.2	0	0	
32	for_concat	12,956,489	0.3%	20,574,851	0.4%	185,906,306	79	3	0.63	0	0	
33	PSYCHROMETRICS_mp_PSYRHOVFNTDBRH	9,227,431	0.2%	37,154,079	0.8%	164,535,660	1	1	0.25	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
34	PSYCHROMETRICS_mp_PSYRHOVFNTDBWPB	5,184,547	0.1%	5,184,547	0.1%	164,535,660	1	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
35	pow	7,568,842	0.2%	7,568,842	0.2%	127,741,117	13	0	1	0	0	
36	WATERCOILS_mp_SIMULATEWATERCOILCOMPONENTS	14,632,573	0.3%	117,961,443	2.5%	112,134,654	3	8	0.12	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
37	WATERCOILS_mp_UPDATEWATERCOIL	13,293,440	0.3%	13,293,440	0.3%	112,134,654	1	0	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
38	WATERCOILS_mp_INITWATERCOIL	9,326,334	0.2%	9,329,252	0.2%	112,134,654	1	12	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
39	WATERCOILS_mp_REPORTWATERCOIL	4,087,567	0.1%	4,087,567	0.1%	112,134,654	1	0	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
40	allmul	1,241,384	0.0%	1,241,384	0.0%	108,956,999	6	0	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\llmul.asm
41	WATERCOILS_mp_CALCSIMPLEHEATINGCOIL	23,463,078	0.5%	40,895,026	0.9%	104,986,697	2	6	0.57	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
42	PSYCHROMETRICS_mp_CPCW	844,404	0.0%	844,404	0.0%	77,113,108	17	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
43	PSYCHROMETRICS_mp_CPHW	957,455	0.0%	957,455	0.0%	74,816,341	13	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
44	PSYCHROMETRICS_mp_PSYHGAIRFNWTDB	1,034,803	0.0%	1,034,803	0.0%	71,061,982	3	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
45	SYSTEMREPORTS_mp_CALCSYSTEMENERGYUSE	43,094,033	0.9%	128,957,190	2.8%	69,915,462	1	1	0.33	0	0	C:\Dev\E+\2.2\SystemReports.f90
46	ZONEEQUIPMENTMANAGER_mp_UPDATESYSTEMOUTPUTREQUIRED	1,792,506	0.0%	1,792,506	0.0%	49,156,328	2	0	1	0	0	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
47	ZONEEQUIPMENTMANAGER_mp_INITSYSTEMOUTPUTREQUIRED	2,069,161	0.0%	2,069,161	0.0%	47,110,164	2	0	1	0	0	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
48	ZONEEQUIPMENTMANAGER_mp_SETZONEEQUIPSIMORDER	13,280,063	0.3%	35,161,586	0.8%	47,061,772	1	2	0.38	0	0	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
49	SIMAIRSERVINGZONES_mp_SIMAIRLOOPCOMPONENT	3,452,363	0.1%	96,048,579	2.1%	44,567,508	1	5	0.04	0	0	C:\Dev\E+\2.2\SimAirServingZones.f90
50	SINGLEDUCT_mp_UPDATESYS	2,665,224	0.1%	2,665,224	0.1%	44,320,723	1	0	1	0	0	C:\Dev\E+\2.2\HVACSingleDuctSystem.f90

Source: Lawrence Berkeley National Laboratory

Table 38. Code Profiling Results Sorted by Subroutine Self Time for the Hospital Run

Rank	Function	Self Time	% Self Time	Total Time	% Total Time	Calls	Callers	Callees	% in function	Average Self time per call	Average Total time per call	Source File
1	energyplus.exe - Total	2,069,362,554	100.0%	2,095,540,245	100.0%	19,723,399,580						
2	UPDATEDATAANDREPORT	671,191,997	32.4%	801,752,891	38.3%	106,969	2	14	0.84	6.27	7.5	C:\Dev\E+\2.2\OutputProcessor.f90
3	HEATBALANCEINTRADEXCHANGE_mp_CALCINTERIORRADEXCHANGE	161,012,767	7.8%	281,309,058	13.4%	409,791	3	3	0.57	0.39	0.69	C:\Dev\E+\2.2\HeatBalanceIntRadExchange.f90
4	__powr8i4	123,999,843	6.0%	123,999,843	5.9%	3,813,096,152	14	0	1	0	0	
5	OUTPUTPROCESSOR_mp_SETREPORTNOW	95,538,395	4.6%	95,538,395	4.6%	3,662,418,398	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
6	for_f90_index	75,876,100	3.7%	135,614,971	6.5%	215,611,558	40	3	0.56	0	0	
7	for_cpstr	53,165,709	2.6%	80,203,003	3.8%	1,148,276,171	164	1	0.66	0	0	
8	for_trim	52,428,691	2.5%	62,062,624	3.0%	394,765,509	106	1	0.84	0	0	
9	OUTPUTREPORTTABULAR_mp_GATHERMONTHLYRESULTSFORTIMESTEP	46,191,505	2.2%	67,864,827	3.2%	106,969	1	2	0.68	0.43	0.63	C:\Dev\E+\2.2\OutputReportTabular.f90
10	CALCHEATBALANCEINSIDESURF	41,574,437	2.0%	323,580,785	15.4%	54,576	1	10	0.13	0.76	5.93	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
11	HEATBALANCESURFACEMANAGER_mp_UPDATETHERMALHISTORIES	31,318,782	1.5%	31,318,782	1.5%	54,576	1	2	1	0.57	0.57	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
12	_intel_fast_memcmp	27,037,294	1.3%	27,037,294	1.3%	1,148,276,174	2	0	1	0	0	
13	PSYCHROMETRICS_mp_PSYPSATFNTEMP	26,490,142	1.3%	43,950,490	2.1%	269,368,127	8	2	0.6	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
14	PSYCHROMETRICS_mp_PSYCPAIRFNWTDB	25,987,958	1.3%	40,707,632	1.9%	373,173,862	22	1	0.64	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
15	OUTPUTPROCESSOR_mp_SETMINMAX	25,649,009	1.2%	25,649,009	1.2%	1,436,077,427	2	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
16	GETINTERNALVARIABLEVALUE	22,375,708	1.1%	22,457,733	1.1%	213,687,474	2	1	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
17	memcpy	22,164,662	1.1%	22,164,750	1.1%	330,176,134	158	1	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\memcpy.asm
18	WATERCOILS_mp_CALCSIMPLEHEATINGCOIL	20,732,673	1.0%	37,687,448	1.8%	75,949,184	2	6	0.55	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
19	PSYCHROMETRICS_mp_PSYHFNTDBW	18,341,570	0.9%	18,341,570	0.9%	898,744,659	20	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
20	HEATBALANCESURFACEMANAGER_mp_INITSOLARHEATGAINS	18,034,361	0.9%	23,035,074	1.1%	54,576	1	2	0.78	0.33	0.42	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
21	HEATBALANCESURFACEMANAGER_mp_INITSURFACEHEATBALANCE	17,457,920	0.8%	113,233,930	5.4%	54,576	1	19	0.15	0.32	2.07	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
22	GETVARIABLEKEYCOUNTANDTYPE	14,981,353	0.7%	135,366,388	6.5%	3,235	2	11	0.11	4.63	41.84	C:\Dev\E+\2.2\OutputProcessor.f90
23	GETINSTANTMETERVALUE	14,552,226	0.7%	14,552,226	0.7%	2,654,768	3	0	1	0.01	0.01	C:\Dev\E+\2.2\OutputProcessor.f90
24	GETVARIABLEKEYS	13,207,084	0.6%	126,816,726	6.1%	3,235	2	9	0.1	4.08	39.2	C:\Dev\E+\2.2\OutputProcessor.f90
25	_intel_fast_memcpy	12,577,571	0.6%	12,577,571	0.6%	594,118,754	16	0	1	0	0	
26	for_concat	12,098,619	0.6%	18,085,631	0.9%	196,950,868	75	3	0.67	0	0	
27	CONTROLCOMPOUTPUT	11,960,706	0.6%	98,556,358	4.7%	4,210,684	1	3	0.12	0	0.02	C:\Dev\E+\2.2\GeneralRoutines.f90
28	free	11,838,525	0.6%	28,021,650	1.3%	199,090,964	6	3	0.42	0	0	f:\sp\vctools\crt_bld\self_x86\crt\src\free.c
29	exp	11,532,400	0.6%	11,532,400	0.6%	391,906,956	11	0	1	0	0	
30	ZONEEQUIPMENTMANAGER_mp_CALCZONELEAVINGCONDITIONS	10,041,765	0.5%	22,235,193	1.1%	263,133	2	5	0.45	0.04	0.08	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
31	FLOWRESOLVER_mp_REQUESTNETWORKFLOWANDSOLVE	9,612,282	0.5%	19,013,499	0.9%	1,221,234	2	2	0.51	0.01	0.02	C:\Dev\E+\2.2\PlantFlowResolver.f90
32	PIPES_mp_SIMPIPES	9,550,644	0.5%	26,306,881	1.3%	66,457,180	3	2	0.36	0	0	C:\Dev\E+\2.2\PlantPipes.f90
33	SCHEDULEMANAGER_mp_GETCURRENTSCHEDULEVALUE	9,399,124	0.5%	9,399,124	0.4%	155,432,517	24	0	1	0	0	C:\Dev\E+\2.2\ScheduleManager.f90
34	SYSTEMREPORTS_mp_CALCSYSTEMENERGYUSE	9,384,611	0.5%	28,134,190	1.3%	15,778,610	1	1	0.33	0	0	C:\Dev\E+\2.2\SystemReports.f90
35	WATERCOILS_mp_SIMULATEWATERCOILCOMPONENTS	9,374,593	0.5%	92,160,999	4.4%	78,846,101	3	8	0.1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
36	log	8,953,137	0.4%	8,953,137	0.4%	270,065,502	7	0	1	0	0	
37	WATERCOILS_mp_UPDATEWATERCOIL	8,224,170	0.4%	8,224,170	0.4%	78,846,101	1	0	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
38	PSYCHROMETRICS_mp_PSYRHOVFNTDBRH	7,373,719	0.4%	31,616,060	1.5%	149,417,583	1	1	0.23	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
39	ZONETEMPPREDICTORCORRECTOR_mp_CALCZONESUMS	7,229,315	0.3%	7,896,604	0.4%	6,371,090	2	1	0.92	0	0	C:\Dev\E+\2.2\ZoneTempPredictorCorrector.f90
40	HEATBALANCESURFACEMANAGER_mp_COMPUTEDIFSOLEXCZONESWIZWINDOWS	7,219,715	0.3%	7,219,770	0.3%	54,576	1	2	1	0.13	0.13	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
41	DEMANDSIDESOLVERS_mp_SIMPLANTDEMANDSIDES	6,787,688	0.3%	56,846,239	2.7%	281,491	1	7	0.12	0.02	0.2	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
42	pow	6,682,865	0.3%	6,682,865	0.3%	118,281,942	13	0	1	0	0	
43	PLANTCONDLOOPOPERATION_mp_CHECKFOREMSCTRL	6,625,363	0.3%	6,625,363	0.3%	1,324,031	2	0	1	0.01	0.01	C:\Dev\E+\2.2\PlantCondLoopOperation.f90
44	malloc	6,512,645	0.3%	20,771,245	1.0%	199,069,623	8	1	0.31	0	0	f:\sp\vctools\crt_bld\self_x86\crt\src\malloc.c
45	for__free_vm	6,205,933	0.3%	33,939,337	1.6%	198,200,826	14	1	0.18	0	0	
46	PSYCHROMETRICS_mp_PSYRHOAIRFNPBTDBW	6,171,207	0.3%	6,171,207	0.3%	191,331,111	14	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
47	INTERNALHEATGAINS_mp_INITINTERNALHEATGAINS	6,081,106	0.3%	7,030,597	0.3%	54,576	1	7	0.86	0.11	0.13	C:\Dev\E+\2.2\HeatBalanceInternalHeatGains.f90
48	PSYCHROMETRICS_mp_PSYTSATFNPB	6,035,420	0.3%	26,643,231	1.3%	7,078,767	2	2	0.23	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
49	OUTPUTPROCESSOR_mp_UPDATEMETERS	5,845,458	0.3%	8,463,872	0.4%	52,560	1	1	0.69	0.11	0.16	C:\Dev\E+\2.2\OutputProcessor.f90
50	SYSTEMREPORTS_mp_INITENERGYREPORTS	5,836,561	0.3%	8,864,963	0.4%	54,409	1	7	0.66	0.11	0.16	C:\Dev\E+\2.2\SystemReports.f90

Source: Lawrence Berkeley National Laboratory

Table 39. Code Profiling Results Sorted by Subroutine Total Time for the Hospital Run

Rank	Function	Self Time	% Self Time	Total Time	% Total Time	Calls	Callers	Callees	% in function	Average Self time per call	Average Total time per call	Source File
1	energyplus.exe - Total	2,069,362,554	100.0%	2,095,540,245	100.0%	19,723,399,580						
2	ENERGYPLUS	14	0.0%	2,095,540,062	100.0%	1	1	20	0	0.01	2095540.06	C:\Dev\E+\2.2\EnergyPlus.f90
3	SIMULATIONMANAGER_mp_MANAGESIMULATION	82,952	0.0%	2,092,307,421	99.8%	1	1	30	0	82.95	2092307.42	C:\Dev\E+\2.2\SimulationManager.f90
4	HEATBALANCEMANAGER_mp_MANAGEHEATBALANCE	133,598	0.0%	2,087,066,137	99.6%	54,576	2	7	0	0	38.24	C:\Dev\E+\2.2\HeatBalanceManager.f90
5	HEATBALANCESURFACEMANAGER_mp_MANAGESURFACEHEATBALANCE	110,013	0.0%	1,400,756,960	66.8%	54,576	1	9	0	0	25.67	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
6	HEATBALANCEAIRMANAGER_mp_MANAGEAIRHEATBALANCE	32,129	0.0%	883,074,139	42.1%	54,576	1	4	0	0	16.18	C:\Dev\E+\2.2\HeatBalanceAirManager.f90
7	HEATBALANCEAIRMANAGER_mp_CALCHEATBALANCEAIR	82,504	0.0%	882,736,376	42.1%	54,576	1	1	0	0	16.17	C:\Dev\E+\2.2\HeatBalanceAirManager.f90
8	HVACMANAGER_mp_MANAGEHVAC	531,584	0.0%	882,653,872	42.1%	54,576	1	44	0	0.01	16.17	C:\Dev\E+\2.2\HVACManager.f90
9	UPDATEDATAANDREPORT	671,191,997	32.4%	801,752,891	38.3%	106,969	2	14	0.84	6.27	7.5	C:\Dev\E+\2.2\OutputProcessor.f90
10	HEATBALANCEMANAGER_mp_REPORTHEATBALANCE	129,480	0.0%	679,334,586	32.4%	54,576	1	5	0	0	12.45	C:\Dev\E+\2.2\HeatBalanceManager.f90
11	HVACMANAGER_mp_SIMHVAC	99,571	0.0%	338,918,570	16.2%	57,325	1	17	0	0	5.91	C:\Dev\E+\2.2\HVACManager.f90
12	HVACMANAGER_mp_SIMSELECTEDEQUIPMENT	277,037	0.0%	337,258,621	16.1%	168,619	1	9	0	0	2	C:\Dev\E+\2.2\HVACManager.f90
13	OUTPUTREPORTTABULAR_mp_UPDATETABULARREPORTS	106,014	0.0%	330,685,459	15.8%	106,969	2	9	0	0	3.09	C:\Dev\E+\2.2\OutputReportTabular.f90
14	CALCHEATBALANCEINSIDESURF	41,574,437	2.0%	323,580,785	15.4%	54,576	1	10	0.13	0.76	5.93	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
15	HEATBALANCEINTRADEXCHANGE_mp_CALCINTERIORRADEXCHANGE	161,012,767	7.8%	281,309,058	13.4%	409,791	3	3	0.57	0.39	0.69	C:\Dev\E+\2.2\HeatBalanceIntRadExchange.f90
16	OUTPUTREPORTTABULAR_mp_GETINPUTTABULARMONTHLY	26,965	0.0%	262,345,710	12.5%	1	1	19	0	26.97	262345.71	C:\Dev\E+\2.2\OutputReportTabular.f90
17	ZONEEQUIPMENTMANAGER_mp_MANAGEZONEEQUIPMENT	84,772	0.0%	175,176,388	8.4%	263,133	3	6	0	0	0.67	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
18	ZONEEQUIPMENTMANAGER_mp_SIMZONEEQUIPMENT	3,249,785	0.2%	174,302,825	8.3%	261,663	1	9	0.02	0.01	0.67	C:\Dev\E+\2.2\Zoneequipmentmanager.f90
19	for_f90_index	75,876,100	3.7%	135,614,971	6.5%	215,611,558	40	3	0.56	0	0	
20	GETVARIABLEKEYCOUNTANDTYPE	14,981,353	0.7%	135,366,388	6.5%	3,235	2	11	0.11	4.63	41.84	C:\Dev\E+\2.2\OutputProcessor.f90
21	ZONEAIRLOOPEQUIPMENTMANAGER_mp_MANAGEZONEAIRLOOPEQUIPMENT	1,571,396	0.1%	129,468,624	6.2%	14,129,802	1	5	0.01	0	0.01	C:\Dev\E+\2.2\Zoneairloopequipmentmanager.f90
22	GETVARIABLEKEYS	13,207,084	0.6%	126,816,726	6.1%	3,235	2	9	0.1	4.08	39.2	C:\Dev\E+\2.2\OutputProcessor.f90
23	ZONEAIRLOOPEQUIPMENTMANAGER_mp_SIMZONEAIRLOOPEQUIPMENT	3,187,674	0.2%	126,314,505	6.0%	14,129,802	1	2	0.03	0	0.01	C:\Dev\E+\2.2\Zoneairloopequipmentmanager.f90
24	__powr8i4	123,999,843	6.0%	123,999,843	5.9%	3,813,096,152	14	0	1	0	0	
25	SINGLEDUCT_mp_SIMULATESINGLEDUCT	2,044,660	0.1%	120,415,391	5.7%	14,129,802	1	6	0.02	0	0.01	C:\Dev\E+\2.2\HVACSingleDuctSystem.f90
26	SINGLEDUCT_mp_SIMVAV	4,357,657	0.2%	114,320,219	5.5%	14,129,802	1	4	0.04	0	0.01	C:\Dev\E+\2.2\HVACSingleDuctSystem.f90
27	HEATBALANCESURFACEMANAGER_mp_INITSURFACEHEATBALANCE	17,457,920	0.8%	113,233,930	5.4%	54,576	1	19	0.15	0.32	2.07	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
28	CONTROLCOMPOUTPUT	11,960,706	0.6%	98,556,358	4.7%	4,210,684	1	3	0.12	0	0.02	C:\Dev\E+\2.2\GeneralRoutines.f90
29	OUTPUTPROCESSOR_mp_SETREPORTNOW	95,538,395	4.6%	95,538,395	4.6%	3,662,418,398	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
30	WATERCOILS_mp_SIMULATEWATERCOILCOMPONENTS	9,374,593	0.5%	92,160,999	4.4%	78,846,101	3	8	0.1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
31	PLANTMANAGER_mp_MANAGEPLANTLOOPS	103,734	0.0%	81,868,110	3.9%	168,619	1	6	0	0	0.49	C:\Dev\E+\2.2\PlantManager.f90
32	for_cpstr	53,165,709	2.6%	80,203,003	3.8%	1,148,276,171	164	1	0.66	0	0	
33	OUTPUTREPORTTABULAR_mp_GATHERMONTHLYRESULTSFORTIMESTEP	46,191,505	2.2%	67,864,827	3.2%	106,969	1	2	0.68	0.43	0.63	C:\Dev\E+\2.2\OutputReportTabular.f90
34	for_trim	52,428,691	2.5%	62,062,624	3.0%	394,765,509	106	1	0.84	0	0	
35	DEMANDSIDESOLVERS_mp_SIMPLANTDEMANDSIDES	6,787,688	0.3%	56,846,239	2.7%	281,491	1	7	0.12	0.02	0.2	C:\Dev\E+\2.2\PlantDemandSideSolvers.f90
36	SIMAIRSERVINGZONES_mp_MANAGEAIRLOOPS	49,037	0.0%	49,812,741	2.4%	313,123	2	4	0	0	0.16	C:\Dev\E+\2.2\SimAirServingZones.f90
37	SIMAIRSERVINGZONES_mp_SIMAIRLOOPS	270,502	0.0%	49,250,058	2.4%	313,122	1	6	0.01	0	0.16	C:\Dev\E+\2.2\SimAirServingZones.f90
38	SIMAIRSERVINGZONES_mp_SIMAIRLOOP	104,457	0.0%	47,235,039	2.3%	682,098	1	2	0	0	0.07	C:\Dev\E+\2.2\SimAirServingZones.f90
39	PSYCHROMETRICS_mp_PSYPSATFNTEMP	26,490,142	1.3%	43,950,490	2.1%	269,368,127	8	2	0.6	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
40	SIMAIRSERVINGZONES_mp_SOLVEAIRLOOPCONTROLLERS	608,935	0.0%	42,518,086	2.0%	583,515	1	2	0.01	0	0.07	C:\Dev\E+\2.2\SimAirServingZones.f90
41	CALCHEATBALANCEOUTSIDESURF	2,217,782	0.1%	41,427,287	2.0%	54,576	1	3	0.05	0.04	0.76	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
42	PSYCHROMETRICS_mp_PSYCPAIRFNWTDB	25,987,958	1.3%	40,707,632	1.9%	373,173,862	22	1	0.64	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
43	SIMAIRSERVINGZONES_mp_SIMAIRLOOPCOMPONENTS	1,538,154	0.1%	39,509,553	1.9%	2,897,801	2	3	0.04	0	0.01	C:\Dev\E+\2.2\SimAirServingZones.f90
44	WATERCOILS_mp_CALCSIMPLEHEATINGCOIL	20,732,673	1.0%	37,687,448	1.8%	75,949,184	2	6	0.55	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
45	SIMAIRSERVINGZONES_mp_SIMAIRLOOPCOMPONENT	734,936	0.0%	36,900,457	1.8%	11,591,204	1	3	0.02	0	0	C:\Dev\E+\2.2\SimAirServingZones.f90
46	SYSTEMREPORTS_mp_REPORTSYSTEMENERGYUSE	4,797,713	0.2%	34,361,950	1.6%	54,409	1	3	0.14	0.09	0.63	C:\Dev\E+\2.2\SystemReports.f90
47	for__free_vm	6,205,933	0.3%	33,939,337	1.6%	198,200,826	14	1	0.18	0	0	
48	PSYCHROMETRICS_mp_PSYRHOVFNTDBRH	7,373,719	0.4%	31,616,060	1.5%	149,417,583	1	1	0.23	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
49	HEATBALANCESURFACEMANAGER_mp_UPDATETHERMALHISTORIES	31,318,782	1.5%	31,318,782	1.5%	54,576	1	2	1	0.57	0.57	C:\Dev\E+\2.2\HeatBalanceSurfaceManager.f90
50	SYSTEMREPORTS_mp_CALCSYSTEMENERGYUSE	9,384,611	0.5%	28,134,190	1.3%	15,778,610	1	1	0.33	0	0	C:\Dev\E+\2.2\SystemReports.f90

Source: Lawrence Berkeley National Laboratory

Table 40. Code Profiling Results Sorted by Number of Calls for the Hospital Run

Rank	Function	Self Time	% Self Time	Total Time	% Total Time	Calls	Callers	Callees	% in function	Average Self time per call	Average Total time per call	Source File
1	energyplus.exe - Total	2,069,362,554	100.0%	2,095,540,245	100.0%	19,723,399,580						
2	__powr8i4	123,999,843	6.0%	123,999,843	5.9%	3,813,096,152	14	0	1	0	0	
3	OUTPUTPROCESSOR_mp_SETREPORTNOW	95,538,395	4.6%	95,538,395	4.6%	3,662,418,398	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
4	OUTPUTPROCESSOR_mp_SETMINMAX	25,649,009	1.2%	25,649,009	1.2%	1,436,077,427	2	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
5	_intel_fast_memcmp	27,037,294	1.3%	27,037,294	1.3%	1,148,276,174	2	0	1	0	0	
6	for_cpstr	53,165,709	2.6%	80,203,003	3.8%	1,148,276,171	164	1	0.66	0	0	
7	PSYCHROMETRICS_mp_PSYHFNTDBW	18,341,570	0.9%	18,341,570	0.9%	898,744,659	20	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
8	_intel_fast_memcpy	12,577,571	0.6%	12,577,571	0.6%	594,118,754	16	0	1	0	0	
9	for_trim	52,428,691	2.5%	62,062,624	3.0%	394,765,509	106	1	0.84	0	0	
10	exp	11,532,400	0.6%	11,532,400	0.6%	391,906,956	11	0	1	0	0	
11	PSYCHROMETRICS_mp_PSYCPAIRFNWTDB	25,987,958	1.3%	40,707,632	1.9%	373,173,862	22	1	0.64	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
12	memcpy	22,164,662	1.1%	22,164,750	1.1%	330,176,134	158	1	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\memcpy.asm
13	memmove	4,476,344	0.2%	4,490,165	0.2%	288,266,814	77	1	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\Intel\MEMCPY.ASM
14	log	8,953,137	0.4%	8,953,137	0.4%	270,065,502	7	0	1	0	0	
15	PSYCHROMETRICS_mp_PSYPSATFNTEMP	26,490,142	1.3%	43,950,490	2.1%	269,368,127	8	2	0.6	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
16	chkstk	3,633,782	0.2%	3,633,782	0.2%	218,947,616	167	0	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\chkstk.asm
17	for_f90_index	75,876,100	3.7%	135,614,971	6.5%	215,611,558	40	3	0.56	0	0	
18	GETINTERNALVARIABLEVALUE	22,375,708	1.1%	22,457,733	1.1%	213,687,474	2	1	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
19	_SEH_prolog4	4,846,945	0.2%	4,846,945	0.2%	199,104,026	19	0	1	0	0	
20	_SEH_epilog4	1,237,575	0.1%	1,237,575	0.1%	199,104,024	17	0	1	0	0	
21	free	11,838,525	0.6%	28,021,650	1.3%	199,090,964	6	3	0.42	0	0	f:\sp\vctools\crt_bld\self_x86\crt\src\free.c
22	malloc	6,512,645	0.3%	20,771,245	1.0%	199,069,623	8	1	0.31	0	0	f:\sp\vctools\crt_bld\self_x86\crt\src\malloc.c
23	for__free_vm	6,205,933	0.3%	33,939,337	1.6%	198,200,826	14	1	0.18	0	0	
24	for__get_vm	4,511,000	0.2%	24,868,346	1.2%	198,121,978	15	1	0.18	0	0	
25	for_concat	12,098,619	0.6%	18,085,631	0.9%	196,950,868	75	3	0.67	0	0	
26	PSYCHROMETRICS_mp_PSYRHOAIRFNPBTDBW	6,171,207	0.3%	6,171,207	0.3%	191,331,111	14	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
27	SCHEDULEMANAGER_mp_GETCURRENTSCHEDULEVALUE	9,399,124	0.5%	9,399,124	0.4%	155,432,517	24	0	1	0	0	C:\Dev\E+\2.2\ScheduleManager.f90
28	ENCODEMONDAYHRMIN	2,171,143	0.1%	2,171,143	0.1%	153,616,394	2	0	1	0	0	C:\Dev\E+\2.2\UtilityRoutines.f90
29	PSYCHROMETRICS_mp_PSYRHOVFNTDBRH	7,373,719	0.4%	31,616,060	1.5%	149,417,583	1	1	0.23	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
30	PSYCHROMETRICS_mp_PSYRHOVFNTDBWPB	4,351,184	0.2%	4,351,184	0.2%	149,417,583	1	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
31	pow	6,682,865	0.3%	6,682,865	0.3%	118,281,942	13	0	1	0	0	
32	GENERAL_mp_ITERATE	4,029,287	0.2%	4,029,287	0.2%	98,421,320	3	0	1	0	0	C:\Dev\E+\2.2\General.f90
33	PSYCHROMETRICS_mp_CPHW	999,841	0.0%	999,841	0.0%	86,379,473	13	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
34	_intel_fast_memset	2,477,569	0.1%	2,477,570	0.1%	82,209,692	18	1	1	0	0	
35	for_cpystr	3,231,482	0.2%	6,650,567	0.3%	80,448,793	172	2	0.49	0	0	
36	WATERCOILS_mp_SIMULATEWATERCOILCOMPONENTS	9,374,593	0.5%	92,160,999	4.4%	78,846,101	3	8	0.1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
37	WATERCOILS_mp_UPDATEWATERCOIL	8,224,170	0.4%	8,224,170	0.4%	78,846,101	1	0	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
38	WATERCOILS_mp_INITWATERCOIL	5,290,783	0.3%	5,304,273	0.3%	78,846,101	1	12	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
39	WATERCOILS_mp_REPORTWATERCOIL	2,748,679	0.1%	2,748,679	0.1%	78,846,101	1	0	1	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
40	WATERCOILS_mp_CALCSIMPLEHEATINGCOIL	20,732,673	1.0%	37,687,448	1.8%	75,949,184	2	6	0.55	0	0	C:\Dev\E+\2.2\HVACWaterCoilComponent.f90
41	PIPES_mp_SIMPIPES	9,550,644	0.5%	26,306,881	1.3%	66,457,180	3	2	0.36	0	0	C:\Dev\E+\2.2\PlantPipes.f90
42	PSYCHROMETRICS_mp_RHOH2O	1,283,579	0.1%	2,175,785	0.1%	32,152,997	27	1	0.59	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
43	PSYCHROMETRICS_mp_CPCW	378,238	0.0%	378,238	0.0%	31,317,259	17	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
44	DATAENVIRONMENT_mp_OUTDRYBULBTEMPAT	3,179,688	0.2%	3,179,688	0.2%	30,125,952	1	0	1	0	0	C:\Dev\E+\2.2\DataEnvironment.f90
45	DATAENVIRONMENT_mp_OUTWETBULBTEMPAT	629,484	0.0%	629,484	0.0%	30,125,952	1	0	1	0	0	C:\Dev\E+\2.2\DataEnvironment.f90
46	OUTPUTPROCESSOR_mp_UPDATEMETERVALUES	1,520,907	0.1%	1,520,907	0.1%	29,433,600	1	0	1	0	0	C:\Dev\E+\2.2\OutputProcessor.f90
47	CONVECTIONCOEFFICIENTS_mp_CALCASHRAEDETAILEDINTCONVCOEFF	1,936,578	0.1%	3,518,666	0.2%	27,124,272	1	1	0.55	0	0	C:\Dev\E+\2.2\HeatBalanceConvectionCoeffs.f90
48	PSYCHROMETRICS_mp_PSYHGAIRFNWTDB	308,254	0.0%	308,254	0.0%	22,519,057	3	0	1	0	0	C:\Dev\E+\2.2\PsychRoutines.f90
49	allmul	221,145	0.0%	221,145	0.0%	21,630,070	6	0	1	0	0	F:\SP\vctools\crt_bld\SELF_X86\crt\src\intel\llmul.asm
50	for_index	1,602,740	0.1%	1,602,740	0.1%	18,898,312	1	0	1	0	0	

5.4. Code Profiling Results Analysis

5.4.1. Call Tree and Critical Path

The function names in Figure 11 to Figure 13 are prefixed by the names of code modules where the functions reside. Unfortunately these names are long and get truncated. For the critical path shown in Figure 13, the subroutine call sequences are:

EnergyPlus → ManageSimulation → ManageHeatBalance → ManageSurfaceHeatBalance → ManageAirHeatBalance → CalcHeatBalanceAir → ManageHVAC → SimHVAC → SimSelectedEquipment → ManagePlantLoops → SimPlantDemandSides → SimulatePipes → SimPipes → FindIteminList → String Comparisons (native IVF FORTRAN run time subroutines: for_cpstr and _intel_fast_memcmp)

Where A → B denotes subroutine A calls subroutine B.

For details of the EnergyPlus call tree, please refer to the EnergyPlus Guide for Module Developers. Major sections of the call tree are attached in Appendix A for reference.

It can be seen that even for the relatively simple large office model, EnergyPlus uses a very complex call tree (Figure 11 and Figure 12) with a critical path of 12 levels of calls from EnergyPlus main entry to the subroutine SimPipes (Figure 13). Each level of calls further executes a few sequential subroutine calls, for example, the ManageHVAC subroutine calls 44 other subroutines as illustrated in Figure 12. The structure of EnergyPlus code is designed for modularity and ease of maintenance. On the other hand, deeper calls involve much more data packaging, exchanging, and sharing between modules and subroutines, which no doubt consumes more execution time. From the run time perspective, it is not sure whether this is the most efficient way.

5.4.2. The Large Office Run

From Table 26 and Figure 14, which shows the top 50 self time function calls, it can be seen that:

- The top 50 functions consume about 85.6% of total EnergyPlus run time, while the remaining more than 1000 functions (not showing in Table 26) consume about 14.4% of total run time.
- Among the top 50 functions, the subroutine UPDATEDATAANDREPORT consumes 23.7% of total run time, followed by 7.2% for CALCINTERIORRADEXCHANGE and 6.7% for SETREPORTNOW. All three subroutines together consume 37.6% of run time. These three subroutines are the only ones that consume more than 5% of the total run time, excluding the native IVF run time subroutines of for_cpstr and __powr8i4.
- String operations, including string searching, concatenation, trim, copying, and comparison, consume 12.9% of run time. They are listed as functions of for_cpstr, _intel_fast_memcmp, for_f90_index, for_trim, memcpy, for_concat, _intel_fast_memcpy, for_cpystr, and for_f90_scan.

- Mathematics operations consume 6.8% of run time by functions of __powr8i4, log, exp, and pow. The __powr8i4 function is the 4th power operation mostly (96.2%) used in surface long wave radiant heat exchange calculations. The log and exp functions are mostly (96% and 81.3% respectively) used in the psychrometric function PSYPSATFNTEMP which calculates the air saturation pressure based on the air dry bulb temperature. The pow function is mostly used in three subroutines: CalcASHRAEDetailedIntConvCoeff, CalcSimpleHeatingCoil, and CalcThermalComfortFanger.

- Output processing and reporting consumes significant amount of run time. The top four functions together consume 35.3% of run time: 23.7% for UPDATEDATAANDREPORT, 6.7% for SETREPORTNOW, 2.6% for GATHERMONTHLYRESULTSFORTIMESTEP, and 2.3% for SETMINMAX.

- Six psychrometric functions, PSYPSATFNTEMP, PSYCPAIRFNWTDB, PSYHFNTDBW, PSYRHOVFNTDBRH, PSYTSATFNPB, and PSYRHOAIRFNPBTDBW, show up in the top 50 list consuming a total of 4.7% of run time. Summary of EnergyPlus psychrometric functions is presented in Appendix B.

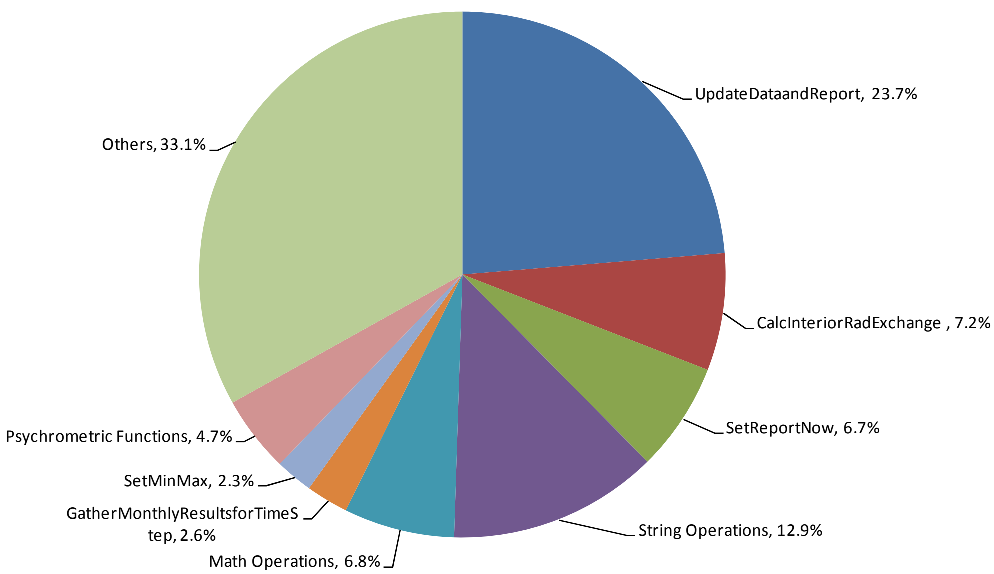


Figure 14. Top Functions by Self Time – The Large Office Run

Source: Lawrence Berkeley National Laboratory

Table 27 shows the top 50 functions sorted by total time. Obviously the subroutines shown up in the critical path consume the greatest total time. It is worth pointing out that:

- The UPDATEDATAANDREPORT subroutine consumes a total of 33.5% of run time which includes 6.6% of run time from its downstream calling subroutine SETREPORTNOW. The UPDATEDATAANDREPORT upstream caller subroutines are ManageHVAC (30.9%) and ReportHeatBalance (69.1%).

- Another report subroutine UPDATETABULARREPORTS consumes about 9% of run time, which is contributed by 63.2% and 36.0% from its downstream calling subroutines GetInputTabularMonthly and GatherMonthlyResultsForTimeStep respectively. The upstream caller subroutines are ManageHVAC (77.1%) and ReportHeatBalance (22.9%).
- Two report subroutines UPDATEDATAANDREPORT and UPDATETABULARREPORTS together consume 42.5% of run time.

Table 28 shows the top 50 functions sorted by number of calls. Several facts can be observed:

- The SetReportNow function gets called 1,087,157,992 times by the UPDATEDATAANDREPORT subroutine; that is more than 1 billion! This also translates to more than 1000 calls per loads time step per zone , i.e. 1,087,157,992 / (8760*16*6) = 1292.76, where 8760 is the annual number of hours, 16 is the number of zones, and 6 is the number of loads time step per hour.
- The second EnergyPlus subroutine SETMINMAX gets called 463,230,963 times mostly (87%) by the UPDATEDATAANDREPORT subroutine. Another three input and output related subroutines also get called more than 30 million times: GETINTERNALVARIABLEVALUE (63,734,186) and ENCODEMONDAYHRMIN (48,438,282) both mostly (85.6% and 99.6%) get called by the GATHERMONTHLYRESULTSFORTIMESTEP subroutine, and GETCURRENTSCHEDULEVALUE (31,681,606).
- The IVF native string functions (_intel_fast_memcmp, for_cpstr, memcpy, for_trim, for_f90_index, etc.) and the mathematics functions (__powr8i4, log, exp, and pow) show up at the top of the top 50 list.
- Nine psychrometric functions show up in the top 50 list, including PSYHFNTDBW(187,063,090), PSYCPAIRFNWTDB (76,720,326), PSYPSATFNTEMP (61,248,462), PSYRHOAIRFNPBTDBW (46,019,998), PSYRHOVFNTDBRH (34,167,296), PSYRHOVFNTDBWPB (34,167,296), CPCW (14,853,076), CPHW (12,523,552), and RHOH2O (5,524,475).
- The initialization of the water coils subroutine INITWATERCOIL gets called 12,420,340 times by the SIMULATEWATERCOILCOMPENENTS subroutine.

5.4.3. The Large Office Run Without Any Reports

The profile results in Table 29 to Table 31 show similar patterns as in the run with reports. It is worth pointing out:

- By the function self time, the top two function names are the same, UPDATEDATAANDREPORT and CALCINTERIORRADEXCHANGE, although they consume relatively higher percentage of the total run time than in the run with reports.
- The subroutine SETREPORTNOW is moved down from top 3 to top 5 in terms of the function self time, but still consumes 4.4% of total run time.

- The subroutine GATHERMONTHLYRESULTSFORTIMESTEP is no longer called.
- The subroutine UPDATETABULARREPORTS is still called the same 114,361 times, but consumes negligible run time, moving from the top 16 with 9% of run time to top 449 with very small percentage of run time.
- In terms of the number of calls, the top 6 function names are the same. The psychrometric functions move to the top of the top 50 list compared with the IVF native string functions at the top of the list for the run with reports.

5.4.4. The Other Runs

The other three EnergyPlus code profiling runs, including the elementary school run (Table 32 to Table 34), the high school run (Table 35 to Table 37), and the hospital run (Table 38 to Table 40), show surprisingly consistent run time patterns as the large office run, no matter by results sorted by the function self time, the function total time, and the function number of calls.

5.5 Proposed Actions

Based on the code profiling results analysis, the major run time issue is that the input and output related subroutines, the string operation functions, and the psychrometric functions get called so many times and consume so much run time.

It is crucial to further investigate why and how those top 50 subroutines get called that many times and consume that much run time. The proposed actions are to:

1. Investigate why and how the input and output related subroutines, including UPDATEDATAANDREPORT, SETREPORTNOW, and SETMINMAX, get called so many times and consume so much time. Separate functionality of data updates for time step (history) calculations and for output reporting to reduce or avoid unnecessary calls. Explore the feasibility and potential of re-writing these subroutines for parallel computing in order to reduce EnergyPlus run time.
2. Identify reasons that reporting subroutines like UPDATETABULARREPORTS get called the same number of times even if no reports are requested.
3. Reduce psychrometric functions calling times and run time by simplifying the function algorithm and/or using data table lookup and interpolation. In normal building and HVAC operation conditions, many air properties have a limited range of variations.
4. Reduce string operations as much as possible. Avoid unnecessary string operations.
5. Replace string operations with logical or integer type operations, and cache string operation results for later use.
6. Improve string operations by using variable length strings to avoid the use of the trim function. Explore potential of using a string function library written in C or C++ language for better performance.

7. Cache intermediate results to avoid unnecessary time consuming re-calculations. Computer memory has become much more affordable now.

8. Explore potential of short-cutting and bypassing loops. Identify idle loops and avoid the call from the upstream calling subroutines. This is normally beyond the capability of compiler optimization.

9. Analyze why input subroutines like GETCURRENTSCHEDULEVALUE get called so many times? Any way to cache the schedule values once and be accessible for faster later use?

10. Investigate why the initialization subroutines get called so many times, for example the INITWATERCOIL subroutine? Is every call necessary? Any way to limit the number of calls?

11. Reduce the number of HVAC iterations by developing more intelligent algorithms to automatically adjust the HVAC time step based on system dynamics and history calculation results.

12. Research the consistency of many threshold values used to determine the convergence of iterative calculations. For complex software like EnergyPlus, one or a few calculations with high resolutions may not improve the overall resolution at all!

13. Review EnergyPlus code for possibilities of software architecture improvement and data structure reengineering, with the goal of improving computer execution time.

6.0 Computer Platform

It is certain that EnergyPlus run time depends on computer platform. A faster computer will run EnergyPlus simulations quicker. Both the computer hardware and software have impacts on EnergyPlus run time.

6.1. Computer Hardware

For small EnergyPlus models, which do not require large amount of computer memory, PCs with faster CPUs are more effective in reducing run time than PCs with more RAM. For large models, more and faster computer memory including RAM and internal cache will be more effective in reducing run time.

Paging memory to disk during EnergyPlus simulations can cause EnergyPlus to grind to a halt. In computer operating systems that have their main memory divided into pages, paging (sometimes called swapping) is a transfer of pages between main memory and an auxiliary store, such as hard disk drive (HDD). Paging memory is typically many orders of magnitude slower than RAM. Therefore it is desirable to reduce or eliminate swapping, where practical. Some operating systems offer settings to influence the kernel's decisions. The memory paging is probably occurred in the H4a run in Table 1, which takes more than 3 hours to run the large office model on the very old desktop computer with 192 MB of RAM.

If an energy model run will produce lots of hourly or time step reports, HDD access speed becomes more important in reducing run time.

Current available and affordable PCs with 2GHZ of 32-bit CPUs and 2GB of RAM are sufficient for most EnergyPlus simulation runs. For large and complex energy models, it is recommended to have powerful PCs with 3 or more GHZ of CPUs and 3 or more GB of RAM.

EnergyPlus, as of Version 2.2.0.023, is a single thread application running on a single CPU. PCs with multiple CPUs would not benefit more than PCs with one CPU assuming no other time consuming processes occur simultaneously with the EnergyPlus simulation run. But for a large volume of parametric runs on PCs with multiple CPUs, users can still harness the potential of launching multiple parallel EnergyPlus runs from separate folders with their own copies of the EnergyPlus engine files including the EnergyPlus.exe, the Energy+.idd, and the linked DLL files. Future improvements to EnergyPlus could allow EnergyPlus to run multiple simultaneous simulations from the same folder.

As an experiment, the large office model takes 89 seconds to run, and two sequential runs would take 178 seconds. But if two parallel runs are launched simultaneously, each run takes 109 seconds. This means a reduction of run time by as much as 39% ((178-109)/178). Therefore, for a large volume of parametric runs, it is recommended to launch multiple parallel simulations on PCs with multiple CPUs. The optimal number of parallel runs has to be determined by experiments, but the general rule is not more than the number of CPUs on the PC. If running on a distributive computing network, many more runs may be launched parallel.

Although not covered in this analysis, it is worth looking into the impact of using PCs with 64-bit CPUs for EnergyPlus simulations as most numeric calculations within EnergyPlus (as of version 2.2 and later) use 64-bit real variables.

The current trend of personal computer progress is to embed more CPUs rather than to increase the clock speed of a single CPU for a PC. This poses a challenge to EnergyPlus as one EnergyPlus simulation only runs on a single CPU. To make EnergyPlus efficient in parallel computing, EnergyPlus code needs to be parallelized by programmers rather than relying on compiler parallelism settings.

6.2. Computer Software

Computer software plays a key role in enabling EnergyPlus simulations on PCs with multiple CPUs. Either this is done by reengineering EnergyPlus code or using future parallel computer language compilers, is an interesting and challenging question hard to answer at the moment.

EnergyPlus is used for building performance simulations which involve a sequential run period and the integrated coupling of building envelope, lighting/daylighting, HVAC, service water heating, and on-site energy generations. The time step correlated calculations makes it difficult to completely rewrite the EnergyPlus code for parallel computing. As can be seen in the short period of runs, the a series runs in Table 13 to Source*: Lawrence Berkeley National Laboratory*

Table 16, the one-time run time overhead makes it inefficient to split a longer run period into multiple shorter run periods. In other words, trying to split an annual run into say 12 monthly runs would not speed up EnergyPlus simulations, besides the challenge of combining results from the monthly runs.

6.3. FORTRAN Compiler Settings

Modern FORTRAN compilers have options to turn on the optimization and parallelism. Previous studies on profile guided optimization and parallel computing using only compiler settings for EnergyPlus by Michael Wetter at LBNL did not get noticeable improvements in run time. The profile guided optimization resulted in less than 2% improvement in run time; turning on the parallel compiling option resulted in longer run time! It is recommended to try using programming instructions, as opposed to compiler settings, to exploit parallel computing for EnergyPlus.

As shown in Table 41, different settings of optimization levels are used to compile EnergyPlus with Intel Visual FORTRAN version 10.1.024. Then the compiled EnergyPlus.exe is used to run the four selected DOE commercial benchmark energy models on the current desktop PC. The run time is summarized in Figure 15.

Table 41. Compiler Settings Runs

Run ID	Description	Intel Visual FORTRAN Compiler Settings	EnergyPlus.exe File Size (KB)
O2	Official release of EnergyPlus 2.2.0.023. Enables optimizations for speed, the generally recommended optimization level.	Fortran: /nologo /assume:buffered_io /recursive /fpscomp:nolibs /fpe:0 /traceback /check:uninit /4Yportlib /c Link: /INCREMENTAL:NO /NOLOGO /SUBSYSTEM:CONSOLE	11,392
O1	Enables optimizations for speed and disables some optimizations that increase code size and affect speed.	O2 settings + /O1	11,000
O3	Enables O2 optimizations plus more aggressive optimizations, such as prefetching, scalar replacement, and loop and memory access transformations. Recommended for applications that have loops that heavily use floating-point calculations and process large data sets.	O2 settings + /O3	11,436
NoOpt	Optimization is disabled.	O2 settings + /Od	20,876
P	Parallelism is turned on.	O2 settings + /Qparallel	11,672

Source: Lawrence Berkeley National Laboratory

Table 42. Compiler Settings vs. EnergyPlus Run Time

Model	Compiler Settings	EnergyPlus Run Time (seconds)
Large Office	Official Release	153
	O1 Optimization	169
	O3 Optimization	152
	No Optimization	279
	Parallelism	155
Elementary School	Official Release	653
	O1 Optimization	694
	O3 Optimization	641
	No Optimization	1119
	Parallelism	646
High School	Official Release	1884
	O1 Optimization	2043
	O3 Optimization	1813
	No Optimization	3029
	Parallelism	1838
Hospital	Official Release	911
	O1 Optimization	980
	O3 Optimization	896
	No Optimization	1351
	Parallelism	908

Source: Lawrence Berkeley National Laboratory

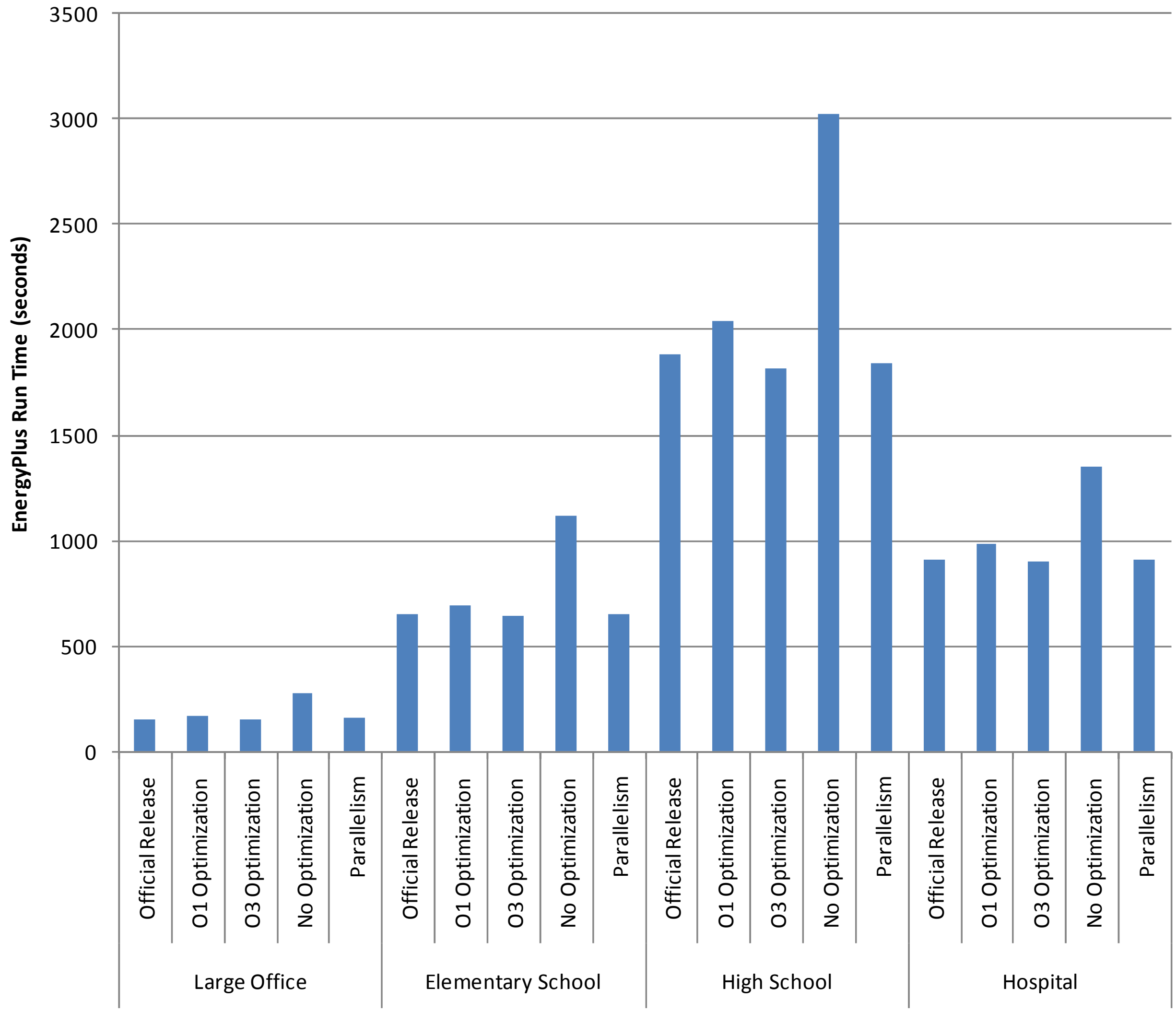


Figure 15. FORTRAN Compiler Settings vs. EnergyPlus Run Time

Source: Lawrence Berkeley National Laboratory

From Figure 15, the following can be observed:

- The official release of EnergyPlus implements compiler optimizations for fast speed.
- Turning on the parallelism option only marginally impact EnergyPlus run time. Compared with the official EnergyPlus release, it uses about 1% more time for the large office model and about 2.4% less tome for the high school model. It should be noted that these runs are performed on the current desktop PC which has Core 2 Duo two CPUs. Further experiments should be done on PCs with more CPUs to see whether the parallelism option makes more differences in EnergyPlus run time.
- Without optimization, the EnergyPlus.exe file size almost doubles. The run time increases significantly. Compared with the official release, the run time increases by ranging from 48% for the hospital model to 82% for the large office model.

- The O1 option reduces the EnergyPlus.exe file size by about 3%, but compared with the official release, the run time increases by ranging from 6% for the elementary school model to 10% for the large office model.
- The O3 option provides a marginally better run time than the official release, with run time reduction ranging from about 0% for the large office model to 4% for the high school model.

7.0 Recommendations to Improve EnergyPlus Run Time

Compared with creating energy models either by hand coding the IDF file or by using GUI tools or a combination of both, EnergyPlus run time is normally a small fraction of the total time needed to complete an energy modeling job. Therefore it is very important to build a clean and concise EnergyPlus model up front. Techniques of simplifying large and complex building and systems should be used during the creation of energy models, especially during the early design process when detailed zoning and other information is not available. Producing lots of hourly or sub-hourly reports from EnergyPlus runs can take significant amount of time. Modelers should only request time step reports when necessary. On the other hand, producing summary reports and typical monthly reports take relatively small amount of run time. These reports are valuable references for troubleshooting and model fine tuning.

With powerful personal computers get more and more affordable, EnergyPlus modelers should choose to use current available PCs with 3 or more GHZ and 3 or more GB of RAM. For a large volume of EnergyPlus parametric runs, modelers can launch multiple runs in parallel. Minor changes to EnergyPlus code should be made to make this more convenient to use.

For modelers, most time is spent on troubleshooting and fine tuning energy models. During the early modeling process, it is recommended to keep the model as simple as possible and make quick runs to identify problems. Then modify the IDF file to fix problems and re-run the model. This is an iterative process until satisfactory solutions are found. The simulation process can be split into three phases: the diagnostic runs, the preliminary runs, and the final runs. The three phases would use different simulation settings. The diagnostic runs would use a set of simulation settings to speed up the runs with simulation accuracy being set as the second priority. The diagnostic runs will help catch most model problems by running simulations on summer and winter design days. The preliminary runs use a tighter set of simulation settings in order to catch problems missed in the diagnostic runs, and provide better results for quality assurance purpose. The final runs use the EnergyPlus recommended set of simulation settings in order to achieve better accuracy for simulation results ready for review and reporting. Table 43 gives samples of simulation settings for the three phases of runs.

Table 43. Recommended Simulation Settings for EnergyPlus Runs

Parameter	Value		
	Diagnostic Runs	Preliminary Runs	Final Runs
Run Period	Design Days	Annual	Annual
Loads Time Step	1 (60 minutes)	4 (15 minutes)	6 (10 minutes)
Maximum Number of HVAC Iterations	5	20	50
Minimum HVAC Time Step	20 minutes	10 minutes	5 minutes
Solar Distribution Algorithm	MinimalShadowing	MinimalShadowing	FullInteriorAndExterior
Heat Balance Solution Algorithm	CTF	CTF	CTF or CondFD or EMPD
Warmup Loads Convergence Limit	0.04 (4%)	0.04 (4%)	0.02 (2%)
Warmup Temperature Convergence Limit	0.2°C	0.2°C	0.1°C
Number of Warmup Days	7	14	21
Inside Convection Algorithm	Simple	Simple	Detailed

Outside Convection Algorithm	Simple	Simple	Detailed
Reports	HVAC sizing reports, Envelope summary reports	All Predefined Summary Reports	All Predefined Summary Reports, and other reports as needed

Source: Lawrence Berkeley National Laboratory

Inside EnergyPlus, code review and enhancements to the critical subroutines, identified in the code profiling section, should be done. This task is undergoing, and a separate report will document the findings and results.

Another potential improvement in EnergyPlus run time is to make EnergyPlus capable of parallel computing on current and future PCs, which do not increase CPU clock speed much over the past, but carry more and more CPUs. To make this happen, EnergyPlus code needs to be parallelized by programmers rather than relying on compiler parallelism settings.

EnergyPlus development was started in late 1990s.The FORTRAN 90/95 language, used by EnergyPlus code, although has some object based features, is not an object oriented computer programming language that fully supports encapsulation, modularity, polymorphism, and inheritance. FORTRAN is especially inefficient in handling string operations which are used intensively in EnergyPlus code. DOE-2 was rewritten twice from scratch in order to have better software architecture, data structure, and better run time performance. Therefore, in the long term, it is worth considering rewriting EnergyPlus in an object oriented language like C++, so that EnergyPlus can better integrate with future computer hardware, software, operating systems, and make it easier to add new features to EnergyPlus and allow EnergyPlus to more effectively interoperate with other simulation programs.

8.0 References

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Glossary

ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
BLAST	Building Loads Analysis and System Thermodynamics
CBECS	Commercial Buildings Energy Consumption Survey
CondFD	Conduction Finite Difference
CPU	Central Processing Unit
CTF	Conduction Transfer Function
DOE	United States Department of Energy
EMPD	Empirical Moisture Penetration Depth
Energy Commission	California Energy Commission
GHZ	Gigahertz
HVAC	Heating, Ventilation, and Air Conditioning
IDD	EnergyPlus Input Data Dictionary
KSU	Kansas State University
LBNL	Lawrence Berkeley National Laboratory
MoWiTT	Mobile Window Thermal Test
NREL	National Renewable Energy Laboratory
OS	Operating System
PCM	Phase Change Material
PIER	Public Interest Energy Research
PNNL	Pacific Northwest National Laboratory
PSZ	Packaged Single Zone
PTAC	Packaged Terminal Air Conditioners
PVAV	Packaged Variable Air Volume
RAM	Random Access Memory
RD&D	Research, Development, and Demonstration

SPZ	Seconds Per Zone
TMY2	Typical Meteorological Year, Version 2
VAV	Variable Air Volume

Appendix A:

EnergyPlus Call Tree

Appendix A: EnergyPlus Call Tree

Top Level Calling Tree

EnergyPlus

- ProcessInput (in InputProcessor)
- ManageSimulation (in SimulationManager)
  - ManageWeather (in WeatherManager)
  - ManageHeatBalance (in HeatBalanceManager)
    - ManageSurfaceHeatBalance (in HeatBalanceSurfaceManager)
    - ManageAirHeatBalance (in HeatBalanceAirManager)
      - CalcHeatBalanceAir (in HeatBalanceAirManager)
        - ManageHVAC (in HVACManager)

The HVAC part of EnergyPlus is divided into a number of simulation blocks. At this point, there are blocks for the air system, the zone equipment, the plant supply, the plant demand, the condenser supply, and the condenser demand. There will be simulation blocks for waste heat supply and usage as well as electricity and gas. Within each HVAC time step, the blocks are simulated repeatedly until the conditions on each side of each block interface match up. The following calling tree represents the high level HVAC simulation structure. It is schematic – not all routines are shown.

High Level HVAC Calling Tree

(schematic – not all routines are shown)
ManageHVAC (in HVACManager)

- ZoneAirUpdate('PREDICT', . . .) (in HVACManager)
  estimate the zone heating or cooling demand

- SimHVAC (in HVACManager)
  - ManageSetPoints (in SetPointManager)
  - SimSelectedEquipment (in HVACManager)
    - ManageAirLoops (in SimAirServingZones)
    - ManageZoneEquipment (in ZoneEquipmentManager)
    - ManagePlantSupplySides (in PlantLoopSupplySideManager)
    - ManagePlantDemandSides (in PlantdemandSideLoops)
    - ManageCondSupplySides (in CondLoopManager)
    - ManageCondenserDemandSides (in CondenserDemandSideLoops)

- ZoneAirUpdate('CORRECT', . . .) (in HVACManager)

From the amount of heating and cooling actually provided by the HVAC system, calculate the zone temperatures.

Each of the "Manage" routines has a different structure, since the simulation to be performed is different in each case. The authors will show schematic calling trees for several of the "Manage" routines.

Air System Calling Tree

(schematic – not all routines are shown)

ManageAirLoops (in SimAirServingZones)

- GetAirPathData (in SimAirServingZones)
- InitAirLoops (in SimAirServingZones)
- SimAirLoops (in SimAirServingZones)
  - SimAirLoopComponent (in SimAirServingZones)
  - UpdateBranchConnections (in SimAirServingZones)
    - ManageOutsideAirSystem (in MixedAir)
      - SimOutsideAirSys (in MixedAir)
        - SimOAController (in MixedAir)
        - SimOAComponent (in Mixed Air)
          - SimOAMixer (in MixedAir)
          - SimulateFanComponents(in FanSimulation; file HVACFanComponent)
          - SimulateWaterCoilComponents (in WaterCoilSimulation; file HVACWaterCoilComponent)
          - SimHeatRecovery (in HeatRecovery)
          - SimDesiccantDehumidifier (in DesiccantDehumidifiers)
    - SimulateFanComponents (in FanSimulation; file HVACFanComponent)
    - SimulateWaterCoilComponents (in WaterCoilSimulation; file HVACWaterCoilComponent)
    - SimulateHeatingCoilComponents (in HeatingCoils; file HVACHeatingCoils)
    - SimDXCoolingSystem (in HVACDXSystem)
    - SimFurnace (in Furnaces; file HVACFurnace)
    - SimHumidifier (in Humidifiers)
    - SimEvapCooler (in EvaporativeCoolers; file HVACEvapComponent)
    - SimDesiccantDehumidifier (in DesiccantDehumidifiers)
    - SimHeatRecovery (in HeatRecovery)
  - ManageControllers (in Controllers)
    - GetControllerInput (in Controllers)
    - InitController (in Controllers)
    - SimpleController (in Controllers)
    - LimitController (in Controllers)
    - UpdateController (in Controllers)
    - Report Controller (in Controllers)
  - ResolveSysFlow (in SimAirServingZones)
  - UpdateHVACInterface (in HVACInterfaceManager)
- ReportAirLoops (in SimAirServingZones)

Plant Supply Calling Tree

(schematic – not all routines are shown)
ManagePlantSupplySides (in PlantLoopSupplySideManager)

- GetLoopData (in PlantLoopSupplySideManager)
- SetLoopInitialConditions (in PlantLoopSupplySideManager)
- CalcLoopDemand (in PlantLoopSupplySideManager)
- ManagePlantLoopOperation (in PlantCondLoopOperation)
- DistributeLoad (in PlantLoopSupplySideManager)
- SimPlantEquip (in PlantLoopSupplySideManager)
  - SimPipes (in Pipes; file PlantPipes)
  - SimPumps (in Pumps; file PlantPumps)
  - SimEngineDrivenChiller (in ChillerEngineDriven ; file PlantChillers)
  - SimBLASTAbsorber (in ChillerAbsorption ; file PlantAbsorptionChillers)
  - SimElectricChiller (in ChillerElectric ; file PlantChillers)
  - SimGTChiller (in ChillerGasTurbine ; file PlantChillers)
  - SimConstCOPChiller (in ChillerConstCOP; file PlantChillers)
  - SimBLASTChiller (in ChillerBLAST ; file PlantChillers)
  - SimOutsideCooling (in OutsideCoolingSources ; file PlantOutsideCoolingSources)
  - SimGasAbsorber (in ChillerGasAbsorption ; file PlantGasAbsorptionChiller)
  - SimBoiler (in Boilers; file PlantBoilers)
  - SimWaterHeater (in WaterHeaters ; file PlantWaterHeater)
  - SimOutsideHeating (in OutsideHeatingSources; file PlantOutsideHeatingSources)
- UpdateSplitter (in PlantLoopSupplySideManager)
- SolveFlowNetwork (in PlantLoopSupplySideManager)
- CalcLoopDemand (in PlantLoopSupplySideManager)
- SimPlantEquip (in PlantLoopSupplySideManager)
- UpdateSplitter
- UpdateMixer (in PlantLoopSupplySideManager)
- SimPlantEquip (in PlantLoopSupplySideManager)
- CheckLoopExitNodes (in PlantLoopSupplySideManager)
- UpdateHVACInterface (in HVACInterfaceManager)
- UpdateReportVars (in PlantLoopSupplySideManager)

Zone Equipment Calling Tree

(schematic – not all routines are shown)
ManageZoneEquipment (in ZoneEquipmentManager)

- GetZoneEquipment (in ZoneEquipmentManager)
- InitZoneEquipment (in ZoneEquipmentManager)
- SimZoneEquioment (in ZoneEquipmentManager)
  - SimAirLoopSplitter (in Splitters; file HVACSplitterComponent)

- SimAirZonePlenum (in ZonePlenum; file ZonePlenumComponent)
- SetZoneEquipSimOrder (in ZoneEquipmentManager)
- InitSystemOutputRequired (in ZoneEquipmentManager)
- ManageZoneAirLoopEquipment (in ZoneAirLoopEquipmentManager)
  - GetZoneAirLoopEquipment (in ZoneAirLoopEquipmentManager)
  - SimZoneAirLoopEquipment (in ZoneAirLoopEquipmentManager)
    - SimulateDualDuct (in DualDuct; file HVACDualDuctSystem)
      - GetDualDuctInput (in DualDuct; file HVACDualDuctSystem)
      - InitDualDuct (in DualDuct; file HVACDualDuctSystem)
      - SimDualDuctConstVol (in DualDuct; file HVACDualDuctSystem)
      - SimDualDuctVarVol (in DualDuct; file HVACDualDuctSystem)
      - UpdateDualDuct (in DualDuct; file HVACDualDuctSystem)
      - ReportDualDuct (in DualDuct; file HVACDualDuctSystem)
    - SimulateSingleDuct (in SingleDuct; file HVACSingleDuctSystem)
      - GetSysInput (in SingleDuct; file HVACSingleDuctSystem)
      - InitSys (in SingleDuct; file HVACSingleDuctSystem)
      - SimConstVol (in SingleDuct; file HVACSingleDuctSystem)
      - SimVAV (in SingleDuct; file HVACSingleDuctSystem)
      - ReportSys (in SingleDuct; file HVACSingleDuctSystem)
    - SimPIU (in PoweredInductionUnits)
      - GetPIUs (in PoweredInductionUnits)
      - InitPIUs (in PoweredInductionUnits)
      - CalcSeriesPIU (in PoweredInductionUnits)
      - CalcParallelPIU (in PoweredInductionUnits)
      - ReportPIU (in PoweredInductionUnits)
- SimDirectAir (in DirectAirManager; file DirectAir)
- SimPurchasedAir (in PurchasedAirManager)
- SimWindowAC (in WindowAC)
- SimFanCoilUnit (in FanCoilUnits)
- SimUnitVentilator (in UnitVentilator)
- SimUnitHeater (in UnitHeater)
- SimBaseboard (in BaseboardRadiator)
- SimHighTempRadiantSystem (in HighTempRadiantSystem; file RadiantSystemHighTemp)
- SimLowTempRadiantSystem (in LowTempRadiantSystem; file RadiantSystemLowTemp)
- SimulateFanComponents (in Fans; file HVACFanComponent)
- SimHeatRecovery (in HeatRecovery)
- UpdateSystemOutputRequired (in ZoneEquipmentManager)
- SimAirLoopSplitter (in Splitters; file HVACSplitterComponent)
- SimAirZonePlenum (in ZonePlenum; file ZonePlenumComponent)
- CalcZoneMassBalance (in ZoneEquipmentManager)
- CalcZoneLeavingConditions (in ZoneEquipmentManager)

    - SimReturnAirPath (in ReturnAirPathManager; file ReturnAirPath)
        - SimAirMixer (in Mixers; HVACMixerComponent)
        - SimAirZonePlenum (in ZonePlenum; file ZonePlenumComponent)
- RecordZoneEquipment (in ZoneEquipmentManager)
- ReportZoneEquipment (in ZoneEquipmentManager)

Appendix B:

EnergyPlus Psychrometric Functions

Appendix B – EnergyPlus Psychrometric Functions

EnergyPlus has a full complement of psychrometric functions. All arguments and results are in SI units.

Variable Definition and Unit

- H = Enthalpy, J/kg
- W= Humidity Ratio, kg.H_2O/kg.dry.air
- Rh= Relative Humidity, fraction
- V= Specific Volume, m^3/kg
- Rhov= Vapor Density of Air, kg.H_2O/ m^3.d.a
- Hfg = Latent energy (heat of vaporization for moist air), J/kg
- Hg= Enthalpy of gaseous moisture, J/kg
- Pb= Barometric Pressure, Pa
- Twb=Temperature Wet Bulb, °C
- Twd= Temperature Dry Bulb, °C
- Tdp= Temperature Dew Point, °C
- Tsat and Psat= Saturation Temperature and Saturation Pressure, °C
- T = Temperature, °C

Function Definition

PsyRhoAirFnPbTdbW (Pb,Tdb,W,calledfrom)

Returns the density of air as a function of barometric pressure [Pb], dry bulb temperature [Tdb], and humidity ratio [W].

PsyCpAirFnWTdb (W,Tdb,calledfrom)

Returns the specific heat of air as a function of humidity ratio [W] and dry bulb temperature [Tdb].

PsyHfgAirFnWTdb (W,Tdb,calledfrom)

Returns the Latent energy of air [Hfg] as a function of humidity ratio [W] and dry bulb temperature [Tdb]. It calculates hg and then hf and the difference is Hfg.

PsyHgAirFnWTdb (W,Tdb,calledfrom)

Returns the specific enthalpy of the moisture as a gas in the air as a function of humidity ratio [W] and dry bulb temperature [Tdb].

PsyTdpFnTdbTwbPb (Tdb,Twb,Pb,calledfrom)

Returns the dew point temperature as a function of dry bulb temperature [Tdb], wet bulb temperature [Twb], and barometric pressure [Pb].

PsyTdpFnWPb (W,Pb,calledfrom)

Returns the dew point temperature as a function of humidity ratio [W] and barometric pressure [Pb].

PsyHFnTdbW (Tdb,W,calledfrom)

Returns the specific enthalpy of air as a function of dry bulb temperature [Tdb] and humidity ratio [W].

PsyHFnTdbRhPb (Tdb,Rh,Pb,calledfrom)

Returns the specific enthalpy of air as a function of dry bulb temperature [Tdb], relative humidity [Rh], and barometric pressure [Pb].

PsyTdbFnHW (H,W,calledfrom)

Returns the air temperature as a function of air specific enthalpy [H] and humidity ratio [W].

PsyRhovFnTdbRh (Tdb,Rh,calledfrom)

Returns the Vapor Density in air [RhoVapor] as a function of dry bulb temperature [Tdb], Relative Humidity [Rh].

PsyRhovFnTdbWP (Tdb,W,Pb,calledfrom)

Returns the Vapor Density in air [RhoVapor] as a function of dry bulb temperature [Tdb], humidity ratio [W] and barometric pressure [Pb].

PsyRhFnTdbRhov (Tdb,Rhov,calledfrom)

Returns the Relative Humidity [Rh] in air as a function of dry bulb temperature [Tdb] and Vapor Density in air [RhoVapor].

PsyRhFnTdbWPb (Tdb,W,Pb,calledfrom)

Returns the relative humifity as a function of of dry bulb temperature [Tdb], humidity ratio [W] and barometric pressure [Pb].

PsyTwbFnTdbWPb (Tdb,W,Pb,calledfrom)

Returns the air wet bulb temperatute as a function of dry bulb temperature [Tdb], humidity ratio [W] and barometric pressure [Pb].

PsyVFnTdbWPb (Tdb,W,Pb,calledfrom)

Returns the specific volume as a function of dry bulb temperature [Tdb], humidity ratio [W] and barometric pressure [Pb].

PsyWFnTdpPb (Tdp,Pb,calledfrom)

Returns the humidity ratio as a function of the dew point temperature [Tdp] and barometric pressure [Pb].

PsyWFnTdbH (Tdb,H,calledfrom)

Returns the humidity ratio as a function of dry bulb temperature [Tdb] and air specific enthalpy [H].

PsyWFnTdbTwbPb (Tdb,Twb,Pb,calledfrom)

Returns the humidity ratio as a function of dry bulb temperature [Tdb], wet bulb temperature [Twb], and barometric pressure [Pb].

PsyWFnTdbRhPb (Tdb,Rh,Pb,calledfrom)

Returns the humidity ratio as a function of dry bulb temperature [Tdb], relative humidity [RH], and barometric pressure [Pb].

PsyPsatFnTemp (T,calledfrom)

Returns the saturation pressure as a function of the air saturation temperature [T].

PsyTsatFnHPb (H,Pb,calledfrom)

Returns the air saturation temperature as a function of air specific enthalpy [H] and barometric pressure [Pb].

PsyTsatFnPb (P,calledfrom)

Returns the air saturation temperature as a function of saturation pressure [P].

CPCW (T,calledfrom)

Returns Specific heat capacity (J/kg-K) for chilled water as function of temperature [T].

CPHW (T,calledfrom)

Returns Specific heat capacity (J/kg-K) for hot water as function of temperature [T].

CVHW (T,calledfrom)

Returns Specific heat capacity (J/kg-K) for hot water at constant volume as function of temperature [T].

RhoH2O (T,calledfrom)

Returns density of water (kg/m^3) as function of Temperature [T].