

Procedure for modeling and analysis of energy consumption for data center space

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Abstract - Research on power management in Servers can ease the installation of the Data Center, cost reduction, and environmental protection. In order to evaluate the thermal performance and energy efficiency of buildings and building sub-sectors, several simulation tools have been proposed. In this work, the researcher exploits the potential of EnergyPlus software. EnergyPlus is a software platform that is used in relation to other tools in order to create a simulation environment. In order to develop a modeling procedure, the researcher studied the simulation tools and used them in order to create and simulate a data center space in an Educational building in Heraklion, Crete.

INTRODUCTION

Green technologies of information and communication (Green ICT) include the study and practice of environmentally sustainable IT. Modern IT systems rely on a complex mix of people, networks and hardware. Therefore, a green initiative should cover all these areas. One solution may also need to address end-user satisfaction, management restructuring, regulatory compliance, and return on investment (ROI). There are also considerable fiscal incentives for companies to take control of their own energy consumption. Energy efficient Data Center design should contribute to a better use of space and increase performance and efficiency. The huge energy consumptions of data centers demonstrate the significant potential of energy saving, and make them the desired target of energy conservation measures [1] [2]. Energy efficient Data Center design should address all aspects of the use of energy contained in a Data Center: from the IT equipment as the HVAC equipment to the actual location, configuration and construction of the building. From the power management tools available, one of the most powerful may still be simple common sense in monitoring and managing the energy use with advanced software tools.

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RELATED WORK

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) published in 2011 the whitepaper “Thermal Guidelines for Data Processing Environments. The purpose of thermal guidelines is to develop recommended envelopes as to give guidance to data center operators on maintaining high reliability and also operating their data centers in the most energy efficient manner [3]. Any choice outside of recommended envelopes should be a balance between the additional energy savings of the cooling system considering the operating temperature, versus the deleterious effects in performance, reliability, or acoustics (See fig. 1).

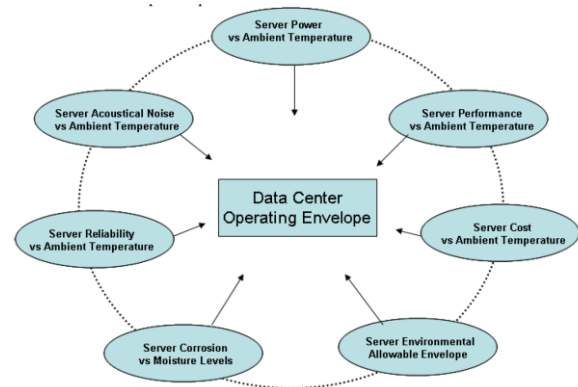


Figure 1: Server Metrics for Determining Data Center Operating Environmental Envelope

Lizhe Wang and Samee U. Khan [4] categorized green computing performance metrics in Data Centers as presented in Figure 2 and presented the formal process for benchmarking a Data Center using developed software tools, including EnergyPlus, for benchmarking and designing energy efficient buildings and Data Centers.

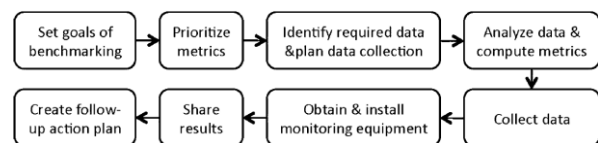


Figure 2: Formal process for designing energy efficient Data Center (Source: Lizhe Wang et al 2011)

Yiqun Pan et al. [1] developed energy model with EnergyPlus for two office buildings in a R&D center in Shanghai, China to evaluate the energy cost savings of

green building design options compared with the baseline building.

A number of recent efforts have devised models and simulation tools for capturing thermal effects, and temperature measurement facilities exist at various levels (starting from chip level) which can be useful for control purposes [5]. The refrigeration periods can be modelled, based on the weather data for different locations, and hence the total energy consumption of the Data Center equipment for a given IT load. [6]

This work investigates thermal performance of buildings with emphasis on data center spaces. In order to evaluate the thermal performance and energy efficiency of buildings and building sub-sectors, several simulation tools have been proposed. In this work, the researcher exploits the potential of EnergyPlus software. EnergyPlus is a software platform that is used in relation to other tools in order to create a user friendly simulation environment. In order to develop a modeling procedure, the researcher studied the simulation tools and used them in order to simulate the Educational building in Heraklion, Crete that hosts the data center of TEI Crete. In order to evaluate the developed model, measurements were performed at specific periods, and the indoor air temperature of the Educational building's spaces was calculated. Main objective of the evaluation procedure is to assure that the model developed for the Data Center space confirms the measurements obtained about temperature variation. All the software utilized for the analysis will be described and all the limitation concerning the research will be discussed. We will describe the development of the 3-D geometry of the case study building in Sketchup, and the input parameter selection and modeling procedure using openstudio. Finally, we will present and discuss our simulation results.



Figure 3: The case study building

MODELING PROCEDURE

The building of interest in this study (see Fig. 3) is a building of TEI of Crete in Heraklion. It is a 3-story building that has study rooms, classrooms, offices and IT rooms. On the 2nd floor there are two rooms, one data/Data Center and one Hardware Laboratory (see Fig. 4)

The HVAC system comprises inventor wall-mounted 24.000 Btu minisplit air conditioners.

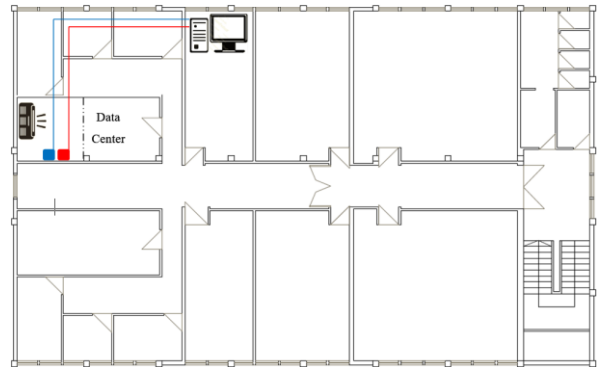


Figure 4: Third floor plan with air conditioner, temperature sensor (red), electricity consumption sensors (blue) and computer with Emoncms software

SOFTWARE SIMULATION TOOLS

EnergyPlus [7] is a thermal analysis software that allows engineers to simulate the thermal behavior of buildings. EnergyPlus is a dynamic simulation modelling tool (DSM) and is used to simulate the thermal performance of new and existing buildings. Dynamic simulation traces the building's thermal state through a series of hourly snapshots, providing a detailed picture of the way the building performs under extreme design conditions and throughout a typical year. Results consist of several data points for each variable that is output. EnergyPlus allows for preparation of a model in 3-D geometry in a third party software (Sketchup) based on already existing building plans and detailed photos and then guides the user to set up the internal condition zones and structural element characteristics that will describe the building model (by relative plugins). The simulation process calculates annual hourly data that can be examined in detailed and filtered for each zone and variable.

Sketchup [8] is a 3D modeling software for a wide range of drawing applications. There is an online open source library of free model assemblies (e.g., windows, doors, automobiles, etc.), 3D Warehouse, to which users may contribute models. The program includes drawing layout functionality, allows surface rendering in variable "styles", supports third-party "plug-in" programs (e.g., openstudio), and enables placement of its models within Google Earth. SketchUp 4 and later support software extensions written in the Ruby programming language, which add specialized functionality. SketchUp has a Ruby console, an environment which allows experimentation with Ruby. The free version of SketchUp also supports Ruby scripts, with workarounds for its import and export limitations

The Legacy OpenStudio Plug-in for SketchUp [9] facilitates the creation and editing of building geometries in EnergyPlus input files. This free plug-in also allows the launching of EnergyPlus simulations

and viewing of the results without leaving the SketchUp 3D drawing program. The Legacy OpenStudio Plug-in was created by the National Renewable Energy Laboratory for the U.S. Department of Energy (www.nrel.gov) as an interface to the EnergyPlus simulation engine. Active development has moved from the Legacy OpenStudio Plug-in to the more comprehensive OpenStudio suite of tools and libraries.

The OpenStudio Application Suite [10] combines all the plug-ins for modeling, simulation and results viewing with EnergyPlus and SketchUp. It is a cross-platform (Windows, Mac, and Linux) collection of software tools to support whole building energy modelling using EnergyPlus. OpenStudio is an open source project to facilitate community development, extension, and private sector adoption. OpenStudio includes graphical interfaces along with a Software Development Kit (SDK). It is the next version of Legacy Openstudio plug-in that incorporates all the necessary tools for EnergyPlus simulations. OpenStudio enables potential developers to write their OpenStudio measure (henceforth referred to as a "measure"). Measure is a program (or 'script', or 'macro') that can access and leverage the OpenStudio model and API to create or make changes to a building energy model, as defined by an OpenStudio model (.osm). Measures are written in Ruby, which allows the measure author to access OpenStudio directly as well as through the SketchUp plugin. Measures can be created from scratch, but existing measures may also be used as a starting basis. [http://nrel.github.io/OpenStudio-user-documentation/reference/measure_writing_guide.]

xEsoView [11] is a file viewer for EnergyPlus .eso output files which gives the user a very fast overview of the simulation results. xEsoView uses the Qt extension of the Qt toolkit from Trolltech Inc. xEsoView presents all reported variable names in a list, which can be sorted and filtered, on the left hand side. On the right hand side it presents the graphical representation of the selected variable. The time axis can be changed using predefined ranges (hour, day, week, month, total) with zooming support. With a selection box you can switch between the available environments, e.g. summer design day and run-period. A simple CTRL+C copies the variable data to the clipboard. So you can easily paste the data into a spreadsheet for further analysis.

Elements software [12], Version 1.0.4, is a free, open-source, cross-platform software tool for creating and editing custom weather files for building energy modeling. Elements software tool was developed by Big Ladder Software with the generous funding and collaboration of Rocky Mountain Institute

CREATING THE 3D GEOMETRY IN SKETCHUP

In this work, we used the SketchUp 15 trial version for 3D modelling. We created the thermal 3D model from scratch, and all surfaces was "matched" and

linked to each other according to the boundary conditions.

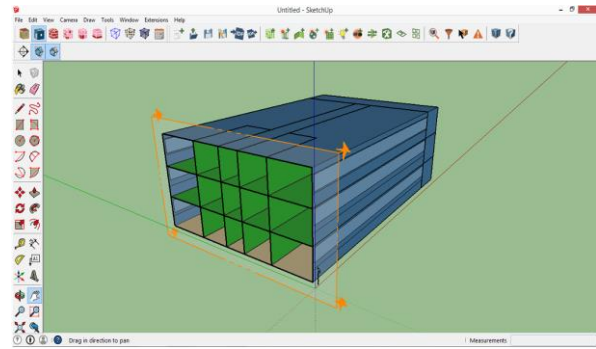


Figure 5: Rendering by boundary conditions view of Sketchup 3D model

Before creating the geometry, a basic template of a Large office building was imported in the design in order to allow for the basic construction and thermal characteristics to be determined automatically. Changes and adaptations were made to account for the specificities of our application later in the modeling process using OpenStudio Application Suite. The basic design of the floor was expanded using the "Create Spaces from Diagram" command. Three floors were created, the ground floor, 1st and 2nd floor. In the 2nd floor, one space was created, which account to the Data Center.

The basic space types and thermal zones can be set in the 3D geometry, while further details are imported later in the .osm model. First the space types are set as large open office areas for all the areas except the corridors, the stairs and the spaces which are of interest for this study. All office areas are imported in the same thermal zone. The corridors and the stairs area of the upper floor, create a second thermal zone. The stairs area of the ground floor is a separate thermal zone. The areas of the Data Center and the Hardware Laboratory are in different thermal zones. The Data Center and was set as IT space in the .osm model. Hence five different thermal zones are set the .osm file is created. The thermal simulation and all further data are imported in the OpenStudio suite environment.

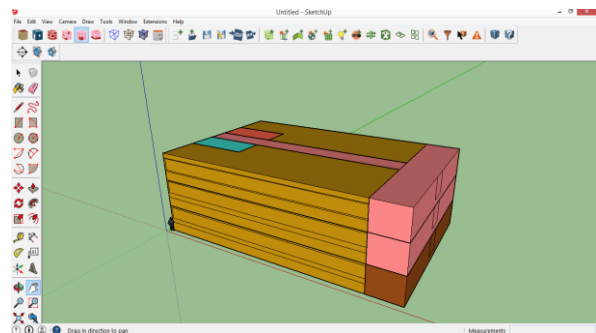


Figure 6: Assignment of thermal zones in Sketchup 3D model

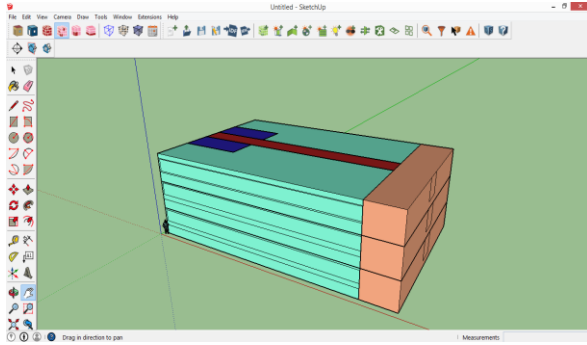


Figure 7: Assignment of space types in Sketchup 3D model.

MEASUREMENTS

For temperature and power consumption measurements used Arduino technology and Emoncms open-source web application used for storage, real time representation and treatment of measurement data archived, which were collected from wire-connected Arduino. In particular, for temperature measurements used Arduino equipped with ds18b20+ temperature sensor and for power consumption used Arduino with three noninvasive current sensor 30 A for one of the three phases. Arduino equipped with power consumption sensor was measuring the total consumption of the Data Center. The data of the IT equipment consumption are provided from the UPS which provide electrical power to IT equipment. Arduino layout is presented in figure 8.



Figure 8: Arduino layout

Emoncms [13] was used for storage, real time representation and treatment of measurement data archived which were collected from wire-connected Arduino. Emoncms is an open-source web application for processing, logging and visualising energy, temperature and other environmental data and is part of the OpenEnergyMonitor project. In brief the emoncms architecture is a combination of a front controller on the Server and model-view-controller design pattern and a directory structure that makes adding features in a self-contained modular way easy.

Temperature and Energy Monitoring achieved through dashboard, the web app and which runs on Emoncms and is also available as a native Android app. Through dashboard we can Explore - visualize Site temperature in Degree Celsius and power consumption in Watts, daily energy consumption in KWh and PUE calculations (see Fig 9 and 10).

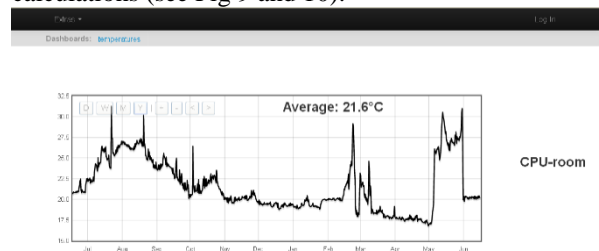


Figure 9: Ambient Temperature in graphical representation



Figure 10: Real time visualization of the power consumption

OBTAINED MEASUREMENTS

Figures 11 present measurements obtained for the Data Center's air temperature, from December 25th to December 30th. Measurements show that Data Center temperatures deviate in the range of 21,4 – 22,7 °C.

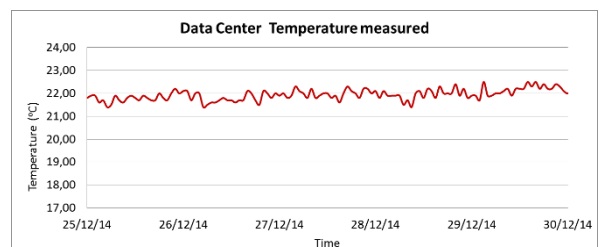


Figure 11: Data Center temperature measured

SETTING MODEL PARAMETERS IN OPENSTUDIO .OSM FILE

In the Site tab (See Fig. 12) we set the path of the .epw weather file for simulation. The weather data has been provided by Weather Station of TEI of Crete which is located in the area of TEI and about 700 meters from the case study building. Weather file has to be in .epw format for simulations in EnergyPlus. A weather file in .epw format was purchased from White Box Technologies Company [14]. The data of the weather file of White Box Technologies Company was edited and updated by the Elements software with the weather data from Weather Station of TEI of Crete.

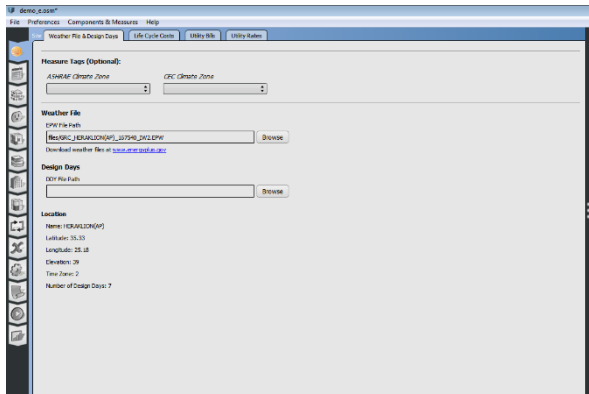


Figure 12: OpenStudio Site tab

In the .osm file we have to make some changes in order to adapt to the case study of the building that we are referring to. We select the appropriate materials from the Library tab and drag and drop them to the relative position. The materials and their attributes were set according to Technical Guideline 20701-2/2010 of Technical Chamber of Greece [15].

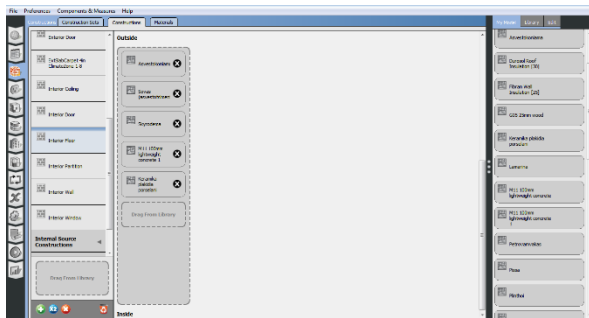


Figure 13: Constructions and their materials

Apart from the materials, we set the HVAC system for heating and cooling (See Fig. 14). As the openstudio does not provide a template for a standard split air condition, standard components from the library were used to build up a simple split AC system. As the thermal zone of Data Center was set to conditioned thermal zone the other thermal zones were set to not conditioned and left drifting during simulation.

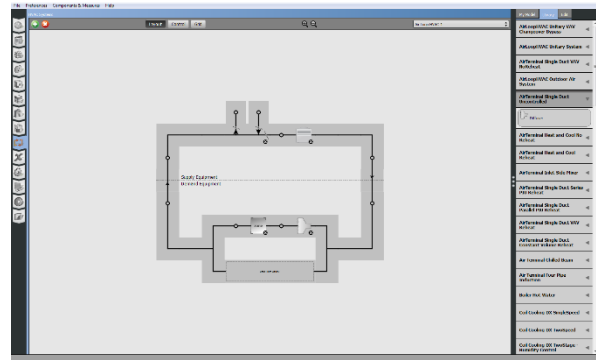


Figure 14: Building up a simple split AC system from standard components

The loads for the Data Center (Space 306) are set according to measurements about the IT and non IT equipment power consumption in the closet of the Data Center and the loads of the equipment was operating at the same period in the Data Center. The Data Center space was set as IT Room space type.

The loads for the Data Center (Space 306) are set as “IT room Equip” according to measurements about the IT and non IT equipment power consumption in the closet of the Data Center. The schedule consists of a series of fraction rules. The fraction was calculated by dividing the power which measured in the corresponding time step, to the maximum power which measured in the total simulate time. Each rule or profile applied from December 25th to December 30th. Figure 15 presents the fractional rules for the Data Center loads.

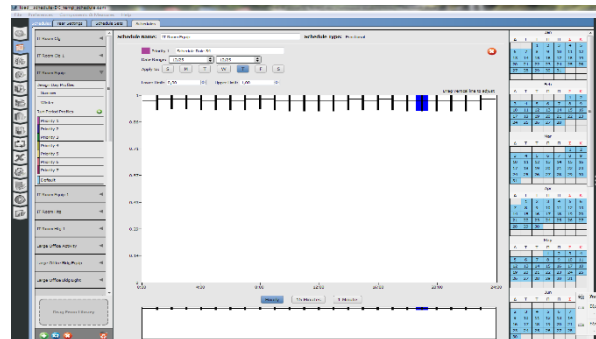


Figure 15: Fractional rules for the Data Center loads

DATA CENTER SIMULATION RESULTS

Simulation Results (See Fig 16) show that Data Center’s air temperature deviates in the range of 21,3 – 22,7 °C.

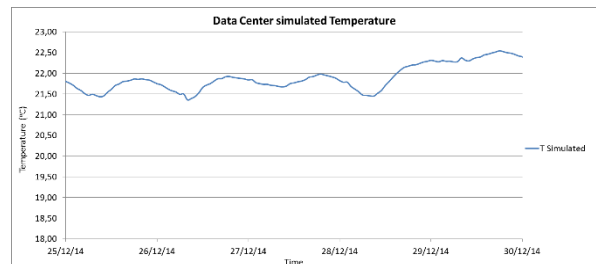


Figure 16: Data Center hourly simulated results from December 25th to December 30th

DATA CENTER EVALUATION OF RESULTS

The evaluation is realized during Christmas holidays, so that no activity or internal gains are perturbing the results. Figures 17 present measurements obtained for the Data Center air temperature, the temperature from simulation and the outdoor temperature from December 25th to December 30th 2014. Measured temperatures deviate in the range of 21,3 – 22,7 °C and the simulated temperatures deviate in the range of 21,4– 22,5 °C. The standard deviation of the difference between simulated and measured temperatures is roughly 0,2 °C. So we can say that the EnergyPlus model gives satisfying results.

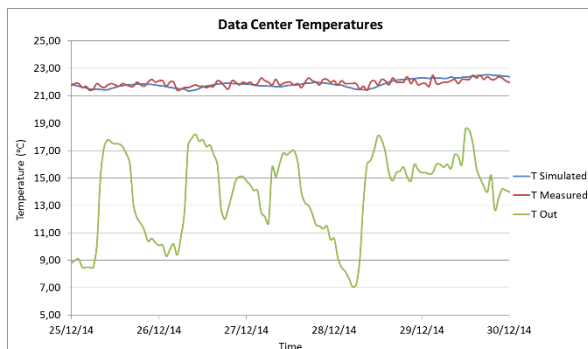


Figure 44: Temperatures measured, simulated and the outdoor temperatures for Data Center

CONCLUSION AND PRESPECTIVES

This work investigates thermal performance of buildings with emphasis on data center spaces. In order to evaluate the thermal performance and energy efficiency of buildings and building sub-sectors, several simulation tools have been proposed. In this work, the researcher exploits the potential of EnergyPlus software. EnergyPlus is a software platform that is used in relation to other tools in order to create a user friendly simulation environment. In order to develop a modeling procedure, the researcher studied the simulation tools and used them in order to simulate the Educational building in Heraklion, Crete that hosts the data center of TEI Crete. In order to evaluate the developed model, measurements were performed at specific periods, and the indoor air temperature of the Educational building's spaces was calculated. Main objective of the evaluation procedure is to assure that the model built for the Data Center space confirms the measurements obtained about temperature variation. All the software utilized for the analysis thoroughly described: the implementation of the 3-D geometry of the case study building in Sketchup using Sketchup 2015 version, the input parameter selection and modeling procedure using openstudio using EnergyPlus.

The huge energy consumptions of the data centers demonstrate the significant potential of energy cost reduction and Green ICT policy and regulations, put more pressure on Data Center operators to consider an

Energy efficient Data Center design so as to contribute to a better use of space and increase performance and efficiency. The Data Center cooling systems are a desired target of energy conservation measures. The design of the Data Center cooling system is driven by the heat released from IT hardware it serves, and it is difficult to predict how this will change. Exhaust temperatures will continue to increase, resulting in even hotter temperatures in the Data Center spaces. Air performance metrics can be used to benchmark improvements and to quantify inefficiencies and calculate Data Center cooling system effectiveness towards optimization

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