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| Main academic Supervisor: | Title, First name, LAST NAME, SMACCs Univ. |
| Academic co-supervizor:  Partner supervisor: | Title, First name, LAST NAME, SMACCs Univ.  Title, First name, LAST NAME, affiliation |

**A Master Thesis submitted for the Erasmus Mundus Joint Master Degree on Smart Cities and Communities (SMACCs)**

June 2021

University of Mons, Heriot Watt University, International Hellenic University, University of the Basque Country

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| Photos, logos, tournages - Université de Mons | Une image contenant texte, signe, arts de la table, vaisselle  Description générée automatiquement | MA in the Classical Archaeology and the Ancient History of Macedonia,  Thessaloniki, Greece 2021 |  |

Acknowledgements

Abstract

Here goes a summary of the dissertation (1 page max): describes briefly the motivation and objectives, the employed methods and the main findings and conclusions.

**Keywords:** Finish by a list of keywords describing the topic of the dissertation

Student Name

Date

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# Introduction

**This file contains the basic formatting instructions and guidelines on how to write your dissertation. Word Styles are being used extensively for the formatting of basic elements, such as titles, legends etc. Minor modifications are permitted with the agreement of the supervisor.**

**This file is also a sample of how your dissertation should look like in the end. In order to avoid distortions and alterations, it is strongly suggested that when you write, you should have control character ¶ always on, by clicking on the button shown below on your toolbar:**

****

**We recommend that you make a copy of this file and   
use it for your dissertation.**

# Energy Plus Simulation

EnergyPlus™ is a building energy simulation program created by the U.S. Department of Energy’s Building Technologies Office. It is an open source and can be operated with the OpenStudio software along with graphical interfaces such as DesignBuilder, Revit, and SketchUp. EnergyPlus can model various aspects related to building operations such as heating, cooling, ventilation, appliance usage, and water.

## EP Inputs and Outputs

The EnergyPlus software is able to simulate buildings under various environments, chosen by the user. The simulation is based on fundamental heat balance principles. EnergyPlus files are ASCII text-based weather, input, and output files in hourly or even sub-hourly formats. The first input file is the building model IDF file, which contains the information about the building, its systems, and its schedules. The second input file is the weather file, which contains information about temperature and solar radiation. The output variables can be selected, and include but are not limited to Air Humidity [%], Zone Temperature [C], Zone Cooling/Heating Energy [J], Zone Cooling/Heating Rate [W], Zone Lighting [J].

EnergyPlus incorporates many modules that work together to simulate the building performance under different environmental and specified operating conditions. The different modules are shown in Figure 1.

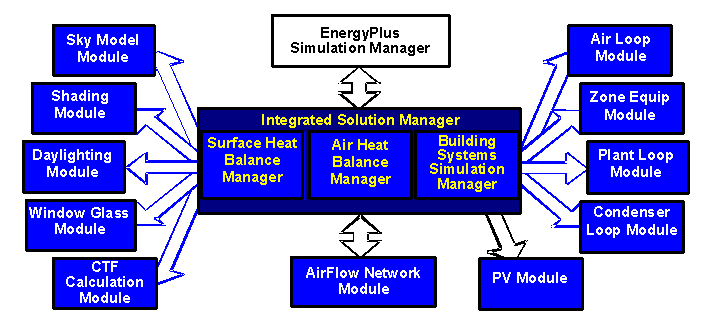
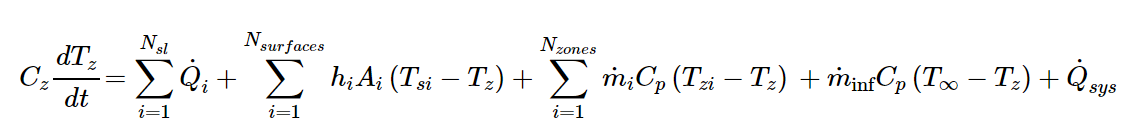


Figure 1: Energy Plus Program Schematic

## Energy Plus Zone Temperature

EnergyPlus operates on basic heat balance equations. The indoor temperature calculations are based on the following heat balance equation.



where,

Graphical user interface, text, application, email

Description automatically generated

This is further simplified to

Chart

Description automatically generated with medium confidenceTo calculate the indoor temperatures each hour, EnergyPlus utilizes a default “third order backward difference” algorithm, which uses the third order finite difference approximation to solve the zone air energy and moisture balance equations.

## EnergyPlus Prototype Buildings

The U.S. Department of Energy (DOE) and the Pacific Northwest National Laboratory (PNNL) have created a stock of prototype commercial and residential buildings that vary according to location and building energy codes. These are also open source and readily available.

There are three base prototypes that are available for simulation.

1. *Single-family* detached house
2. *Multi-family* low-rise apartment building
3. Midrise apartment building

These prototypes are available in each climate zone (1-8) and moisture regime (A,B,C) as defined by the IECC. The prototypes are then modified to accommodate different areas, four different heating system types, and four foundation types typically found in new residential construction. The result is an expanded set of 32 models for each location that can be adjusted in area.

Table

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A picture containing diagram

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Figure 2: Examples of Protype Buildings

The use of Word commands for the creation of cross-references and captions is strongly encouraged, since it relieves you from the burden of maintaining the correct numbering as you edit your text.

### Relevant Simulation Output

After running the simulation, we are able to obtain the hourly results of the indoor temperature, setpoint temperature, appliance usage, internal gains, and heating provided over a given period.

Chart, line chart, histogram

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Figure 3: Example 72h Output

# Optimization of Setpoint Temperature

Typically, the model’s setpoint temperature is held at a constant value such as 20C, and the heating load at each hour is adjusted accordingly. This means that the current prototype model does not consider time of day pricing of electricity. Ideally, we should be able to optimize the setpoint temperatures at each hour to minimize the electricity costs. **For example, Oldewurtel et al finds that the heating pattern significantly changes when optimized with a time-varying price signal.**

## Optimization Formulation

When provided with a time varying price signal ($/kWh), the goal is to shift the heating load to minimize the total costs. This is done by adjusting the decision variables, indoor temperature setpoint at each hour, while maintaining the indoor temperature at a reasonable comfort level, between 18 and 23C. This can be written as an optimization problem as follows:

Qsys=˙msysCpη(Tsup−Tz,desired)

…

## Use of Styles

In order to maintain uniform formatting, you should use the styles defined in this document. The most important ones are the following:

* Normal style for paragraph text
* Headi
* ng 1 for chapters, Heading 2 for first level sections etc. You can use up to Heading 5. Headings 1 to 3 are automatically numbered while 4 and 5 have no numbering.
* Caption style is added automatically when you create a caption

All these styles have already been created in this document so that you can apply them directly.

You should avoid leaving blank lines after the end of the final paragraph of a section or a chapter. Headings are defined so that the necessary space is added automatically.

## Figures and Tables

### Figures

Figures are added in-line, with a caption below them, near the paragraph text where they are referenced (usually, shortly after). All figures should be referenced at least once in the paragraph text. References could be made using the right MS Word shortcuts (cross-reference). This is an example of this: Figure 1 shows two examples of palmtops.

A close-up of a cell phone

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Figure 1: an example of figure

The use of Word commands for the creation of cross-references and captions is strongly encouraged, since it relieves you from the burden of maintaining the correct numbering as you edit your text.

### Tables

For your convenience, we have included TableHeader and TableBody styles so that you can easily format your tables. Of course you can format them as you like. You may use **bold** typeface for header rows and columns.

Table 1: a sample table

|  |  |  |  |
| --- | --- | --- | --- |
|  | Greece | England | France |
| **Population** | 11m | 52m | 66m |
| **Area** | 131990 km2 | 130395 km2 | 674843 km2. |

Table captions are added above the table. After the table leave a blank line, as in the example.

Same as with pictures, tables should be referenced at least once in the paragraph text. Cross-referencing is encouraged here too: Table 1 is an example.

## Titles

Titles and headings should be short and concise. Generally, they should not exceed one line in length. Chapters start on an odd (right) page for duplex printing.

## References and Bibliography

In the end of your thesis, you should include a numbered list of your bibliographic sources. The number of the corresponding source should be referenced inside the paragraph text, where necessary, ideally inside brackets (IEEE style), e.g. [1], [2], etc.

## Equations

|  |  |  |
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|  |  | ( 1 ) |
|  |  | ( 2 ) |

Equations should be referred in text with parentheses. For instance, see equations ( 1 ) and ( 2 ). You can use tables to correctly align multiple equations and their labels.

# Chapter 3 Title

Indicative use of styles (Headings). Headings 4 and 5 could be inserted inside a section of any other level.

## Level 2 Title

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# Chapter 4 Title

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## Level 2 title

# Chapter 5 Title

# Chapter 6 Title

# Conclusion and future work

Bibliography

|  |  |
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| [1] | J. Doe, «A sample reference,» *IEEE Transactions on Smart Cities and Communities,* vol. 2, n° %13, pp. 2-12, 2020. |
| [2] | J. Smith, «Another sample article,» *IEEE Transactions on Smart Cities and Communities,* vol. 1, n° %12, pp. 55-58, 2021. |

Appendix

Example of appendix (extra figures, source code, etc.). Pay attention that reviewers are not forced to read the appendixes.