Interoperability between Building Design and Energy Modeling for Building Performance

Elizabeth Guzmán Garcia

A Thesis

in

The Department

of

Building, Civil and Environmental Engineering

Presented in Partial Fulfillment of the Requirements

for the Degree of Master of Applied Sciences (in Building Engineering) at

Concordia University

Montreal, Quebec, Canada

April 2014

CONCORDIA UNIVERSITY
School of Graduate Studies

This is to certify that the thesis prepared

By: Elizabeth Guzmán Garcia

Entitled: Interoperability between Building Design and Energy Modeling for Building Performance

and submitted in partial fulfillment of the requirements for the degree of

Master of Applied Science in Building Engineering

complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

Signed by the final examining committee:

Dr. Radu Zmeureanu ____________________ Chair

Dr. Amin Hammad ____________________ Examiner

Dr. Liangzhu Wang ____________________ Examiner

Dr. Zhenhua Zhu ____________________ Supervisor

Approved by ____
Chair of Department or Graduate Program Director

____
Dean of Faculty

Date April 30th, 2014

ABSTRACT

Interoperability between Building Design and Energy Modeling for Building Performance

Elizabeth Guzmán Garcia

Interoperability issues have been well acknowledged as an impediment to improve productivity in the Architecture, Engineering and Construction (AEC) industry. The current information exchange between building design and energy models has numerous problems, including object parametric information deficiencies, geometric misrepresentations and re-input data confusion. These problems inevitably lead to huge money, time and effort losses. This thesis presents an automated solution that works towards unified information exchange between building design and energy modeling in building performance. First, an Extensible Style-sheet Language Transformation (XSLT) is designed to specify a set of transform instructions. Based on the instructions in the XSLT, building elements and their attributes in the design open schema are matched to the corresponding energy analysis patterns. The contents in the design open schema can then be automatically transformed through meticulous checking and comparison.

The proposed solution has been implemented with Microsoft Visual C# Studio 2013, through the creation of a Windows form application and a software plug-in component. This method would facilitate the information exchange between existing open standard schemas, gbXML and DOE-2 INP, supported by Autodesk Revit and eQUEST. The effectiveness of the solution has been tested with three real case studies. The results from the proposed solution have demonstrated the overall rectification of the geometric and material misrepresentations inherent to the current software interoperability process.

ACKNOWLEDGMENTS

First, I would like to thank my parents, Antonio M. Guzmán and Leonor M. de Guzmán, and my sister, Jennifer L. Guzmán G. for instilling in me the ethics and courage to be a better person each day and to whom I dedicate this dissertation. I thank them for their love, guidance and support, not only during the course of my career but throughout my life. Sincerely, thank you.

I am very thankful to my supervisor, Dr. Zhenhua Zhu, for his unconditional support and ability to quell my doubts throughout the process of writing my dissertation. For his valuable advice, help and dedication, I will be forever grateful. In addition, I would like to thank my examiners, Dr. Radu Zmeureanu, Dr. Amin Hammad and Dr. Liangzhu Wang, for their precious time, valuable advice and helpful suggestions in reviewing my thesis.

Moreover, I would like to thank the dear professors who have seen me through my academic training at the PUCMM School of Architecture and at Concordia University. Thank you for all the support and advice during my career and for the encouragement to continue to grow, not only intellectually but also personally. Finally, I want to thank my dear friends and colleagues, especially Yannick Caron, Abrar Mohsin, Stuart Thiel and Hilary Bergen. I thank them for the moral and technological support and for giving me their most sincere friendship.

Dedication

To my parents,

Antonio M. Guzmán and Leonor M. de Guzmán

and my sister,

Jennifer L. Guzmán G.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

AEC	Architecture, Engineering and Construction
BEM	Building Energy Modeling
BIM	Building Information Modeling
BLS	Bureau of Labor Statistics
CAD	Computer-Aided Design
CERL	Construction Engineering Research Laboratory
DOE	Department of Energy
GBS	Green Building Studio
gbXML	Green Building Extensible Markup Language
GSF	Gross Square Footage
GUIs	Graphical User Interfaces
IAI	International Alliance for Interoperability
IFC	Industry Foundation Class
LBNL	Lawrence Berkeley National Laboratory
LEED	Leadership in Energy and Environmental Design

NIBS	National Institute of Building Science
NIST	National Institute of Standards and Technology
OSU	Oklahoma State University
UI	University of Illinois
XSLT	Extensible Style-sheet Language Transformation

CHAPTER ONE: INTRODUCTION

1.1 Problem Statement and Motivation

Building Information Modeling (BIM) and Building Energy Modeling (BEM), are currently two of the most promising developments in architecture, engineering, and construction. The implementation of BIM and BEM tools in energy analysis has become imperative to achieve sustainability and development. According to Canada Green Building Council (2014), annual energy costs for the Canadian commercial building sector is $17.6 billion, and lighting, heating and cooling of buildings represent 50-60% of the annual greenhouse gas emissions. The use of BIM and BEM tools to reduce these energy consumptions and greenhouse emissions is expected to increase dramatically in the years to come.

One of the current major benefits of BIM and BEM is that they offer the ability to use the building information (e.g. building geometry) towards energy analysis and energy retrofit solutions at early design stages. Since BIM makes it possible for multi-disciplinary information to be covered within one model, it allows for early implementation of sustainability features, which in turn helps predict environmental performance (Kymmell, 2008). As a result, existing BIM and BEM software tools have improved and simplified the complicated energy analysis process. However, the lack of interoperability between the current tools is a major impediment in improving productivity in the Architecture, Engineering and Construction (AEC) industry (Smith & Tardif, 2009). The BIM and BEM tools do not exchange and interpret information effortlessly between one another. This lack of interoperability represents a long-standing history of inefficiency; object parametric information deficiencies, geometric misrepresentations and re-input data confusion result in losses of money, time and effort for the AEC firms.

A 2004 study commissioned by the National Institute of Standards and Technology (NIST) identified and estimated the efficiency losses resulting from interoperability issues in the U.S. construction industry (Gallaher et al, 2004). This study was based on the survey and interview responses from seventy recruited organizations involved in architecture, engineering, facilities management and business software systems. The results of the study concluded that the annual costs of interoperability issues amounted to $15.8 billion in the year of 2003 (Gallaher et al, 2004). In order to quantify the costs of inadequate interoperability shown by this study, key wage rates for architects, engineers, general contractors, specialty fabricators and owners were taken into consideration (see Table 1). As seen in the table below, the term “CAx user” is used to identify the employees who worked directly with information in design problems. The cost of inadequate interoperability was then quantified by comparing the current activities and costs with a hypothetical scenario in which data exchange, access and management are flawless. The difference between the current and hypothetical scenarios represents the total economic loss attributed to inadequate interoperability (Gallaher et al, 2004) (see Table 2).

Table 1: Key Wage Rates Employed to Quantify Costs of Inadequate Interoperability. Source: U.S. Department of Labor, Bureau of Labor Statistics (BLS). 2003

Stakeholder Group	BLS Occupation Title	Mean Hourly Wage (2002)	Estimated Loaded Hourly Wage
Architects and Engineers			
CAx user (architecture)	Architects, except landscape and naval	$29.88	$59.76
CAx user (engineering)	Civil engineer	$30.53	$61.06
General Contractors			
CAx user	Civil engineer	$28.57	$57.14
Construction laborer	Construction laborer	$14.72	$29.44
Specialty Fabricators and Suppliers			
CAx user	Civil engineer	$27.20	$54.40
Construction laborer	Construction laborer	$14.01	$28.02
Owners and Operators			
CAx user	Architects, except landscape and naval	$30.06	$60.12
Operations and maintenance engineer	Civil engineering technician	$18.71	$37.42

Table 2: Costs of Inadequate Interoperability by Stakeholder Group, by Life-Cycle Phase (in $Millions). Source: (Gallaher, O'Connor, Dettbarn, & Gilday, 2004).

Stakeholder Group	Planning, Engineering, and Design Phase	Construction Phase	Operations and Maintenance Phase	Total
Architects and Engineers	1,007.2	147.0	15.7	1,169.8
General Contractors	485.9	1,265.3	50.4	1,801.6
Specialty Fabricators and Suppliers	442.4	1,762.2	—	2,204.6
Owners and Operators	722.8	898.0	9,027.2	10,648.0
Total	**2,658.3**	**4,072.4**	**9,093.3**	**15,824.0**

The results from the study also determined that the majority of the interoperability issues in the AEC industry are related to computer-aided design, the practice of engineering, and software systems (Gallaher *et al,* 2004). Young et al. (2007) support this result, with their statement that a majority of the construction industry (62%) lists software incompatibility issues as the primary factor impacting build team members' ability to share information across software. The industry is struggling to find software tools that can interoperate well. Therefore, it is imperative to share knowledge and collaborate with all the members of a build team while working with different applications and platforms.

In an effort to reduce interoperability issues in the AEC industry, open standard schemas and integrated software tools from the same design teams were developed. The creation of open schemas can facilitate the unified exchange of information between tools in order to improve efficiency of building design and energy analysis simulation. These open schemas simplify the transfer of building and energy information. However, the results they provide are not perfect. Tools such as Autodesk's Green Building Studio (GBS) provide export capabilities from the gbXML (Green Building XML) open schema to other, available, open schemas. This process presents numerous problems when the files are imported into their respective software tools. Some of the issues resulting from this process include re-input data confusion, insufficient information provided by the tool, loads of geometric misrepresentation and loss of parametric information.

In addition to the creation of open standard schemas, design teams also introduced the development of integrated software tools as a possible solution for solving interoperability issues. However, integrating building design tools, such as Autodesk Revit, with energy analysis tools, such as Ecotect, still presents numerous obstacles. First, the software for the integrated tools has a high cost. Although there are software trials and academic versions of the tools that can be obtained for no cost, these free versions are limited compared with the versions available for purchase. Second, the integration of the software is only based on tools created by the same developers or design teams. Therefore, the integration of tools from different developers, like Autodesk-based products with eQUEST, is not available. Consequently, since there is no standard protocol in the programming of software tools, each developing firm adopts its own standards. This results in discrepancies in the building design and energy analysis information from the software tools. It is imperative to find a novel integration solution for the current interoperability issues between building design and energy models in building performance.

1.2 Objectives and Scope

The ultimate goal of this research is to address the interoperability issues between building design and energy models in the building performance process. The main objective is to design a novel open schema converter which could be used to facilitate the effortlessly information exchange between building modeling and energy modeling tools. For that reason, this dissertation can be divided into five main parts. First, a comprehensive research of the broad uses of BIM and BEM tools in the energy analysis process and the importance of the interoperability issues between these tools is introduced. Then, in order to solve these interoperability issues, a novel open schema converter solution is designed, implemented and evaluated. Next, a software plug-in component in the building design tool environment is developed in order to execute the proposed open schema converter solution. Subsequently, the proposed converter solution and the developed software component are validated through the analysis of three real case studies. Finally, the results from the validation process are highlighted and discussed.

Due to the large number of building design and energy software analysis programs available, the scope of this study is limited to the interoperability issues between Autodesk Revit and eQUEST. Autodesk Revit and eQUEST are currently two of the most highly utilized tools in building design and energy analysis respectively. The purpose of this study is to create a novel open schema converter solution between these software tools. The proposed converter is expected to properly transform the information from the open standard schema gbXML (utilized by Autodesk Revit) to the DOE-2 INP schema (employed by eQUEST) in order to correct all the issues resulting from the current conversion solution practices.

The Autodesk Revit software is selected for the purpose of this study because is one of the most popular software tools used to provide accurate, high quality building designs (Autodesk I. 2011). Autodesk-based products have always been the first, best option when it comes to architectural, engineering and mechanical design. However, in regards to energy analysis modeling, software tools like eQUEST are gaining in popularity and are being used more than Autodesk products. One of the main reasons for this is that eQUEST and other engineering software like Trane Trace and IES are powerful programs that are currently used by engineers to perform detailed energy analyses. These tools have great input flexibility, which Autodesk-based products do not consistently have. eQUEST, which stands for “Quick Energy Simulation Tool,” is therefore selected for this study due to its frequent use in AEC companies all around the world. In addition, eQUEST complies with the National Energy Code of Canada for Buildings (NBC, 2011). eQUEST is an energy analysis simulation tool so comprehensive and intuitive that any team member of a design team can use it. This is due to the fact that eQUEST offers a simple, and easy to follow wizard that helps the user in the energy modeling process. In addition, eQUEST is a completely free software tool that is accessible to any user.

Consequently, the main focus of the conversion process from the gbXML and DOE-2 INP is based on the building location, geometry and material information issues. The information from these three sections presents the most interoperability issues when converted to a different open standard schema. Solving these main issues will serve to rectify the conversion process between gbXML and DOE-2 INP files. Although this paper is focused on these issues, other information such as daily schedule, weekly schedule, building construction and HVAC systems, are also properly transformed when using the proposed open schema converter. Once these interoperability problems, between Autodesk Revit and eQUEST, are addressed, it will significantly benefit today's AEC industry.

1.3 Methodology and Implementation

The creation of a novel open schema converter can achieve the objectives mentioned above. The methodology of the proposed converter includes two general steps. First, the design of an Extensible Stylesheet Language Transformation (XSLT), where the proposed solution takes the gbXML open standard schema as input. This style sheet comprehends a series of code instructions pre-created from a set of gbXML file representatives. After the creation of the XSLT, the comparison and conversion process of the proposed open schema converter initiates. After its creation, the XSLT locates and selects the gbXML element based on its unique ID or building name ID. It is then necessary to go back to the XSLT to determine the corresponding instructions for that element. Based on those instructions, the gbXML file is once more explored in order to retrieve the data needed for the conversion of this information. This step is then repeated for each one of the components needed for conversion (e.g. building geometry, project location and material information). Finally, the gbXML is transformed into a DOE-2 INP file. Adequate element location, material reformulation and proper Metric to Imperial system conversion are required in order to properly convert the schemas. The proposed method has been implementation via the creation of a software plug-in inside the building design tool, Autodesk Revit 2013. This software plug-in executes the proposed converter solution and its effectiveness is then tested with three real case studies. The results of the proposed converter demonstrate the overall rectification of most of the geometric and material misrepresentations resulting from the current software interoperability process.

1.4 Expected Contributions

The main contribution of this study is in the development of a novel open schema converter solution that properly transforms the information from the Green Building XML (gbXML) schema to the DOE-2 INP schema. What follows are the resulting contributions of the proposed open schema converter, determined through the study. The open schema converter:

1. Reduces the amount of time incurred due to interoperability issues. The proposed converter solution is expected to reduce the time and effort losses in the AEC

industry by automating the current manual process of software integration between building design and energy analysis software tools.

2. Provides a convenient and economical approach in solving the interoperability issues between software tools in the building design and the energy modeling integration process. The transition from a manual conversion process to the proposed automated converter solution represents cost savings for the AEC companies, where no requirements for training or upgrading of the conversion solution are necessary.

3. Promotes the use of BIM and BEM in small projects. Companies usually reserve the use of these tools in projects with large budgets. The use of BIM for BEM tools results in investment costs that small projects currently cannot afford. However, due to the preservation of cost and time that the proposed converter solution offers, companies will be able to use BIM for BEM in small projects as well. As a result, more buildings will be eco-friendly and society will be more sustainable.

1.5 Thesis Organization

This dissertation is divided in the following five chapters:

Chapter 1: This is the introduction chapter of this thesis. It provides information about the background of this dissertation, including the motivation, scope and objectives. A summary of the proposed methodology, expected contributions and organization of the thesis are also provided in this chapter.

Chapter 2: This chapter presents an introduction to the uses, advantages and limitations of Building Information Modeling (BIM) and Building Energy Modeling (BEM) tools in the energy analysis process. A review of the integration methods of the building design and energy modeling in the building performance process is also presented in this chapter. A study of the interoperability issues in the current integration process and some of the alternative solutions related to these issues are discussed in this chapter as well.

Chapter 3: This chapter presents detailed information of the objectives, scope and proposed methodology of this dissertation. In addition it examines the creation, components and interrelations of the proposed language transformation style-sheet. A description of the steps in the comparison and conversion process of the proposed novel converter solution is also explained in this chapter.

Chapter 4: This chapter describes the implementation process of the proposed converter solution. A demonstration of the converter solution and the description of its technical information are also defined. In order to validate the implementation of the proposed methodology, and to illustrate the features of the developed converter application, an analysis of three real case examples is presented. The three case examples include building design information from three actual projects. Lastly, the results from the analysis of these real case studies are discussed.

Chapter 5: Finally, chapter five summarizes the remarks of this study and presents its conclusions. The contributions of the proposed method and recommendations for future research work are included in this chapter as well.

CHAPTER TWO: LITERATURE REVIEW

This chapter presents an introduction to Building Information Modeling (BIM) and Building Energy Modeling (BEM), tools crucial to the building performance process. Additionally, this chapter describes current integration methods of building design and energy modeling, along with their issues and possible solutions. Finally, this chapter examines the conclusions obtained by the study in order to present the proposed methodology of this dissertation.

2.1 Building Information Modeling (BIM)

Building Information Modeling (BIM) describes virtual design, construction and facilities management. BIM is an approach to building design and construction in which a reference parametric 3D model of the building is created and embedded with data, making it possible to share the building information between different team members and at different points of the project life cycle (Jernigan, 2007). According to the National Building Information Modeling Standard, and the Committee of the National Institute of Building Science (NIBS) in the United States, BIM presents "an improved planning, design, construction, operation, and maintenance process using a standardized machine readable information model for each facility, new or old, which contains all appropriate information created or gathered about that facility in a format useable by all throughout its lifecycle" (NIBS, 2008). In summary, BIM can be defined as a tool to design, document and exchange building information between all the stakeholders involved in a project.

Advantages and Limitations of BIM

BIM presents a lot of advantages for architects, engineers, construction managers and all those involved in a project. Krygiel (2008) and Crotty (2012) summarized the advantages that BIM provides:

1. Through BIM all the building data is embedded in the model and can be accessed and shared throughout the project's life cycle. In addition, BIM provides the benefit of the ability to make early informed decisions about the project.
2. BIM allows a 3D simulation that can be used to predict collisions, show environmental variables, calculate material, quantities and so much more. Therefore, BIM adds a level of accuracy to the project as it can be virtually constructed before its physical construction.
3. BIM allows users to modify building components in one place and to have those modifications be reflected in all the other views of the project, elevations, sections, details. This feature saves a great deal of time and resources.

Although BIM provides many advantages, as presented above, it also presents a number of limitations that need to be taken into consideration (InfoComm, 2011):

1. The cost of purchasing, maintaining and upgrading BIM software packages tends to be more expensive than the CAD software applications which are currently available. In addition, the hardware requirements to operate BIM software packages are larger than with CAD, representing an additional cost. Consequently, with the creation of any new BIM software application, training must be provided. Monetary investment in training is therefore a necessary cost to consider.

2. With the transition from drafting to modeling using BIM, simple drafting tasks now requires a design drafter with a higher-level skill set. It requires more time, training and knowledge to model using BIM than to draft using CAD tools.

3. Interoperability issues are one of the biggest problems in the current use of BIM, as often, data cannot be exchanged and documented effortlessly within software tools. These issues are not only limited to different software tools, but to the rapid creation of new software versions of programs within the same platform. The updated versions of the software program also present interoperability issues when data cannot be properly imported or exported when using different versions of the same tool.

Examples of Software Tools Available

A number of BIM software tools are available today and they vary in their usage and complexity. In the building design community the following programs are the current most popular used BIM tools:

Autodesk Revit Architecture: Autodesk Revit technology is a building information modeling tool from the Autodesk platform. Built on the Revit model, Autodesk Revit Architecture software is a building design and documentation system that includes all phases of design, from conceptual studies to detailed construction drawings, as well as documentation and schedules. The software program provides tools that are accessible and instinctive to use for any kind of project. In addition to precise 2D drawing and 3D modeling views, Revit Architecture offers a high-quality rendering engine inside the program (Eastman, 2008).

SketchUp Pro: Google SketchUp Pro is used to create 3D models for marketing, preliminary estimation, detailing, site logistics and staging. In addition, Google SkecthUp is used for design and construction validation, sequencing and line-of-sight analysis. It allows cooperation and communication between the numerous stakeholders involved in a project (Trimble, 2013).

ArchiCAD: Graphisoft's ArchiCAD is the first object oriented BIM Architectural application available on the market and is the only BIM architectural application running on both MAC and Windows platforms. The information inside an ArchiCAD model is managed by a centralized database, similar to that of Autodesk Revit. The software's user interface is relatively simple to use and learn. One of the limitations of this tool is the lack of structural BIM applications inside the program. This limitation results in the use of other structural tools, such as Revit Structure and Tekla Structures (GRAPHISOFT, 2014).

Vectorworks: This program guides the user through the design process, from conception to construction documentation phase. Vectorworks Designer offers the most up to date technology for 2D drafting and flexible 3D modeling.Vectorworks user interface offers a very flexible 2D/3D environment that is beneficial for design purposes. However, it does not provide a consistent BIM workflow. This presents a major increase in the amount of time spent on consultation and collaboration between different stakeholders involved in a project (Nemetschek North America, 2010).

Use of BIM for Building Energy Modeling (BEM)

Building Information Modeling (BIM) is currently used in 56% of firms in North America on more than 50% of their projects. Figure 1 shows the frequency of BIM use by AEC firms and contractors, depending on the number of projects:

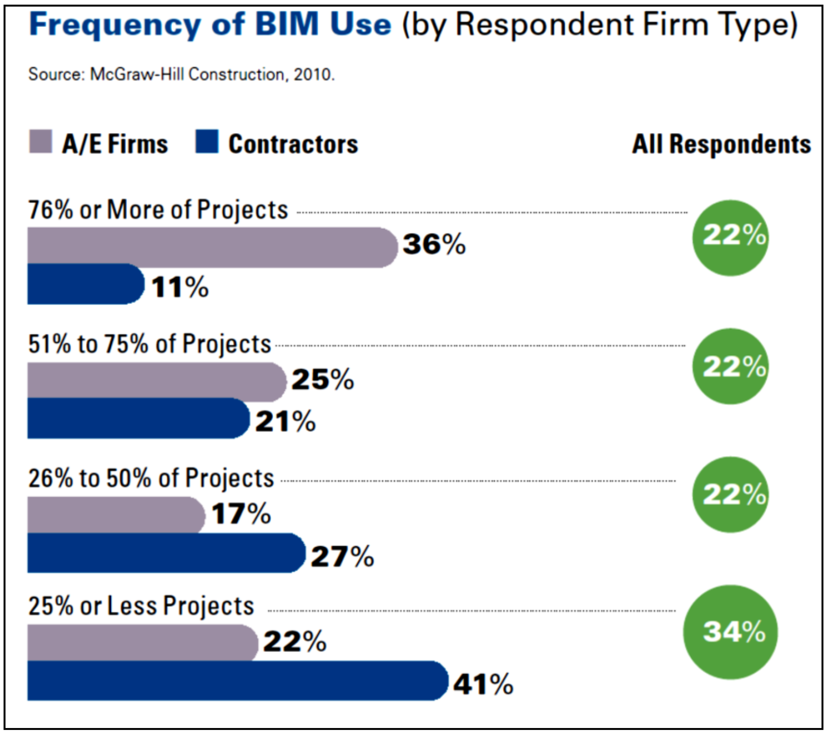


Figure 1: Frequency of BIM Use. Source: (McGraw-Hill Construction, 2010)

In addition, the use of BIM in building performance and energy modeling is currently increasing dramatically. Green BIM is defined as the use of BIM tools for sustainability and building performance purposes in a project. According to McGraw-Hill Construction (2010), 65% of all Green BIM practitioners, have performed total building performance simulations and 73% of practitioners use BIM for energy performance simulations. However, most Green BIM users are only implementing these tools on large projects. This indicates that firms are being selective with the projects in which they perform whole building analysis and energy simulations. This may be due to the high costs required to implement BIM solution in projects. Therefore, BIM is mainly implemented in projects that can support the costs of BIM in their budgets. As a result, incentives are being created to encourage energy efficiency measures in small projects. This will increase the use of BIM tools not only in Green Buildings but in all projects in general.

The following graphs, (see Figure 2 and Figure 3), present the percentage of Green BIM practitioners that use BIM for BEM tools in building and energy performance simulations:

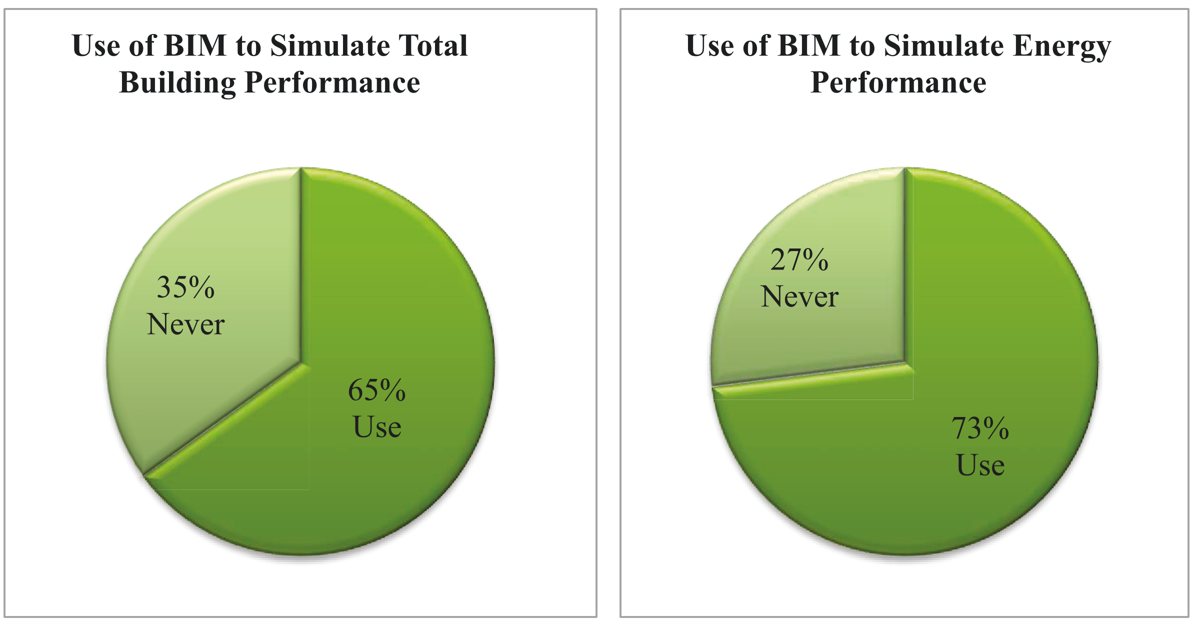


Figure 2 and Figure 3: Use of BIM tools for Building Performance Simulations. Source: (McGraw-Hill Construction, 2010)

The aspects that are most frequently simulated by Green BIM practitioners with the aid of BEM in energy performance analysis are the following:

- Lighting and Daylighting Analysis: 74%

- Whole Building Energy Use: 72%
- Energy Code Compliance: 70%
- Product Qualification & Selection: 64%
- Renewable Energy: 63%
- Natural Ventilation Analysis: 57%

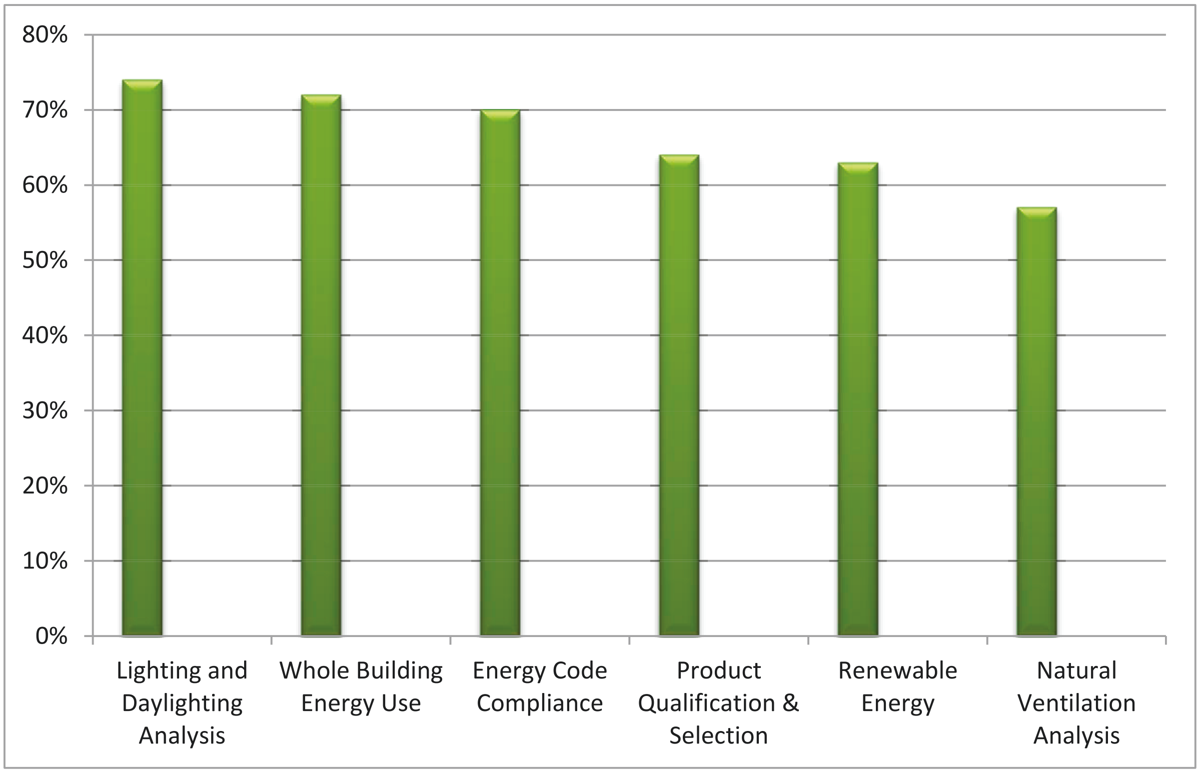


Figure 4: Most frequently simulated aspects by Green BIM practitioners in Energy Performance. Graphic created with the information obtained from (McGraw-Hill Construction, 2010)

2.2 Building Energy Modeling (BEM)

Energy simulation or modeling is used to explore the total energy usage of a building and all related issues. The following factors of energy modeling can predict the building's energy demands and the impact of the building's design on the global environment (Krygiel, 2008):

- Solar heat gain
- Heating, ventilation, and air conditioning systems (HVAC)
- Sun-shading devices
- Daylight dimming
- Lighting levels
- The number of occupants and their activity levels, etc.

Energy models provide an understanding of how features like the building envelope, building massing, window locations, building orientation and other parameters can affect the energy efficiency and demands of a building. Figure 5 presents an energy model created with different energy analysis tools like eQUEST and Autodesk Revit MEP:

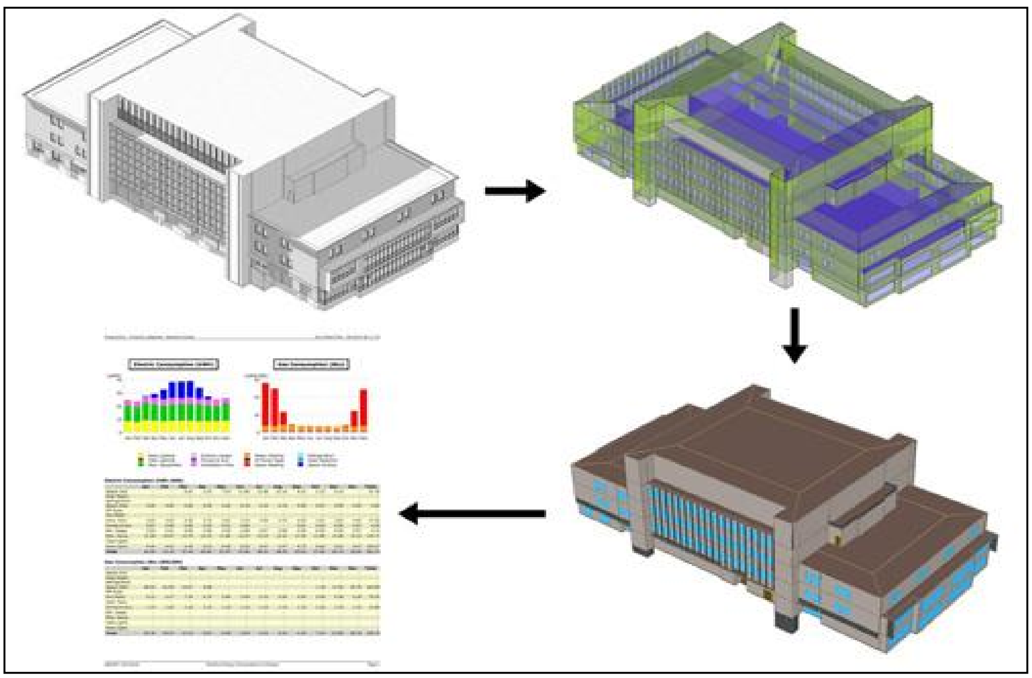


Figure 5: Same Energy Model created with different energy analysis tools. Source: (DesignGroup, 2013)

Advantages and limitations of BEM

There are many advantages of performing energy modeling on any AEC project (Caneta Research, 2007):

1. Energy modeling is a powerful tool that integrates the design process with energy analysis, allowing the design team to prioritize an investment in strategies that will affect the building's energy use. Through energy simulation of the building model, cost effective calculations can be made to meet the environmental requirements of any specific project. This step is necessary to qualify for LEED certification and any government incentives like the High Performance New Construction (HPNC) program of the Ontario Power Authority (OPA).
2. Through the study of a project's site location, building orientation and building massing, energy modeling can provide significant input during the conceptual phase of the building's design. In addition, it can help quantify the operating savings of any building throughout a project's life cycle.
3. Energy modeling provides a better understanding of the energy use of each project's building component. Through the performance of energy simulation, each design component is analyzed in order to evaluate its energy efficiency. When all the results of each building component are compared and examined, what results is a holistic view of the entire project's energy efficiency.

Even though BEM provides all the benefits described above, BEM currently presents a number of limitations as well:

1. One of the main restrictions of BEM is the missing user interface of some of its tools, which limits the capabilities of the software. In order to solve these issues, multiple graphical user interfaces (GUIs) are currently under development. In addition to these advancements, a flexible yet complete user interface is still required in some of the BEM tools in order to allow a more useful user input.

2. Another limitation of BEM is that the geometrical complexity import from the building design tool is constrained, due to the story-based building method. Lack of a reliable direct import of geometry, from building design projects like CAD software, represents a major issue for AEC companies using BEM. The interoperability issues between building design and energy models is a large obstacle in the implementation of BEM for building performance.

Example of Software Tools Available

A number of energy modeling applications are available today and they vary significantly in their level of detail and complexity. In the building performance community the following programs are the current most popular tools used in energy saving analysis (Krygiel, 2008):

EnergyPlus: EnergyPlus 2.1 incorporates the finest features from DOE-2 and BLAST energy simulation engines. The result is a next-generation energy simulation engine. The Building Loads Analysis and System Thermodynamics (BLAST) incorporates multiple programs to calculate energy consumption as well as energy system performance and cost in building construction. EnergyPlus is developed by Lawrence Berkeley National Laboratory (LBNL) and comprises the U.S. Army Construction Engineering Research

Laboratory (CERL), the University of Illinois (UI), Oklahoma State University (OSU), GARD Analytics, Florida Solar Energy Center and the U.S. Department of Energy (DOE) (Crawley *et al.* 2005). The V2.0 version is the latest instalment and, incorporates links to multi-zone airflow engines, COMIS (COMIS, 2003) and SPARK. SPARK's link to EnergyPlus allows for the creation of user-defined HVAC components based on its object library.

RIUSKA: Olof Granlund Oy started RIUSKA development in 1996. One of his primary goals was to create an instrument capable of being used during every life cycle phase, and of the reutilization of data (Jokela et al. 1997). Version 4.4.7 RIUSKA, based on the DOE-2.1E engine, has an IFC interface through the BSPro server middleware. The Granlund-developed BSPRO server systematically simplifies composite geometric material that the IFC model contains for the requirements of thermal simulation (Granlund, 2007 a).

eQUEST: eQUEST 3.60 is a free tool created by James Hirsch and Associates for Southern California Edison based on DOE-2.2, the most recent DOE-2 version. The main differences between DOW-2.1E and 2.2 are the ability to produce enhanced geometric depictions, which support multidimensional convex polygons, as well as an improved HVAC system concept and extra HVAC features (SRG, 1998). eQUEST is an easy to use building energy analysis tool that provides high quality results by combining a building creation wizard, an energy efficiency measure wizard and a graphical results display. Within eQUEST, DOE-2.2 performs an hourly simulation of the building based on walls, windows, glazing, users, plug loads, and ventilation. DOE-2.2 also simulates the performance of fans, pumps, chillers, boilers, and other energy-consuming devices.

eQUEST allows users to create multiple simulations and to view the alternative results in side-by side graphics. In addition, it offers energy cost estimating, daylighting, lighting system control and automatic implementation of energy efficiency measures (Models, 2010). This free energy modeling tool allows all DOE-2.2 replication software functionalities and supports Title 24 California energy code conformance analyses (California Energy Commission, 2007).

2.3 Interoperability Issues between Building Design Models and Building Energy Models

Interoperability issues in the AEC industry are not new. Following the rapid development of information technology, the first generation of data exchange models in the building industry was introduced in 1988. Models such as ICADS (Pohi & Rep, 1988), STEP (ISO, 1992), COMBIME (Augenbroe, 1992) and ARMILLA (Gauchel & Hovestadt, 1992) focused mainly on the building geometry information exchange. The second generation of data exchange models expanded to include energy information such as HVAC design, lighting design, thermal comfort simulation and building life-cycle analysis. KNODES (Rutherford, 1993) is one example of a second generation data model. Upon their creation and release, these models began to address the interoperability issues between various areas in building design. They presented a new opportunity for novel design integration (Lam, Wong, & et al., 2004).

BIM and BEM represent the current, third generation of data exchange models. The current generation models are able to integrate all the information related to a building in a comprehensive data schema in order to facilitate information exchange throughout a project's life cycle. The lack of interoperability between BIM and BEM software programs is the reason behind the current limited use of these tools. Information must ideally be exchanged effortlessly between the BIM and BEM tools in order to have a successful building energy analysis process (Kumar, 2008).

The interoperability issues between BIM and BEM tools are not only limited to the use of different software programs, but to the rapid creation of new software versions of programs within the same platform. Updated versions of software programs also present interoperability issues, as data cannot be properly imported or exported when using different versions of the same tool. These interoperability issues represent extreme losses of money, time and effort for the AEC firms. According to Gallaher *et al*, (2004), interoperability issues amounted to $15.8 billion in the year of 2003 alone. BIM and BEM tools currently do not exchange and interpret information flawlessly between one another. A typical building information conversion from a building model to an energy model currently presents numerous problems:

Loss of Object Parametric Information:

Parametric information consists of the constraints and restrictions pertaining to certain requirements in a building model. These constraints can be geometrical, to control the relationships of objects, or dimensional, to control the distance, angle, radius, and length values of objects. In a model with inadequate interoperability, the loss of object parametric information can be exposed by the lack of parametric data entries in the model's exporting process. Figure 6 shows an example of lost object parametric information of the exporting process from Design Builder V2.3 to EnergyPlus V6.0 (Lam *et al.* 2012):

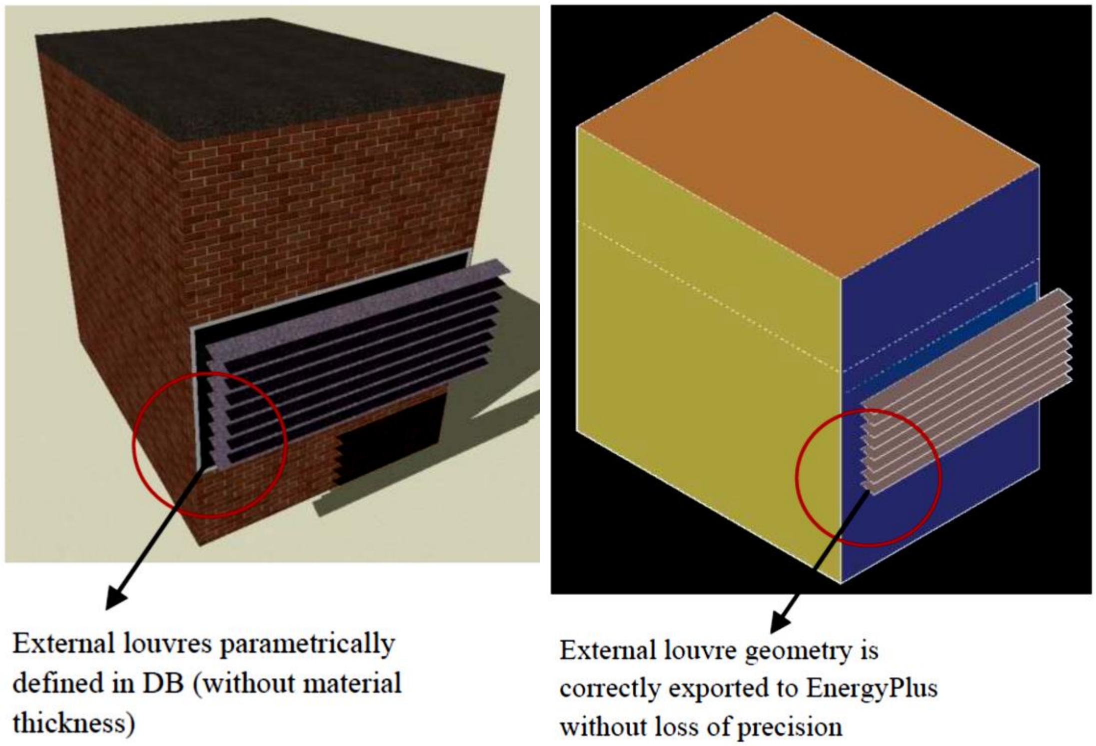


Figure 6: Loss object parametric information of the exporting process from Design Builder V2.3 to EnergyPlus V6.0. Source: (Lam et al. 2012).

Figure 6 shows how the external blinds of the Design Builder model are exported correctly to EnergyPlus, with a specific maximum number of vertices, in regards to element geometry. However, the elements of the external blinds have no thickness and are treated as mere 2D surfaces. Therefore, additional geometric calculations are required to parametrically correct the overall surface geometry of the blinds, complete with their proper tilt and angle (Lam *et al.* 2012).

***Geometric misrepresentations*:**

Geometric misrepresentations are one of the main problems contributing to the current inadequate interoperability between building design and energy modeling. When a building model is exported into an energy modeling tool, import functions seem not to differentiate geometric information of the definition of a shade, wall or roof. This issue not only occurs in the transition from building design tool to energy modeling tool, but also amongst building design tools. Figure 7 presents an example of geometric misrepresentations that may occur during the importing process of a gbXML file, originally created with Autodesk Revit Architecture, into Design Builder V2.3 (Lam *et al.* 2012):

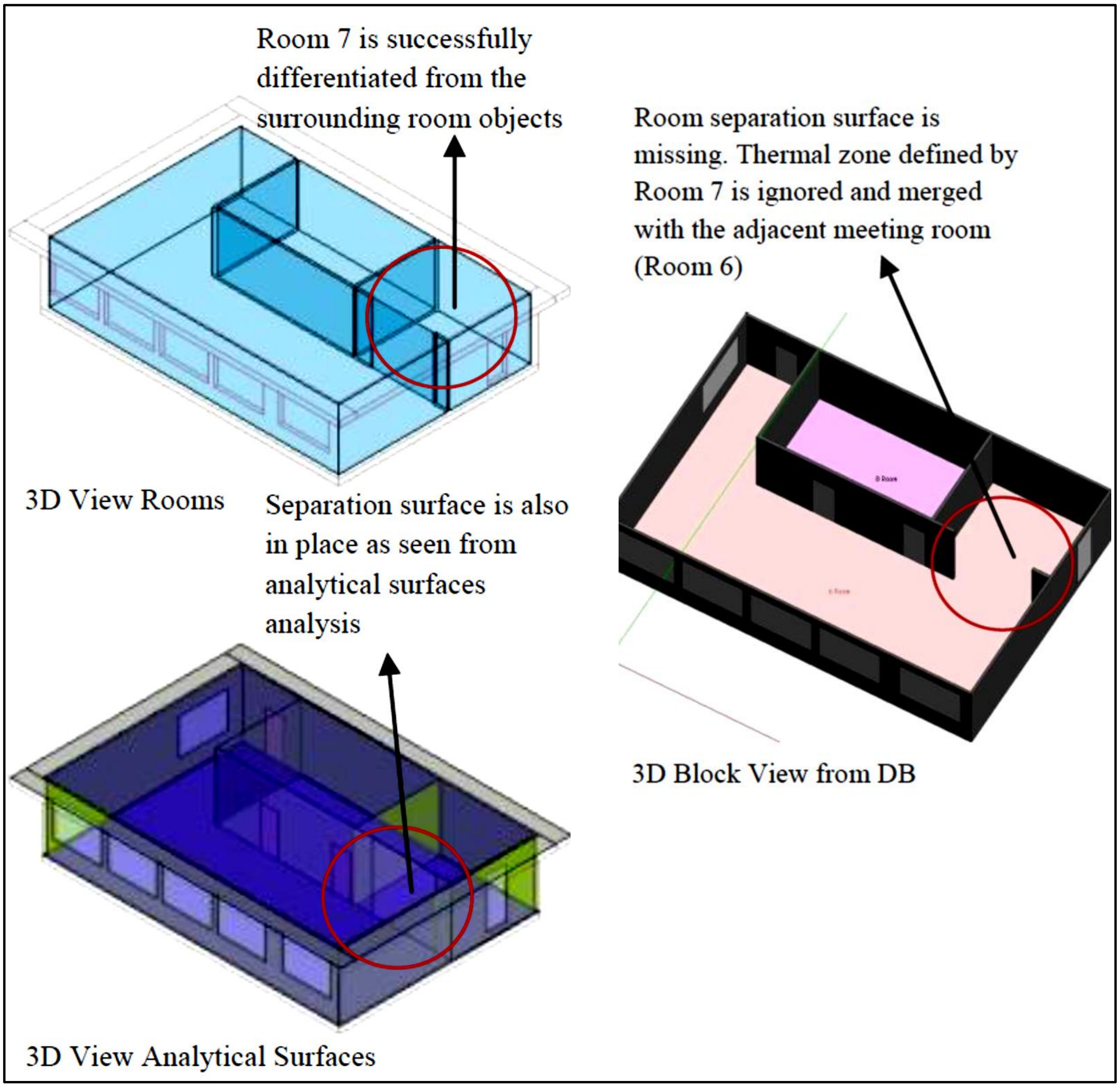


Figure 7: Importing process of a gbXML file created with Autodesk Revit Architecture into Design Builder V2.3. Source: (Lam et al. 2012).

The above figure shows a missing room separation surface in the model, after its import to Design Builder V2.3. This example does not only demonstrate a geometric misrepresentation, but also, because of the missing wall, the already-defined thermal zones of the model are skewed.

Re-input Data Confusion:

Resulting from the many object parametric losses and geometric misrepresentations described above, a re-input of the data in the energy model is necessary to perform a successful energy analysis process. Unfortunately, the re-input data can be easily misinterpreted, resulting in confusion and extra work for the user. This issue therefore represents significant losses of time, money and effort for the AEC industry.

All these barriers to integration are caused by a lack of interoperability between file formats, which affects the import of files between different energy analysis tools. Loss of object parametric information, geometric misrepresentations and re-input data confusion are all factors which interfere with the successful interoperability process between energy analysis tools. This is a significant issue that BIM and BEM are still working on.

2.4 Current Solutions for the Interoperability Issues between Building Design and Building Energy Modeling

There are currently two main types of solutions to the interoperability between BIM and BEM: the employment of modeling tools designed by the same developers and the creation of open standard schemas.

Modeling Tools from the Same Developers

There are a number of energy modeling applications available today, which aid in the current practices of building design and energy analysis. These tools vary significantly in their levels of detail and complexity. The interoperability issues of the applications also vary depending on whether or not the building design and energy analysis tools are software programs from the same developer. When the tools are owned by the same developer, they usually have integration capabilities between them. Software programs developed by different companies, however, do not. In the building design community the following programs are currently the most widely- used tools for performing energy saving analysis that are also developed in collaboration with the same design teams (Krygiel, 2008):

Autodesk Ecotect + Autodesk Revit Architecture: In 2009, Ecotect was acquired by Autodesk from its original creator, Square One Research. This application offers an excellent and easy to use graphical interface that allows designers to simulate building performance in the earliest stages of conceptual design. As an alternative solution to current interoperability issues in the energy analysis process, Ecotect offers great import and export solutions to software created by Autodesk.

Autodesk Green Building Studio (GBS) + Autodesk Revit Architecture: Autodesk Green Building Studio is a web-based energy analysis software that allows the user to upload a gbXML file for a free energy analysis simulation. This tool provides a quick, graphical feedback of the building's energy analysis based on a survey of similar buildings and loads. The GBS service creates a geometric thermal model of the building, applying local building code assumptions and a DOE-2 input to run the analysis and send a summary report back to the user's browser (Autodesk I. 2005). GBS offers interoperability solutions through the Green Building Extensible Markup Language (gbXML). A gbXML file needs to be created and imported into the GBS web service, where export capabilities to DOE-2 INP and EnergyPlus files are provided. However, this process is not always successful.

DProfiler: DProfiler is a "macro" BIM software targeted towards the planning and conceptual design phase to get an accurate cost estimate of a proposed building design. It is a "macro" BIM software tool because it focuses on holistic, high level model information for analysis and decision making. DProfiler provides the user with detailed cost estimates, simple 3D modeling, real-time estimating process, energy analysis and sequencing/cash flow capabilities. In addition, DProfiler advertises its ability for export capabilities to software tools like eQUEST.

Limitations of this Solution

Modeling solutions created by the same developers present interoperability solutions only for the tools designed within the same companies. The challenge of this solution is to import and export model geometries to different applications that are created by outside developers. For example, importing geometries to applications like eQUEST can be very challenging (Autodesk, 2013). Even though tools such as Green Building Studio (GBS) and DProfiler advertise exporting capabilities to other software programs, this process is frequently not successful.

These tools are expensive and require a number of hardware updates and constant training. The license cost for purchasing Autodesk Ecotect is currently US$3,000. While the license cost of Autodesk Revit Architecture is currently US$5, 775. Green Building Studio (GBS) is only available to users that also purchase a subscription to Autodesk products such as: Autodesk Revit, AutoCAD, Autodesk Ecotect Analysis and Autodesk Building Design Suite. The annual subscription rate is currently US$720 (Autodesk, 2013). As for DProfiler, the cost of the entry point license is US$3,400 dollars annually. The network license costs US$7,500 plus US$1,500 annually for support and maintenance. The list price of the non-subscription version is US$5,000 (Beck Technology, 2012).

Creation of Open Standard Schemas

Efforts towards solving the interoperability issues posed by software tools developed by different owners rely mainly on the proposal of general open standard schemas. Open standard schemas are publicly and freely open source tools available to address the problem of interoperability of data formats by offering industry wide languages rules and semantic necessary to support data exchange automation (Owolabi A, Anumba C J and El-Hamalawi A, 2003). The reason new open schemas are proposed to solve interoperability issues, is because developing integration solutions between software tools is a difficult and complex task. This solution requires a lot of effort, heavy coding and accessibility to the tools for both the users and the software developers (Cate, Kolaitis, and Tan, 2013).

.

In order to facilitate the interoperability of building information, the following two open standard schemas have been developed:

Industry Foundation Class (IFC): The International Alliance for Interoperability (IAI) is responsible for the creation of the international data exchange for building information, also called IFC. The IFC file format was adopted by the IAI from ISO (STEP part 21) to be the representation of an object-oriented building description throughout all life cycle phases and disciplines of a building (IAI, 2007). The main goal of IFC is to establish a universal basis for exchanging information in the architecture, engineering and construction industry (Lam *et al.* 2012). The IAI's IFC development efforts were mostly focused on the HVAC domain and the architectural representation of buildings, called coordination view. A main goal of the BIM file is to store and allow data access of a building project, over every building life phase and across all relevant disciplines. BIM files, which can be reused by other programs, can be read or written by software applications, limiting redundancy and loss of accuracy.

The creation of the IFC language played a great role as a solution for inadequate interoperability exchange of information in the AEC industry. However, this schema is limited due to the technological weakness in their specifications. IFC limits the users to a certain level of expression. The models created with unique building elements, complex 3D curved roofs or sloped wall cannot be described in the IFC schema (Pauwels et al. 2011). The following figure presents an instance diagram of material representation in an IFC file (see Figure 8).

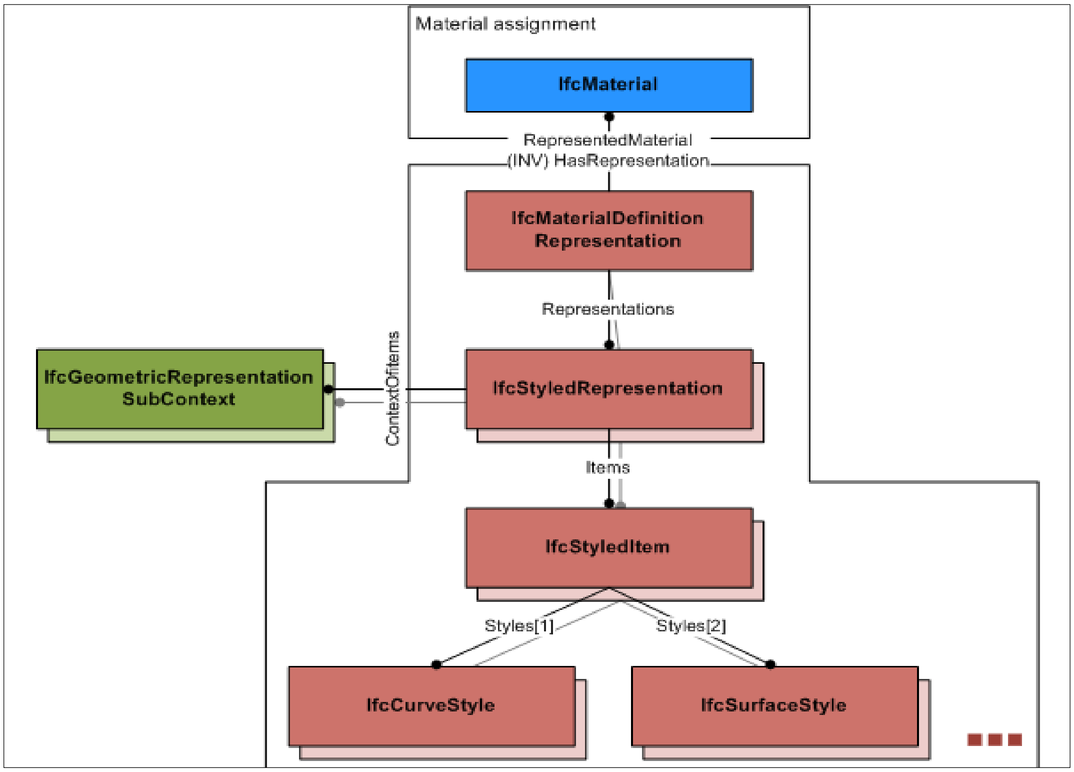


Figure 8: Instance diagram of material and product representation in an IFC file. Source: BuildingSmart-Tech (2013)

Green Building XML (gbXML): gbXML is a conversion format initially designed to trade building geometry with DOE-2 and later, with EnergyPlus software. gbXML is developed based on the Extensible Markup Language (XML) format. It represents a project's building information (e.g. building geometry and material properties), using an XML-based schema. The basic structure of a gbXML file consists of a series of elements that include information of rooms, ceilings, walls, shading surfaces, windows and other inherit properties model information (Green, Aksamija, Thun, Velikov, & Tazelaar, 2013). This tool was formerly developed by GeoPraxis, now known as Green Building Studio. The purpose of the creation of this open standard schema was to facilitate the transfer of CAD building information between current building design tools. gbXML has the support of leading CAD and HVAC software vendors. As a result, gbXML has become the actual industry standard schema. This schema enables building design teams to truly collaborate and benefit from the uses of BIM (McQuiston *et al.* 2005). Figure 9 presents the diagram of the “Frame” element in the gbXML schema.

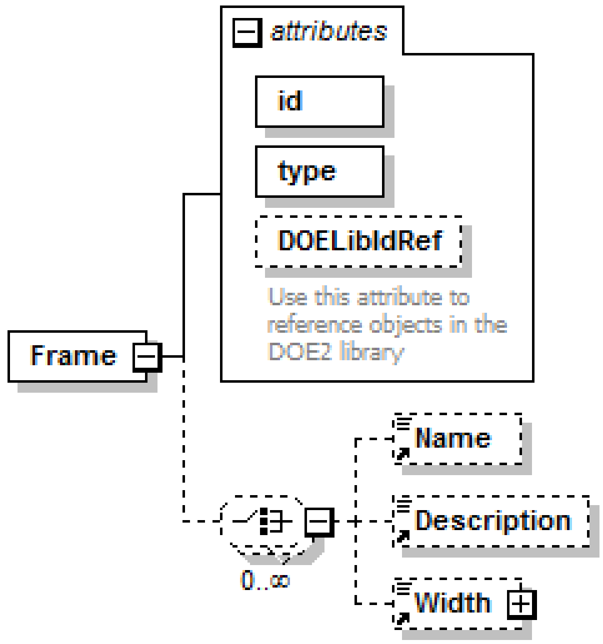


Figure 9: Diagram of the “Frame” element in the gbXML schema. Source: (gbXML org., 2014)

Limitations of this solution

Open schemas are not supported by every software tool. The gbXML (green building XML) open schema is only supported by vendors such as Autodesk, Bentley and Graphisoft at present. Software programs like eQUEST do not support the gbXML open schema and use the DOE-2 input file (INP file) instead. DOE-2 INP files store the building description input from software programs that have a DOE-2 simulation engine. Therefore, file converters to another schema are necessary in order to interoperate with other programs. This poses a vast problem when file exportations are unsuccessful and arduous schema mapping is then required to solve the file converter issues.

The modification of open standard schemas is a complex task. For example, the IFC schema differentiates from the gbXML schemas by using a “Top-down” and relational approach, which results in a relatively complex data representation and an extremely large data file size. On the other hand, the gbXML open schema adopts a “bottom-up” approach, which is considered to be a more flexible, open source and relatively straight-forward data schema. However, there is currently not enough technical information provided by the creators of gbXML to enhance the schema (Lam *et al.* 2012).

CHAPTER THREE: OBJECTIVES, SCOPE AND PROPOSED METHODOLOGY

The objectives and scope of this dissertation are presented in this chapter. The description and development of the proposed integration solution are also defined. In addition, explanations and clarifications of each of the steps involved in the proposed solution are provided. Finally, the implementation and results of the proposed integration solution are highlighted to be addressed in following chapters.

3.1 Objectives

The results obtained from the literature review analysis of this dissertation presented the major limitations of the current solutions to inadequate interoperability in the AEC industry. The current solutions are costly, ineffective, complex and not supported by every software tool. Therefore, the main objective of this dissertation is to resolve these limitations by creating and implementing a novel open schema converter between building design and energy modeling tools. The research goal is to address the interoperability problems of these tools in order to facilitate their unified information exchange. In order to achieve this goal, a set of sub-objectives are defined as follow:

1. To study the broad uses of BIM and BEM tools in the energy analysis process.
2. To conduct comprehensive research on the interoperability issues between existing BIM and BEM software tools.
3. To analyze the importance of the current interoperability issues affecting the AEC industry today.

4. To design, implement and evaluate a novel open schema converter in order to facilitate the effortlessly information exchange in the current interoperability process.
5. To develop software plug-in component in the building design tool environment in order to execute the proposed open schema converter.
6. To validate the proposed converter solution and the developed software plug-in component through the analysis of three real case studies.

3.2 Scope

The purpose of this study is not to create a new open standard schema in the building design and energy modeling integration process, in addition to the many that already exist. Instead, the focus is placed on the design of a novel open schema converter solution. The converter is expected to properly transform the information from the open standard schemas (gbXML and DOE-2 INP files) in order to correct all the issues resulting from the current conversion solution practices. The gbXML (Green Building XML) open schema is currently supported by vendors such as Autodesk, Bentley and Graphisoft. Software programs like eQUEST do not support the gbXML open schema, but rather relies upon the DOE-2 input file (INP file). DOE-2 INP files store the building description and energy input resulting from software programs that support a DOE-2 simulation engine.

The scope of this study is limited to the interoperability issues between Autodesk Revit and eQUEST. Autodesk Revit and eQUEST are currently two of the most highly utilized tools in building design and energy analysis respectively. The Autodesk Revit software is selected for the purpose of this study because is one of the most popular software tools used to provide accurate, high quality building designs (Autodesk I. 2011). Autodesk Revit is intended for Building Information Modeling (BIM), and is capable of design, documentation, construction planning and fabrication. Any change made in the building design is updated along with the corresponding documentation information. Consequently, eQUEST, which stands for "Quick Energy Simulation Tool," is selected for this study due to its frequent use in AEC companies all around the world. eQUEST is a free, simple and easy to follow energy analysis simulation tool so comprehensive and intuitive that any team member of a design team can use it.

Moreover, the proposed open schema converter solution focuses on the conversion of the building location, geometry and material information of the gbXML and DOE-2 INP schemas. The conversion of this information currently presents the most interoperability issues in the transformation process of these open standard schemas. Therefore, solving the conversion issues from these sections will serve to rectify the major interoperability issues from the gbXML schema to the DOE-2 INP schema. Although the conversion process mainly focuses of these issues, other information such as daily schedule, weekly schedule, building construction and HVAC systems, are also properly transformed when using the proposed open schema converter.

In order to perform the conversion process from gbXML to DOE-2 INP, the C# (sharp) programming language and the Extensible Style-sheet Language Transformation (XSLT), are selected. C# is a modern and simple object-oriented programming language created by Microsoft. While XSLT is a powerful and flexible XML-based language for transforming XML documents into other formats. For example, an HTML document, another XML document, a Portable Document (PDF) file, a Scalable Vector Graphics (SVG) file, Java code, a flat text file or a JPEG file, among many others can be resulted from an XSLT. XSLT was developed by the World Wide Web Consortium (W3C). The most recent version is XSLT 2.0, which reached W3C recommendation status on January 23, 2007 (Williams, 2009). The reason behind the selection of XSLT is due to the fact that it's dominate feature consists of a sequence of template rules, each of which describes how a particular element type or other construct should be processed. The rules are not arranged in any particular order, they do not have to match the order of the input or the order of the output. This is what makes XSLT a declarative language, because the user specifies what output should be produced when particular patterns occur in the input.

3.3 Overall Framework of the Proposed Methodology

In order to achieve the objectives of this dissertation, a novel open schema converter is designed. Figure 10 shows the overall framework of the proposed converter solution. The methodology of the proposed converter can be divided in two general steps. First, the design of a novel Extensible Stylesheet Language Transformation (XSLT), where the proposed solution takes the gbXML open standard schema as input. This style sheet comprehends a series of code instructions pre-created from a collection of gbXML files database. Once the XSLT is created, the conversion process of the proposed open schema converter initiates. The XSLT locates and selects the required gbXML element based on its unique building name ID. Afterwards, it is then necessary to go back to the XSLT to determine the corresponding instructions for the conversion of that element into a DOE-2 INP schema. Based on those instructions, the gbXML file is once more explored in order to retrieve the data needed for the conversion of this information. This step is then repeated for each one of the elements needed for conversion (e.g. building geometry, project location and material information). Finally, the gbXML is transformed and serialized into a DOE-2 INP file where adequate element location, material reformulation and proper Metric to Imperial system conversion are required.

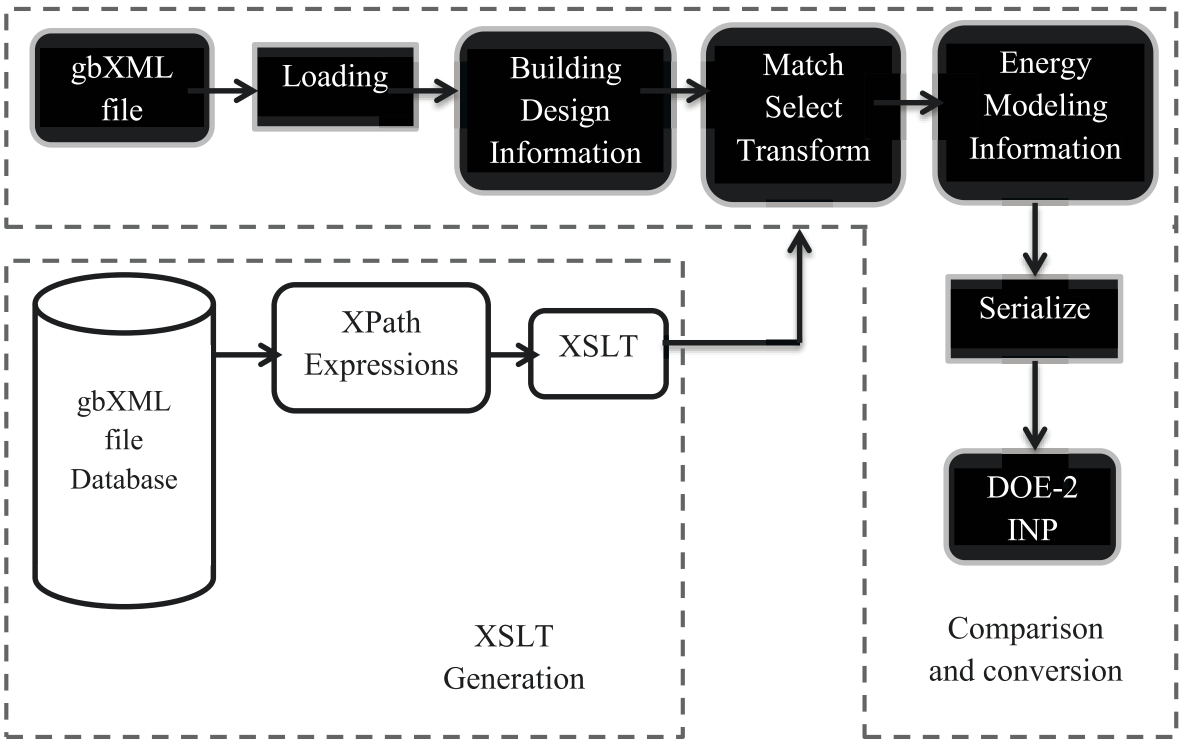


Figure 10: Overall framework of the proposed converter solution

3.4 XSLT Generation

Rationale behind selection

XSLT was chosen to represent the transformation rules of the proposed converter solution due to its ability to formally define the transformation rules separately. Building design and energy models evolve with time. New concepts can be added, and existing concepts can be removed or updated. Therefore, the transformation rules may require continuous updates which can be easily achieved using XSLT. Also, it is possible for the transformation process to use many different types of sources. Therefore, using XSLT enables easy management and evolution of the transformation process with no need to redevelop, rebuild or redistribute the model's conversion tool. In addition, XSLT is specifically designed for XML, which means that there is no need to worry about the details of reading or writing XML files. Furthermore, the transformation code resulted from XSLT is smaller than other languages, which makes it easier to understand and improves its maintainability.

XSLT transformation rules

In the proposed XSLT, every template corresponds to the transformation instructions of one element. Each template consists of a series of XSLT functions created and assigned to properly convert from gbXML to DOE-2 INP schema. The following table summarizes the XSLT functions employed in the open schema conversion process (see Table 3):

XSLT Elements	**Function Description** Source: (Williams, 2009)	**Example**
xsl:apply-templates	Defines a set of nodes to process	***<xsl:apply-templates*** *select="gb:Longitude"/>*
xsl:for-each	Selects a sequence of items for uniform processing	***<xsl:for-each*** *select='//gb:Surface' >*
xsl:if	Defines a test condition, and a sequence constructor to perform if the condition evaluates to *true*	***<xsl:if*** *test="expression">* *"gb:Tilt= 30"*</**xsl:if>**

xsl:output	Determines the format of a result document that is written to the output	***<xsl:output*** *method="text" indent="yes"/>*
xsl: sort	A sort key component, any number of which may be combined in a sort specification	***<xsl:sort*** *select=".//gb:Azimuth"/>*
xsl:stylesheet	Serves as the root element of a style-sheet	***<xsl:stylesheet*** *xmlns:xsl= "http://www.w3.org/1999/XSL /Transform" version="2.0" xmlns:gb= "http://www.gbxml.org/schema">*
xsl:template	Templates are the building blocks of XSLT. This element is used to declare a template for generating nodes in a result tree	***<xsl:template*** *match="/">*
xsl:transform	Serves as a synonym of *<xsl:stylesheet>*	***<xsl:transform*** *xmlns:xsl= "http://www.w3.org/1999/XSL /Transform" version="2.0" xmlns:gb= "http://www.gbxml.org/schema">*
xsl:value-of	Adds a text node to the result sequence	***<xsl:value-of*** *select="gb:Name"/>*

Table 3: XSLT functions employed in the open schema conversion process

The XSLT elements presented above were employed in the proposed XSLT in order to convert from gbXML to DOE-2 INP schema. The examples provided for each XSLT element were taken from the expressions utilized in the proposed XSLT.

Considering the scope of this dissertation, the proposed open schema converter solution focuses on the conversion of the building location, geometry and material information of the gbXML and DOE-2 INP schemas:

Building Location

XSLT elements are used to find the building location information in the gbXML file. For example, the following expression was employed in order to locate the building location information in the proposed open schema converter (see Figure 11):

```
<xsl:template match="gb:gbXML/gb:Campus/gb:Location">
```

Figure 11: XSLT expression employed in order to locate the building location information in the gbXML from the proposed converter solution

This expression is used to detect all the location information inside the gbXML file. The term "gb:" located in front of the name elements, is used to declare the default namespace of the gbXML file. Then, locations tags with the elements name are created, which conforms to how DOE-2 INP file defines locations (see Figure 12):

```
<p><code>---$ Site and Building Data $---</code></p>

<p><code>SITE-PARAMETERS</code></p>

<p><code>LATITUDE=</code></p>

<p><code>LONGITUDE= </code></p>
```

Figure 12: Part of the location tags created with the corresponding DOE-2 INP elements name from the proposed converter solution

Later, templates are applied and added to the location in order to search and match for the correspondent child elements of the location (see Figure 13):

```
<p><code><xsl:apply-templates select="gb:Latitude"/></code></p>

<p><code><xsl:apply-templates select="gb:Longitude"/></code></p>
```

Figure 13: XSLT expression employed in order to locate the child elements of the location information in the gbXML from the proposed converter solution

The following figures present one of the source gbXML files utilized to retrieve the location information needed for conversion, and the resulted DOE-2 INP file from the conversion process (see Figures 14 and 15):

```
<?xml version="1.0" encoding="UTF-8"?>
<gbXML xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
 xsi:schemaLocation="http://www.gbxml.org/schema xsi.xsd"
 xmlns="http://www.gbxml.org/schema"
 temperatureUnit="C" lengthUnit="Meters" areaUnit="SquareMeters"
 volumeUnit="CubicMeters"
 useSIUnitsForResults="true"
 version="0.37">
  <Campus id="cmps-1">
     <Location>
         <Latitude>46.210000</Latitude>
           <Longitude>-72.350000</Longitude>
     </Location>
  </Campus>
</gbXML>
```

Figure 14: Part of the gbXML file location information from Case Study 1: Classroom Project.

```
$ ---------------------------------------------
$                Site and Building Data
$ ---------------------------------------------

SITE-PARAMETERS
   LATITUDE          = 46.210000
   LONGITUDE          = -72.350000
```

Figure 15: Part of the DOE-2 INP file location information resulted from Case Study 1: Classroom Project

Geometry Information

Instruction rules inside each template component make it possible to transform the geometry information inside the gbXML file. For example, the transformation rule created for declaring the geometry information states that:

"For every surface id located in the gbXML file extract the name, description, azimuth, tilt, height and width values. Create the surface's coordinates information using the extracted height and width values and sort the data according to the azimuth and tilt information".

The XSLT functions "*xsl:template match"* and *"xsl:value-of"* are used through the transformation rules to locate the desired element patterns inside the XML tags (see Figure 16). The XSLT function "*xsl:sort*" is used for condition control, which is very similar to "*if statements*" in traditional programming languages. The "*xsl:for-each*" is used to define and locate XML tag elements and attributes where XSLT variables were used to hold temporary values inside the local block (see Figure 17). One important note on the use of XSLT variables is that their value is only defined inside the block that contains them. For instance, the variable “Surface” is only defined within the scope of the “for each” loop. In addition, proper Metric to Imperial system conversion are required. The following XSLT expressions declare a portion of the XSLT created in order to convert the geometry information:

```
<xsl:template match= "gb:Surface">

</td>
        <td>
          <p><code>
            <xsl:value-of select="gb:RectangularGeometry/gb:Height*3.28084"/>
          </code></p>
        </td>
        <td>
          <p><code>
            <xsl:value-of select="gb:RectangularGeometry/gb:Width*3.28084"/>
          </code></p>
        </td>
```

Figure 16: Part of the XSLT functions used to locate the desired geometry patterns inside the gbXML file from the proposed converter solution

```
<td>
          <xsl:for-each select='//gb:Surface' >
            <xsl:sort select=".//gb:Azimuth" data-type='number'
order="ascending"/>
            <xsl:sort select=".//gb:Tilt"     data-type='number'
order="ascending"/>
           <xsl:value-of select="@id" />
            (<xsl:value-of select=".//gb:Width" />,0.00)
            (<xsl:value-of select=".//gb:Width" />,<xsl:value-of
select=".//gb:Height" />)
            (0.00,<xsl:value-of select=".//gb:Height" />)
            (0.00,0.00)
          </xsl:for-each>
        </td>
```

Figure 17: XSLT expression that declares a portion of the XSLT created in order to transform the geometry information from the proposed converter solution

The following figures present part of one of the source gbXML files utilized to retrieve the geometry information needed for conversion, and the resulted DOE-2 INP file from the conversion process (see Figures 18 and 19):


```
  <?xml version="1.0" encoding="UTF-8"?>
- <gbXML version="0.37" useSIUnitsForResults="true" volumeUnit="CubicMeters"
  areaUnit="SquareMeters" lengthUnit="Meters" temperatureUnit="C"
  xmlns="http://www.gbxml.org/schema"
  xsi:schemaLocation="http://www.gbxml.org/schema xsi.xsd"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  - <Campus id="cmps-1">
    + <Location>
    + <Building id="bldg-1" buildingType="Office">
    - <Surface id="su-1" constructionIdRef="ASHWL-66" surfaceType="ExteriorWall">
        <Name>N-1-E-W-1</Name>
        <AdjacentSpaceId spaceIdRef="sp-1-Room_1"/>
      - <RectangularGeometry>
          <Azimuth>0.000000</Azimuth>
        + <CartesianPoint>
          <Tilt>90.000000</Tilt>
          <Height>2.400000</Height>
          <Width>7.900000</Width>
        </RectangularGeometry>
      + <PlanarGeometry>
      + <Opening id="su-1-op-1" constructionIdRef="MDOOR"
        openingType="NonSlidingDoor">
      + <Opening id="su-1-op-2" openingType="OperableWindow"
        windowTypeIdRef="DGL-R-I">
      + <Opening id="su-1-op-3" openingType="OperableWindow"
        windowTypeIdRef="DGL-R-I">
        <CADObjectId>Basic Wall: Generic - 200mm [431543]</CADObjectId>
      </Surface>
    - <Surface id="su-2" constructionIdRef="ASHWL-66" surfaceType="ExteriorWall">
        <Name>E-1-E-W-2</Name>
        <AdjacentSpaceId spaceIdRef="sp-1-Room_1"/>
      - <RectangularGeometry>
          <Azimuth>90.000000</Azimuth>
        + <CartesianPoint>
          <Tilt>90.000000</Tilt>
          <Height>2.400000</Height>
          <Width>8.800000</Width>
        </RectangularGeometry>
```


Figure 18: Part of the gbXML file geometry information from Case Study 1: Classroom Project.

```
$ --------------------------------------------------
$                Polygons
$ --------------------------------------------------

$N-1-E-W-1
"su-1GEOM"= POLYGON

  V1        = ( 25.9186351706, 0.00000000 )

  V2        = ( 25.9186351706, 13.074015748 )

  V3        = ( 0.00000000, 13.074015748 )

  V4        = ( 0.00000000, 0.00000000 )

   ..
$E-1-E-W-2
"su-2GEOM"= POLYGON

  V1        = ( 0.00000000, 0.00000000 )

  V2        = ( 28.8713910761, 0.00000000 )

  V3        = ( 28.8713910761, 13.074015748 )

  V4        = ( 0.00000000, 13.074015748 )

   ..
```

Figure 19: Part of the DOE-2 INP file geometry information resulted from Case Study 1: Classroom Project

Material Information

In the new DOE 2-INP schema the “Material” command now requires the specification of the “Type” keyword. The “Type” keyword must be present and be the first keyword specified. The values for “Type” are either properties or resistance; these values specify which input keywords are to be used (are required) for this “Material” command. Therefore, the material information inside the gbXML file needs to be located and converted according to new DOE-2 INP file specifications. In addition, proper Metric to

Imperial system conversion are required. The material information from the gbXML is created through the instructions of a template rule. This rule states that:

"*For every material id located in the gbXML file, the name, thickness, conductivity, density and specific heat information are extracted. The extracted information is then converted from the Metric System to the Imperial System by using the corresponding multiplication command and values*". The following XSLT expression declares a portion of the XSLT created in order to convert the material information (see Figure 20):

```
<xsl:template match= "gb:Material">
      <p><code>..</code></p>
      <table border="0">
         <tr>
            <td>
               <p><code>$</code></p>
            </td>
            <td>
               <p><code>
                  <xsl:value-of select="gb:Name"/>
               </code></p>
            </td>
         </tr>
         <tr>
            <td>td>
               <p><code>THICKNESS    =</code></p>
            </td>
            <td>
               <p><code>
                  <xsl:value-of select="gb:Thickness *3.28084"/>
               </code></p>
            </td>
```

Figure 20: XSLT expression that declares a portion of the XSLT created in order to convert the material information from the proposed converter solution

The following figures present part of one of the source gbXML files utilized to retrieve the material information needed for conversion, and the resulted DOE-2 INP file from the conversion process (see Figures 21 and 22):


```
  <?xml version="1.0" encoding="UTF-8"?>
- <gbXML version="0.37" useSIUnitsForResults="true" volumeUnit="CubicMeters"
  areaUnit="SquareMeters" lengthUnit="Meters" temperatureUnit="C"
  xmlns="http://www.gbxml.org/schema"
  xsi:schemaLocation="http://www.gbxml.org/schema xsi.xsd"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  - <Material id="mat-AM13">
        <Name>8 in lightweight concrete</Name>
        <Description>8 in (200 mm) lightweight concrete</Description>
        <Thickness unit="Meters">0.2032</Thickness>
        <Conductivity unit="WPerMeterK">0.53</Conductivity>
        <Density unit="KgPerCubicM">1280</Density>
        <SpecificHeat unit="JPerKgK">840</SpecificHeat>
    </Material>
  - <Material id="mat-AF08">
        <Name>Metal surface</Name>
        <Description>Metal surface</Description>
        <Thickness unit="Meters">0.0008</Thickness>
        <Conductivity unit="WPerMeterK">45.28</Conductivity>
        <Density unit="KgPerCubicM">7824</Density>
        <SpecificHeat unit="JPerKgK">500</SpecificHeat>
    </Material>
  - <Material id="mat-860">
        <Name>1 1/2 in wood</Name>
        <Description>1 1/2 in (40 mm) wood</Description>
        <Thickness unit="Meters">0.0376</Thickness>
        <Conductivity unit="WPerMeterK">0.15</Conductivity>
        <Density unit="KgPerCubicM">608</Density>
        <SpecificHeat unit="JPerKgK">1630</SpecificHeat>
    </Material>
```


Figure 21: Part of the gbXML file material information from Case Study 1: Classroom Project.

```
$ ---------------------------------------------------------------
$                  Materials / Layers / Constructions
$ ---------------------------------------------------------------

$8 in lightweight concrete
"mat-AM13 8 in lightweight concrete" = MATERIAL
   TYPE                 = PROPERTIES
   THICKNESS            = 0.66667
   CONDUCTIVITY         = 0.306228334648663
   DENSITY              = 79.9077888
   SPECIFIC-HEAT        = 0.200630553167097
   ..

$4 in brick
"mat-AM01 4 in brick" = MATERIAL
   TYPE                 = PROPERTIES
   THICKNESS            = 0.33333
   CONDUCTIVITY         = 0.514232486485491
   DENSITY              = 119.8616832
   SPECIFIC-HEAT        = 0.188688258335722
   ..

$Wood 2in  (HF-B1)
"mat-394 Wood 2in  (HF-B1)" = MATERIAL
   TYPE                 = PROPERTIES
   THICKNESS            = 0.1667
   CONDUCTIVITY         = 0.07
   DENSITY              = 37
   SPECIFIC-HEAT        = 0.2
   ..
```

Figure 22: Part of the DOE-2 INP file material information resulted from Case Study 1: Classroom Project

The last part of the conversion process contains the transformation rules for creating the schedule information. In addition, a final declaration is created: *"<xsl:apply-templates/>"*. That declaration is responsible for creating instances of the created templates by passing values for the template parameters. The rule states that:

"*For each template created, apply the transformation rules inside the elements and the stylesheet currently generated*".

3.5 Conversion Process

The process of converting from the gbXML schema to DOE-2 INP schema is more complex than a typical XML file conversion process. Meticulous attention to the adequate element location is required. In addition, material information needs to be reformulated, and properly conversion from the Metric system to the Imperial system is essential. For example, the task of converting the geometric information from the gbXML schema to the DOE-2 INP schema is not a simple process of comparison, matching and selection. Since the geometric information in both files is located and formulated differently, extensive coding is necessary in order to generate the DOE-2 INP file. The following tables present the location and description of the primary elements in the gbXML schema and DOE-2 INP schema, respectively (see Tables 4 and 5):

Elements	Description
gbXML	Represents the root element of the gbXML where all its information is located
Campus	This element represents the base for all physical objects. It includes information of the building location, space boundaries and the building geometry
Construction	Contains additional material information of the building project
Layer	Presents how the materials are combined and labeled in the building project
Material	Contains all the material information such as thickness, conductivity, density and specific heat properties of the project
Schedules	Lists all the daily, weekly and annually schedule information in order to run energy simulations of a specific building project

IntEquip	Presents all the internal (e.g. cooling and heating) equipment of the project
ExtEquip	Presents all the external (e.g. cooling and heating) equipment of the project
Document History	Contains the project details about the users and tools utilized to create and modify the gbXML file

Table 4: Main elements of the gbXML schema

Elements	**Description**
Global Parameters	Presents the general information about the run periods, design days and holidays of the DOE-2 INP file
Site and Building Data	This element contains the information of the building location
Materials, Layers and Constructions	Contains all the required material information such as thickness, conductivity, density and specific heat properties of the project including how the materials are combined and labeled in the building project
Schedules	Lists all the daily, weekly and annually schedule information in order to run energy simulations of a specific building project
Polygons	Presents the geometric information of the location of all the polygons and surfaces in the building project
Floors, Spaces, Walls, Windows and Doors	Includes all the detailed information of the geometry parameters of a project
HVAC Circulation Loops and Plant Equipment	Presents all the internal and external (e.g. cooling and heating) equipment of the project.

Table 5: Main elements of the DOE-2 INP schema

As shown in the tables above, the building information from the open schemas are organized and labeled differently. As a consequence, it presents a significant obstacle when converting from gbXML to DOE-2 INP. Converting the geometric information from the open schemas currently presents the major challenge in the conversion process. Complex transformation rules are then required since openings (e.g., window, door) and walls of the gbXML model created from Autodesk Revit are defined as x, y, z coordinates and in eQUEST, windows and walls are defined by reference coordinates of width, height, and tilt. This causes interoperability errors while converting geometry information from a BIM-based architecture model to an energy model. It is difficult to verify if the building geometry is properly converted into the energy modeling program. The figure below presents how the geometry information in the gbXML schema relies on the X, Y, and Z coordinates location, the height, width, azimuth and tilt information of the surface (see Figure 23):

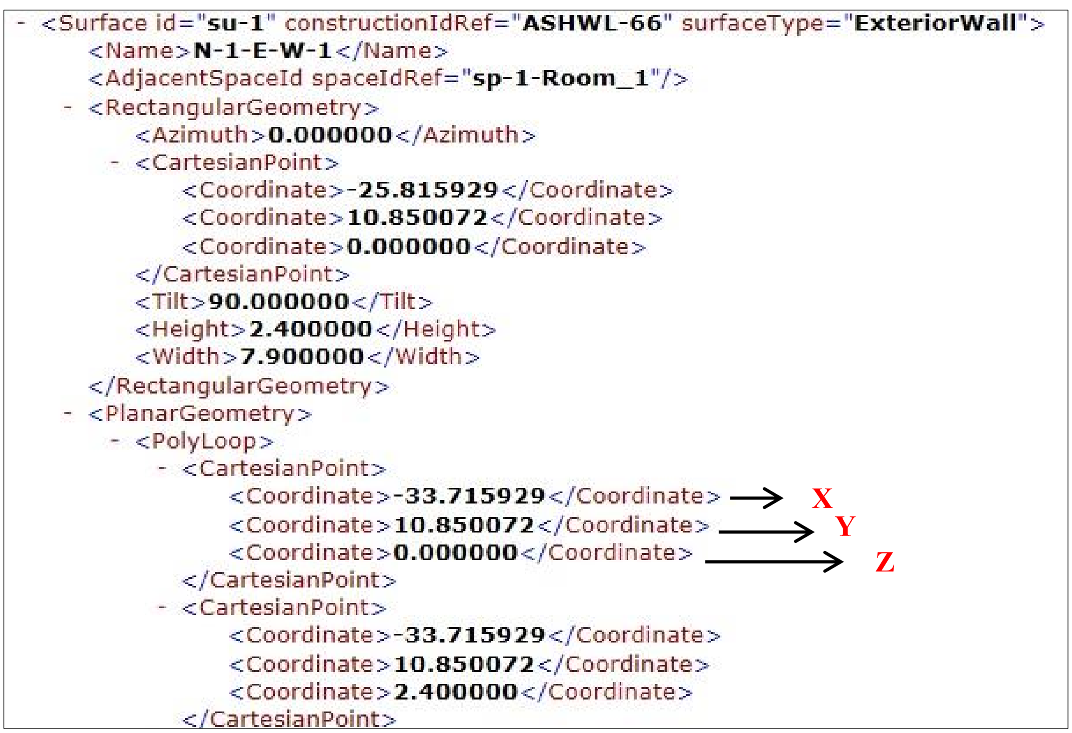

```
- <Surface id="su-1" constructionIdRef="ASHWL-66" surfaceType="ExteriorWall">
    <Name>N-1-E-W-1</Name>
    <AdjacentSpaceId spaceIdRef="sp-1-Room_1"/>
  - <RectangularGeometry>
      <Azimuth>0.000000</Azimuth>
    - <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <Tilt>90.000000</Tilt>
      <Height>2.400000</Height>
      <Width>7.900000</Width>
    </RectangularGeometry>
  - <PlanarGeometry>
    - <PolyLoop>
      - <CartesianPoint>
          <Coordinate>-33.715929</Coordinate>
          <Coordinate>10.850072</Coordinate>
          <Coordinate>0.000000</Coordinate>
        </CartesianPoint>
      - <CartesianPoint>
          <Coordinate>-33.715929</Coordinate>
          <Coordinate>10.850072</Coordinate>
          <Coordinate>2.400000</Coordinate>
        </CartesianPoint>
```


Figure 23: Geometric Information from gbXML schema from Case Study 1: Classroom Project.

On the other hand, the geometry information from the DOE-2 INP file relies on the X and Y coordinates of the shape vertices located in the "Polygons" section. The azimuth, tilt, height, width and Z coordinate information is also required in the DOE-2 INP file, but it is not located in the same element information as shown in the gbXML file. If compared with the gbXML file, it is noticeable than the coordinate information from the DOE-2 INP file and the gbXML file do not match (see Figure 24).

```
$ ------------------------------------------------
$               Polygons
$ ------------------------------------------------

$N-1-E-W-1
"su-1GEOM"= POLYGON
                     X              Y
  V1        = ( 25.9186351706, 0.00000000 )

  V2        = ( 25.9186351706, 7.874015748 )

  V3        = ( 0.00000000, 7.874015748 )

  V4        = ( 0.00000000, 0.00000000 )
```

Figure 24: Geometric Information from DOE-2 INP schema from Case Study 1: Classroom Project.

This is due to the fact that the DOE-2 INP does not take the coordinate information from the gbXML file, rather the height and width information to pair it as the new X and Y coordinate information. The pairing of the coordinates is arranged according to the azimuth and tilt information from each surface. It is important to mention that after the height and width information are extracted from the gbXML file, properly conversion from the Metric system to the Imperial system is required in order to load the information to the DOE-2 INP file.

CHAPTER FOUR: IMPLEMENTATION AND RESULTS

The proposed file converter application and the software plug-in component have been implemented in Microsoft Visual C# Studio 2013. Their effectiveness has been tested with three real case studies. The test was performed using a laptop. The laptop is equipped with Intel Core ™ i3 CPU @ 2.20 GHz and 6.00 GB of installed memory (RAM). The operating system is Microsoft Windows 7 Home Premium 64-bits. The validation of the proposed XSLT has been tested using <oXygen/> XML Editor Version 15.2.

4.1 Implementation

This section will present a simple demonstration of the open schema converter solution. To run the transformation tool, a plug in component inside Autodesk Revit was created (see Figure 25). Figure 26 shows an overview of the tool. It consists of a windows form application that contains three buttons: “Select Source File”, “Transform to DOE-2 INP” and “Show the Converted File”. To open an input gbXML file, the “Open Source File” button is clicked and a select-file window opens (see Figure 27). The input gbXML file can be selected and opened by clicking on it. The input will be displayed in the input panel. The “Transform to DOE-2 INP” button can then be clicked to perform the transformation. This button is only active when an input file is opened. After clicking the “Transform to DOE-2 INP” button, the transformation process is viewed through the display of a progress bar. Once the progress bar is completely loaded, the resulted DOE-2 INP file can be then opened and displayed inside Notepad when clicking to the “Show the Converted File” (see Figure 28). If any location or file name modification are made to the file, the user can save the resulted changes by clicking on the “Save” button, which opens a save-file window. Then a selection of the name and the location can be made in order to save the transformation results.

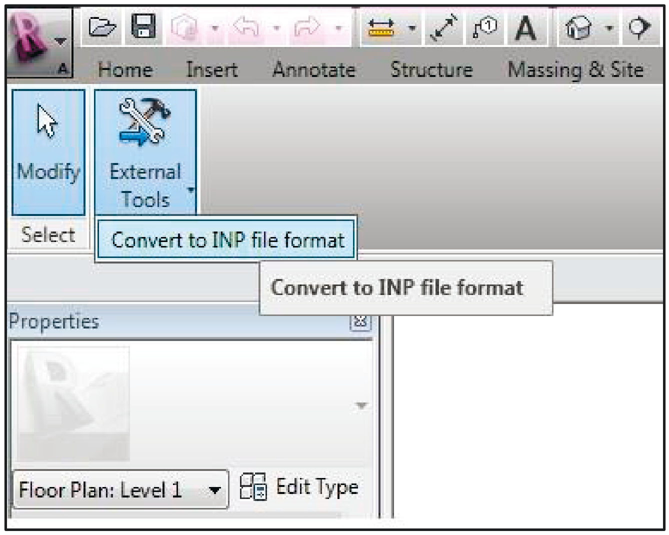


Figure 25: Screenshot- Plug in component inside Autodesk Revit

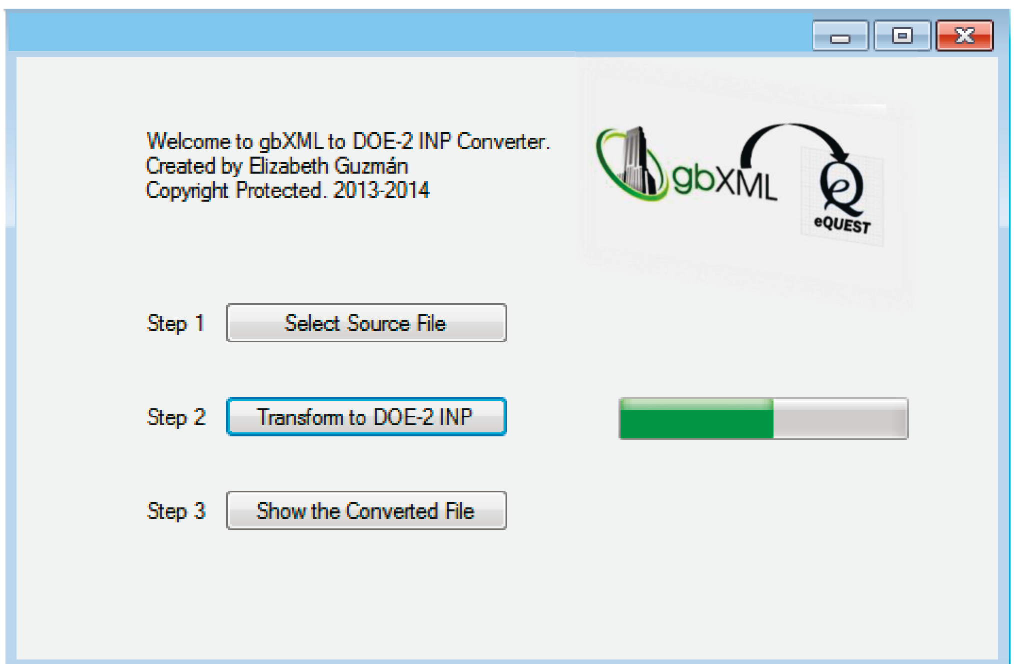


Figure 26: Screenshot- Interface of the proposed transformation tool

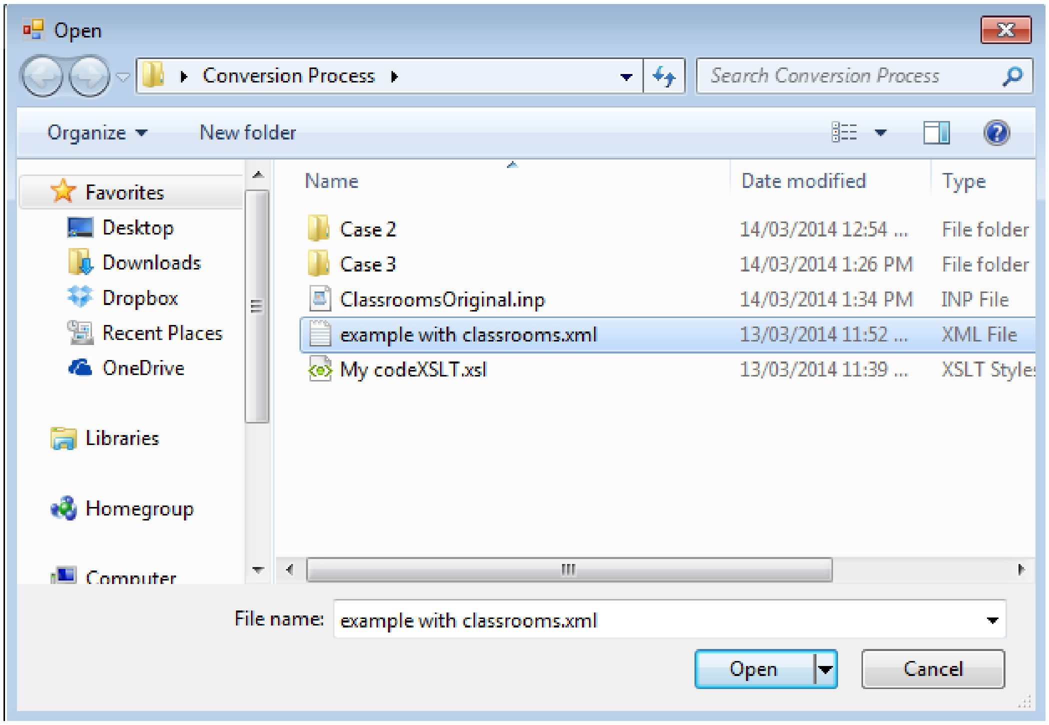


Figure 27: Screenshot- Select-file window open process

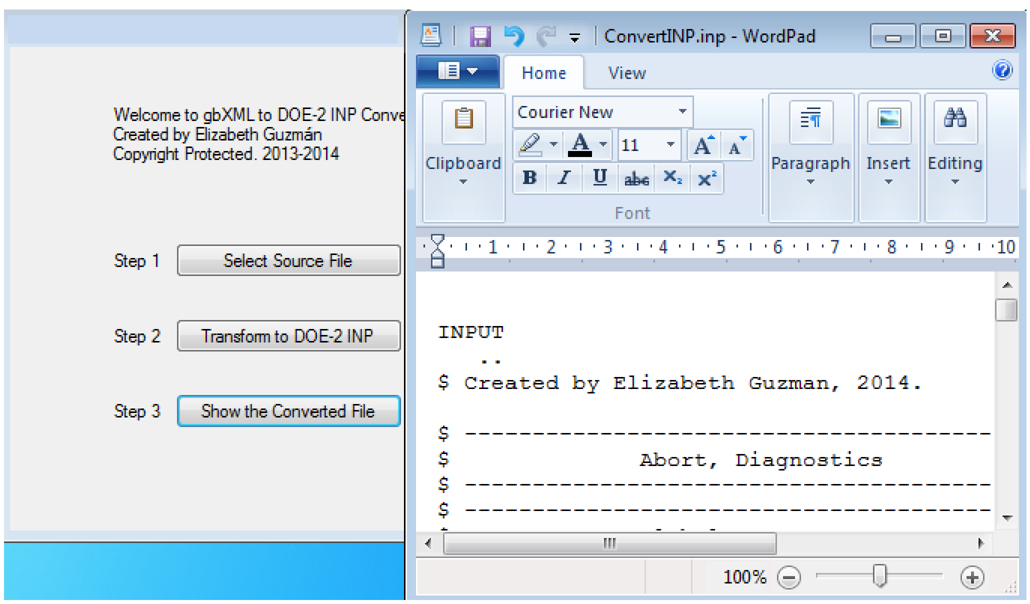


Figure 28: Screenshot- "Show the Converted File"

4.2 Results

This section presents three case examples that were implemented in order to demonstrate the use of the proposed method, and to illustrate the features of the developed converter application. The three case examples include gbXML building design information of three actual projects. The information of the second case study was taken from the gbXML open schema validated file examples available in the standard schema organization website. The reason behind the selection of this example was to demonstrate that even validated and well-structured gbXML files present interoperability issues when converted to DOE-2 INP files. The description, analysis comparison and results of each case study are presented in detail.

4.2.1 Case Study 1: Classroom Project

Building description

The following case study presents the specifications of a small classroom project proposal in Trois-Rivieres, Quebec, Canada. This is a one-story, classroom project, with an integrated stock room and no basement floor. Floor construction consists of a 4-inch thick concrete slab with no reinforcement. The approximate gross square footage project is 132.00 GSF (see Figures 29 and 30).

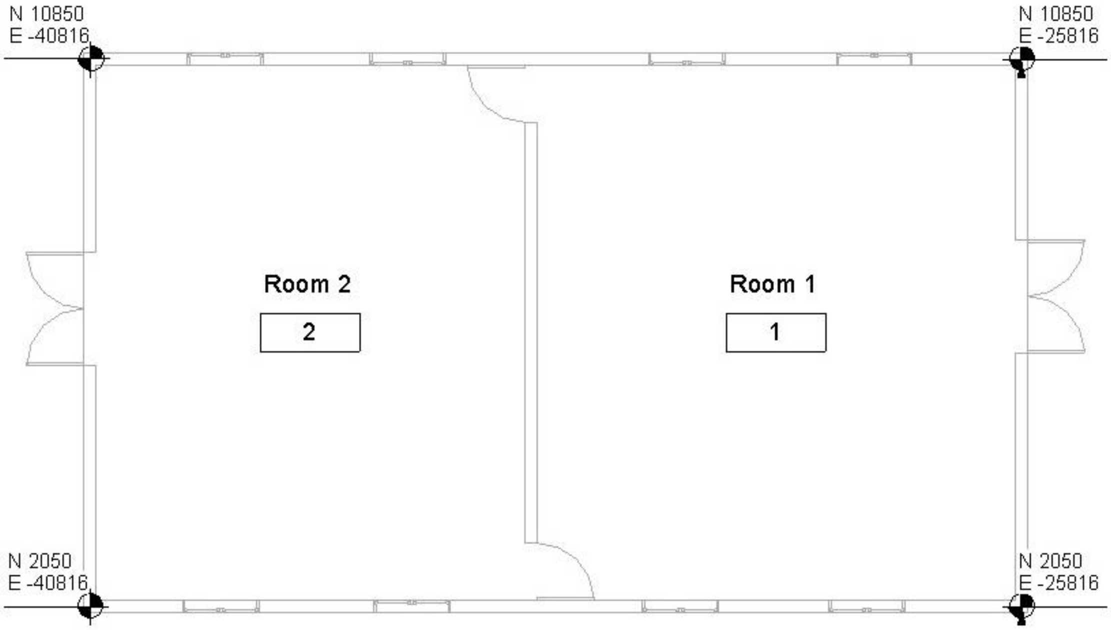


Figure 29: Classroom proposal project floor plan

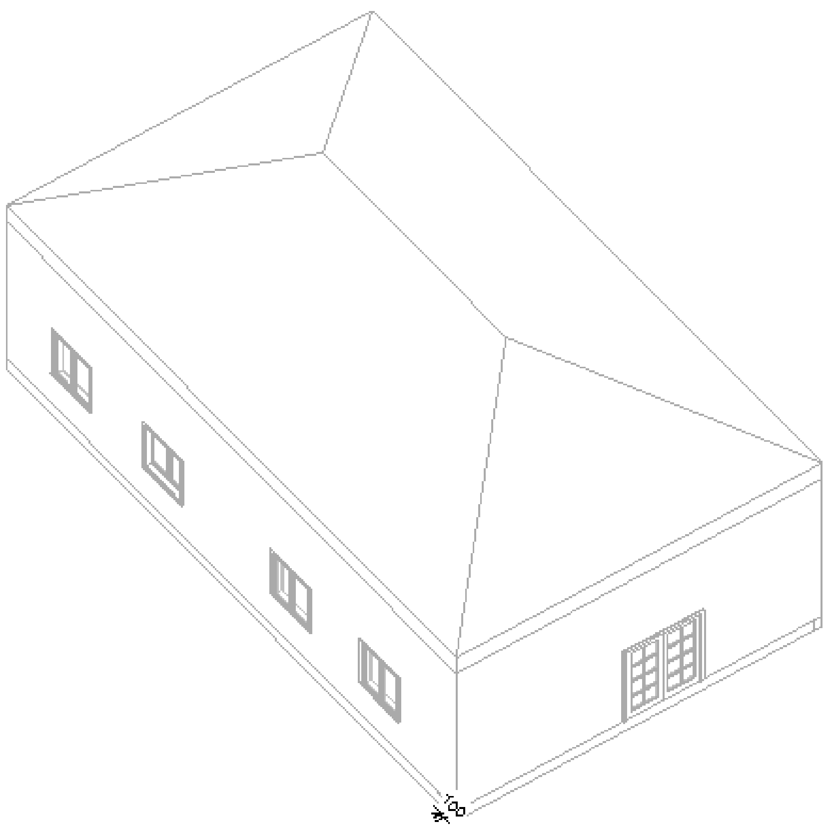


Figure 30: Classroom proposal project Isometric view

Analysis and Evaluation

After inputting the gbXML file and importing the DOE-2 INP schema converted directly from the GBS software, it could be seen that the geometry and material information of the classroom proposal project is misrepresented. Twenty geometry and material information mismatches were found. The mismatches types included the information from the roof, walls and floors of the classroom proposal project. The proposed converter application rectifies all the geometric and material mismatches resulted from the current interoperability process between building design and building energy modeling (see Figures 31, 32 and 33)

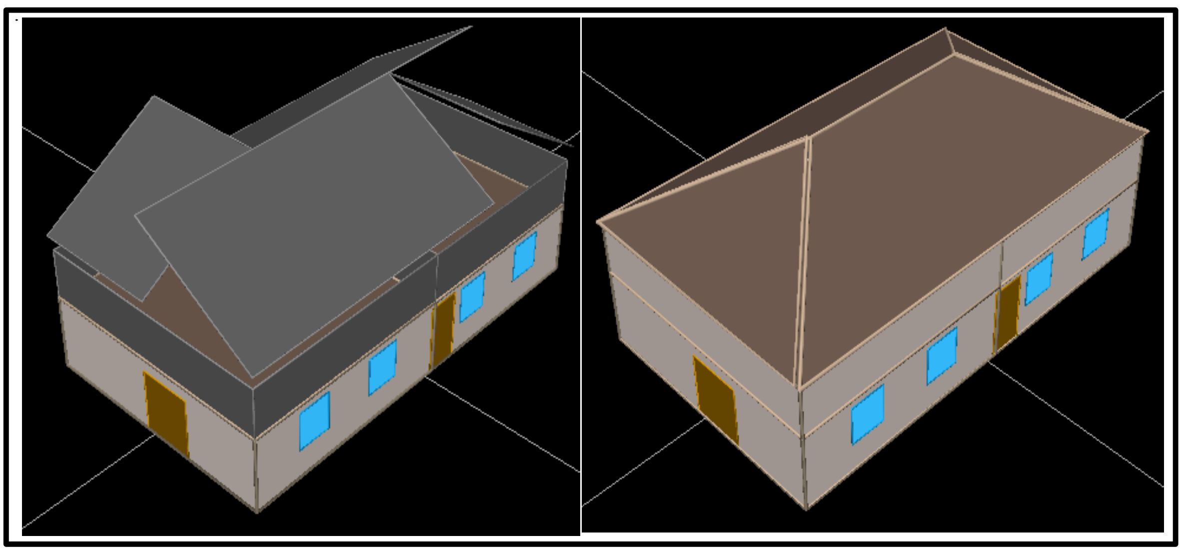


Figure 31: Geometry and material information of type "Roof" before and after conversion

The figure above presented the geometric and material misrepresentations and its proper correction with the use of the proposed converter solution. It is noticeable how each section of the roof is broken into multiple surfaces with irregular azimuth angles. In other to correct this issue, eQUEST users would need to identify each irregular shading type surface and correct azimuth angle one-by-one in eQUEST. However, the proposed converter solution automatically and properly converts the files and avoids re-work.

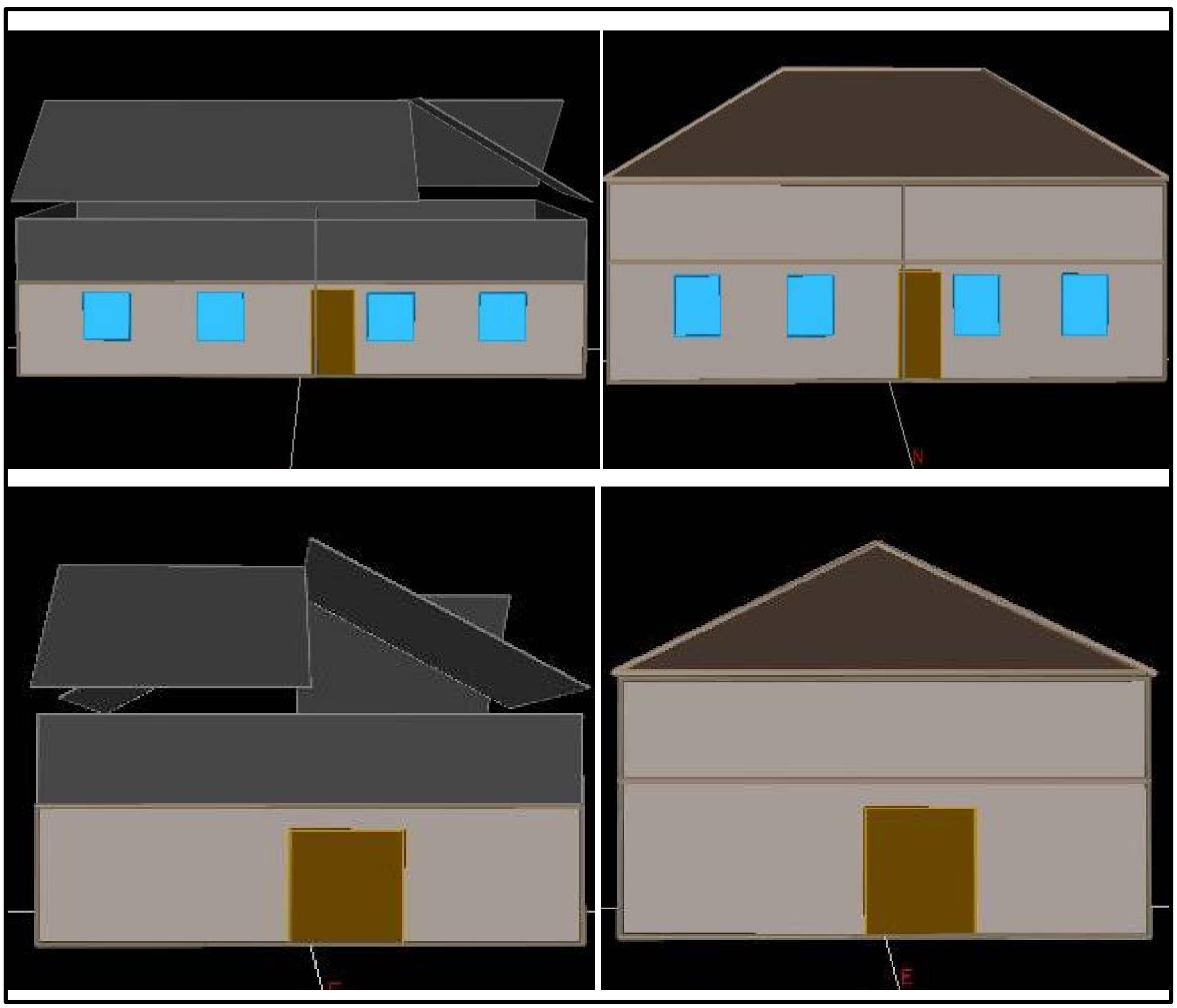


Figure 32: Geometry and material information of type "Walls" before and after conversion

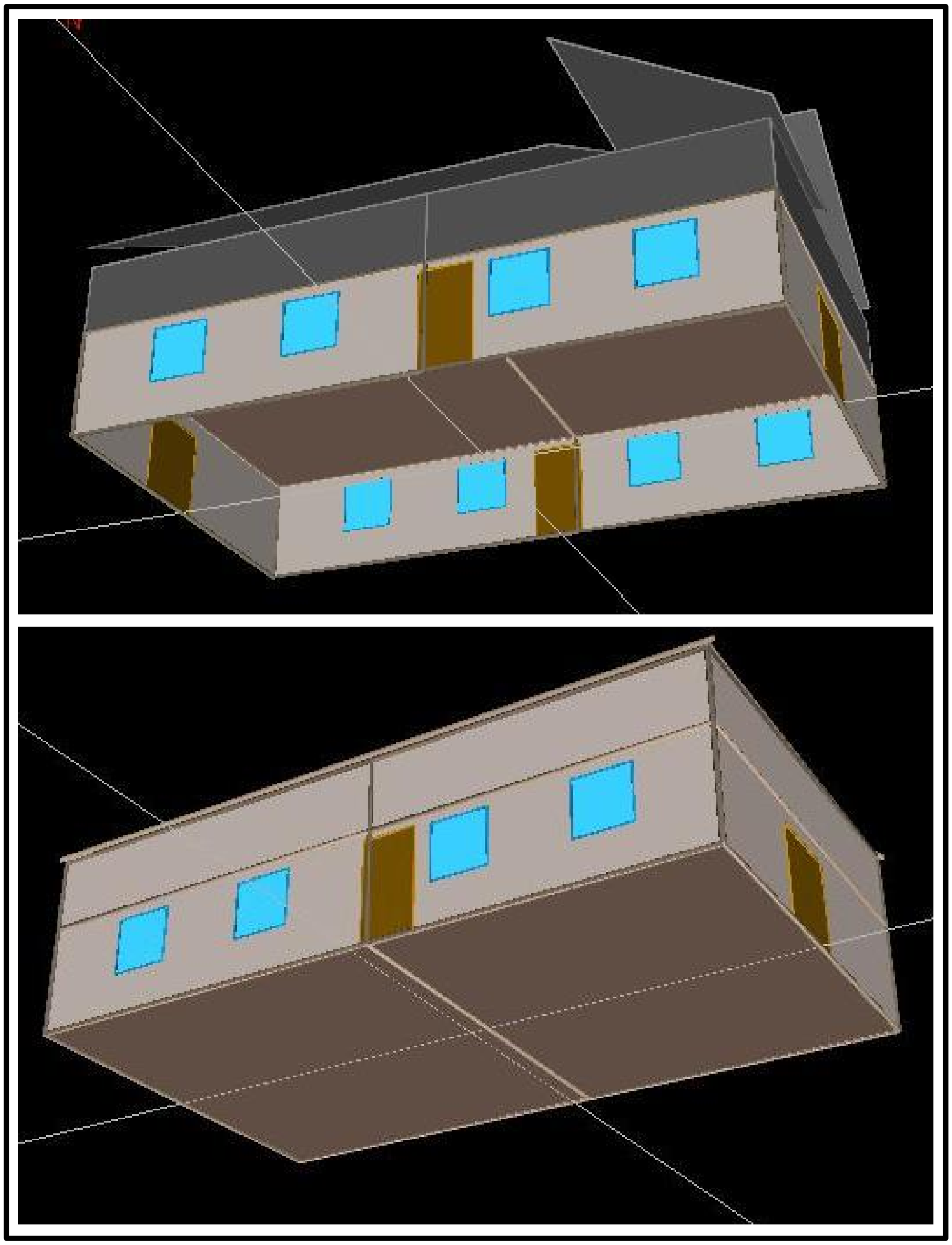


Figure 33: Geometry and material information of type "Floors" before and after conversion

The proposed converter application corrected all the geometry surfaces of the classroom proposal model and the ninth material information misrepresentations presented in the model.

Table 6: Correction of the Geometry misrepresentations

Surfaces that presented geometry misrepresentations	Results from the proposed converter application solution
Surface Id= “su-1”	Corrected
Surface Id= “su-2”	Corrected
Surface Id= “su-3”	Corrected
Surface Id= “su-4”	Corrected
Surface Id= “su-5”	Corrected
Surface Id= “su-6”	Corrected
Surface Id= “su-7”	Corrected
Surface Id= “su-8”	Corrected
Surface Id= “su-9”	Corrected
Surface Id= “su-10”	Corrected
Surface Id= “su-11”	Corrected
Surface Id= “su-12”	Corrected
Surface Id= “su-13”	Corrected
Surface Id= “su-14”	Corrected
From Surface Id= “su-15” to Surface Id= “su-20”	Corrected

Table 7: Correction of the Material misrepresentations

Surfaces that presented Material misrepresentations	Results from the proposed converter application solution
Surface Id= "su-12"	Corrected
Surface Id= "su-13"	Corrected
Surface Id= "su-14"	Corrected
Surface Id= "su-15"	Corrected
Surface Id= "su-16"	Corrected
Surface Id= "su-17"	Corrected
Surface Id= "su-18"	Corrected
Surface Id= "su-19"	Corrected
Surface Id= "su-20"	Corrected

4.2.2 Case Study 2: Multi-story Office Project

Building description

The following case study presents the specifications of a multi-storey office building located in Boston, MA, United States. This is a complex multi-storey office building that comprehends more than two hundred surface geometric information. The information for this case study was taken from the gbXML open schema validated file examples available in the standard schema organization website. The reason behind the selection of this example was to demonstrate that even validated and well-structured gbXML files present interoperability issues when converted to DOE-2 INP files. Therefore, only the gbXML file information was provided for this case example, excluding plans and specifications. The approximate gross square footage project is 15811.39 GSF.

Analysis and Evaluation

If the DOE-2 INP schema converted directly from the Autodesk Green Building Studio software is used in the eQUEST Version 3-65 environment, it could be seen that the majority of the geometry and material information of the multi-story office project is misrepresented (see Figure 34). More than two hundred geometry and material information mismatches were found. The proposed converter application rectified the majority the resulted mismatches, where only three mismatches were not corrected (see Figures 35, 36, 37 and 38).

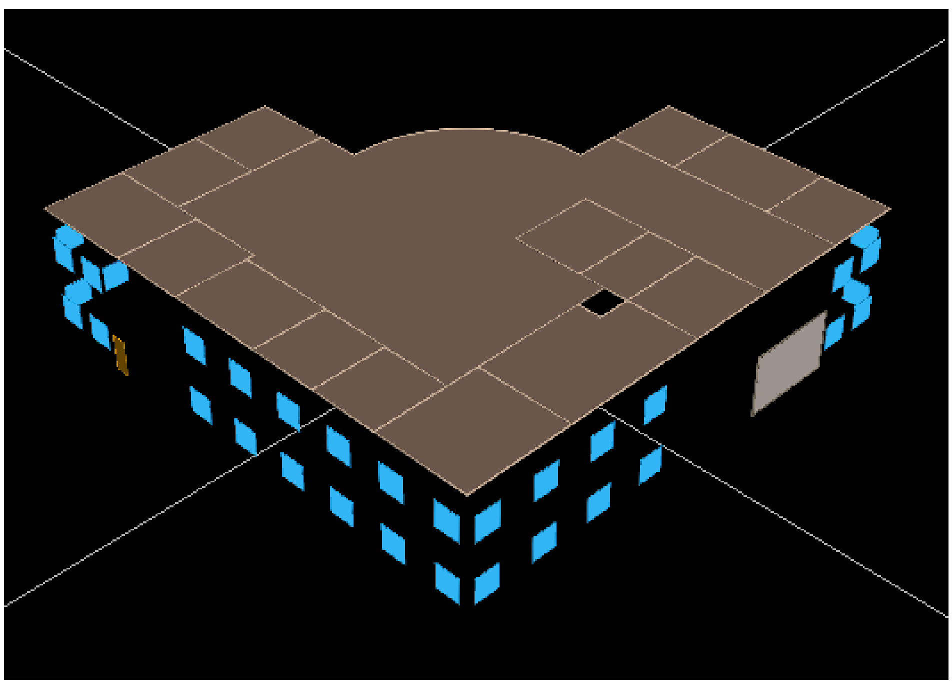


Figure 34: Geometry and material of the whole project before conversion. Source: (gbXML org., 2014)

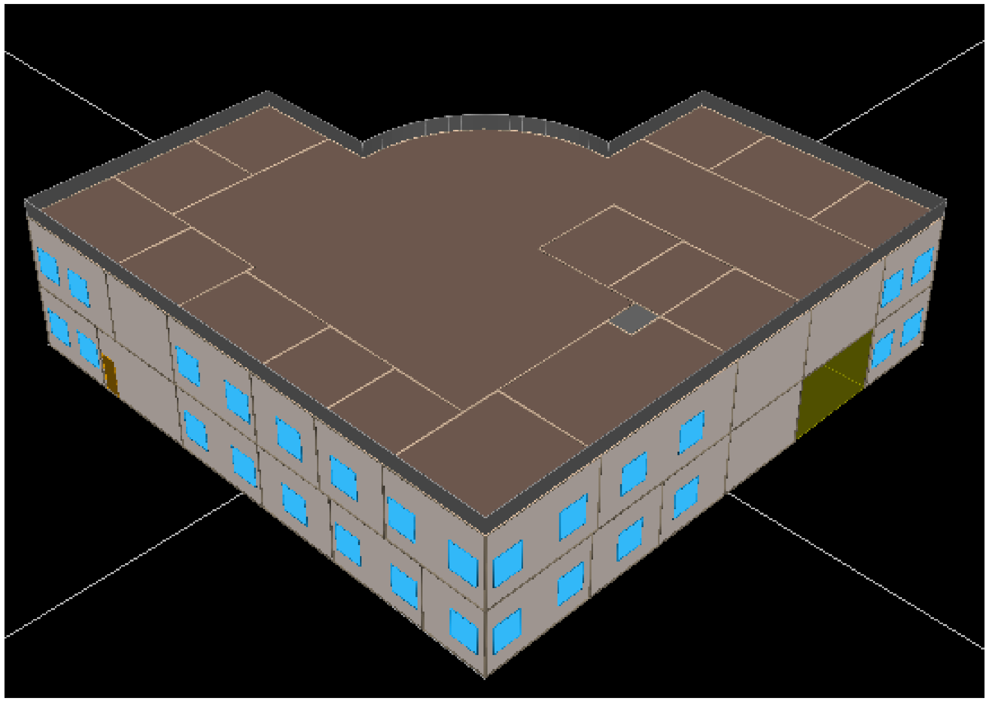


Figure 35: Geometry and material of the whole project after conversion

Source: (gbXML org., 2014)

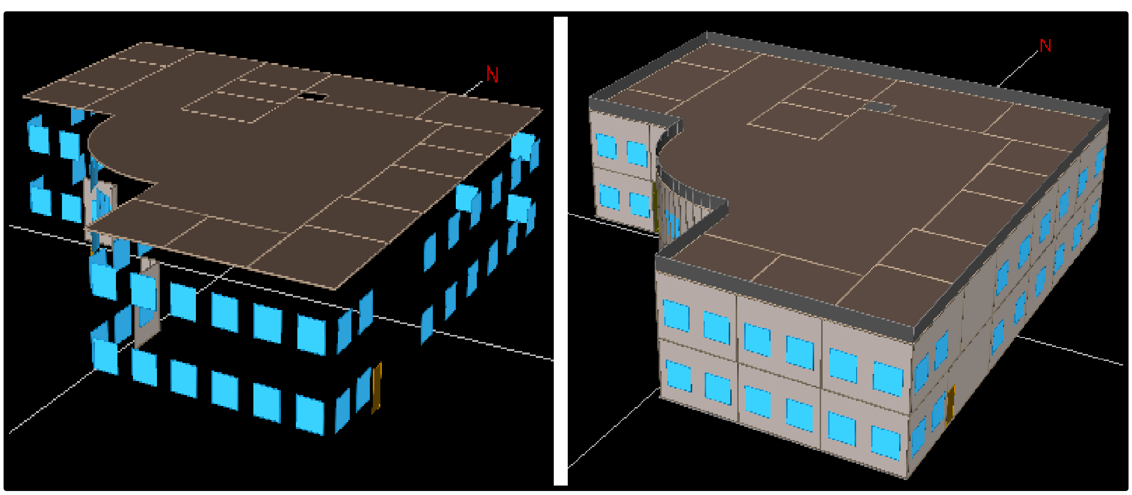


Figure 36: Geometry and material of side view project before and after conversion

Source: (gbXML org., 2014)

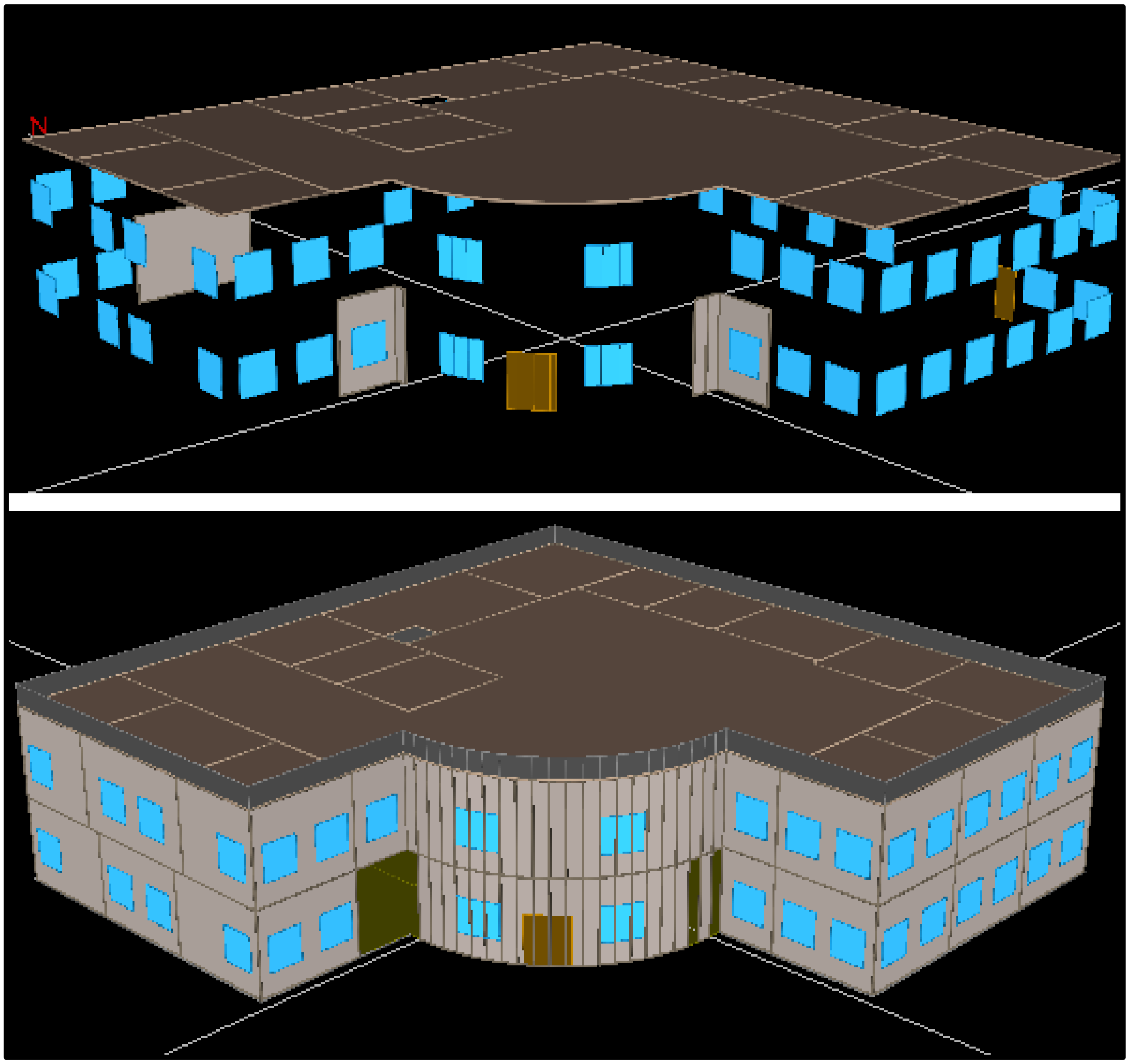


Figure 37: Geometry and material of side view project before and after conversion

Source: (gbXML org., 2014)

The proposed converter application corrected the majority of geometry surfaces of the multi-story office project model and the same number of material misrepresentations presented in the model (97.8%). However, three of the mismatches found could not be corrected.

Table 8: Correction of the Material and Geometry misrepresentations

Surfaces that presented geometry misrepresentations	Results from the proposed converter application solution
Surface Id= “su-1”	Corrected
Surface Id= “su-2”	Corrected
Surface Id= “su-3”	Corrected
Surface Id= “su-4”	Not Corrected
Surface Id= “su-5”	Corrected
Surface Id= “su-6”	Corrected
Surface Id= “su-7”	Not Corrected
Surface Id= “su-8”	Corrected
Surface Id= “su-9”	Corrected
Surface Id= “su-10”	Corrected
Surface Id= “su-11”	Corrected
Surface Id= “su-12”	Corrected
Surface Id= “su-13”	Corrected
Surface Id= “su-14”	Not Corrected
From Surface Id= “su-15” to Surface Id= “su-242”	Corrected

4.2.3 Case Study 3: Retail Store Project

Building description

The following case study presents the plans and specifications of a retail store building proposal in Toronto, ON. The architectural and engineering information of the retail store building was taken from TARGET’s Property Development Guide. The intent of this guide is to assist the developer and construction project team plan to prepare the scope and specifications for the design of a new TARGET department store.

The following specifications of the Development Guide were taken into consideration (TARGET, 2013):

- TARGET P09.400 store type. This is a one-story, general merchandise, limited grocery retail with an integrated stock room and no basement floor.
- Floor construction consists of a 4-inch thick concrete slab with no reinforcement.
- The approximate gross square footage for the TARGET prototype buildings is ± 135,300 GSF

Plans and specifications:

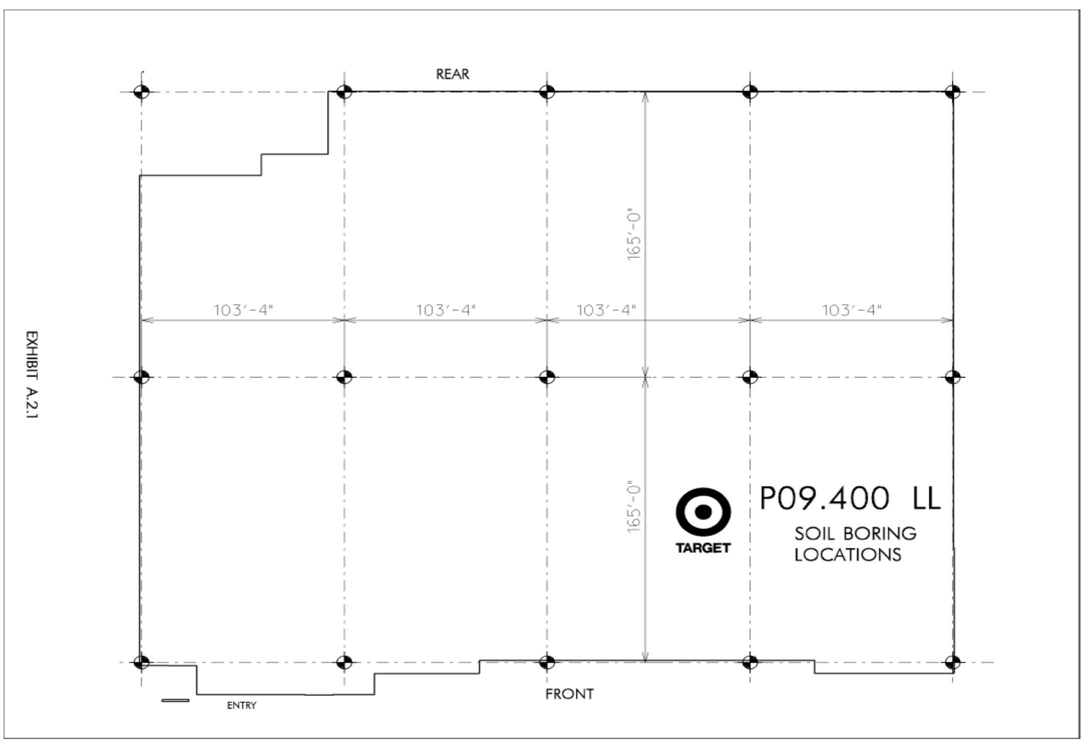


Figure 38: TARGET Exhibit A.2.1 Soil Boring Locations P09. 400 LL. Source: (TARGET, 2013)

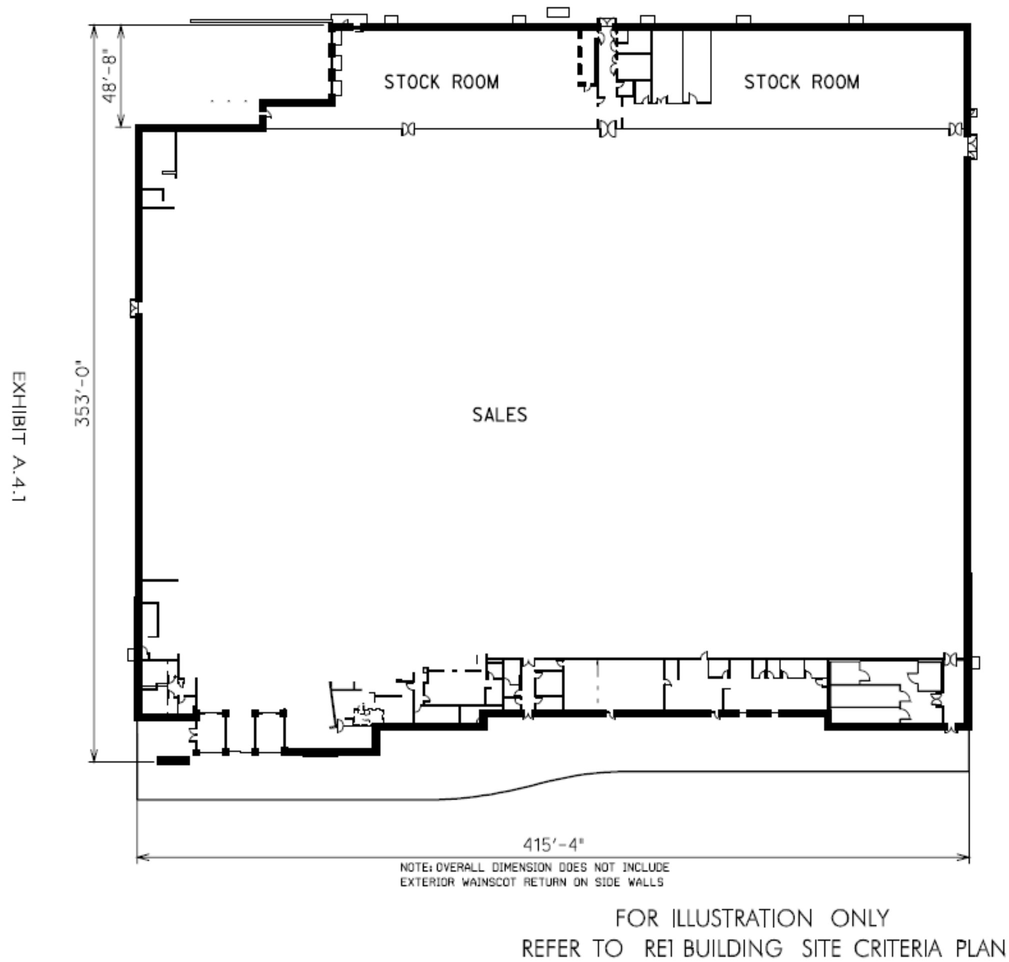


Figure 39: TARGET Exhibit A.2.1 Floor plan type P09. 400 LL. Source: (TARGET, 2013)

Analysis and evaluation

If the DOE-2 INP schema converted directly from the Autodesk Green Building Studio software is used in the eQUEST Version 3-65 environment, it could be seen that the geometry information is well presented, however, some of the material information of retail stored is misrepresented (see Figure 40). The proposed converter application rectifies all the material misrepresentations resulted from the current interoperability process between building design and building energy modeling (see Figure 41).

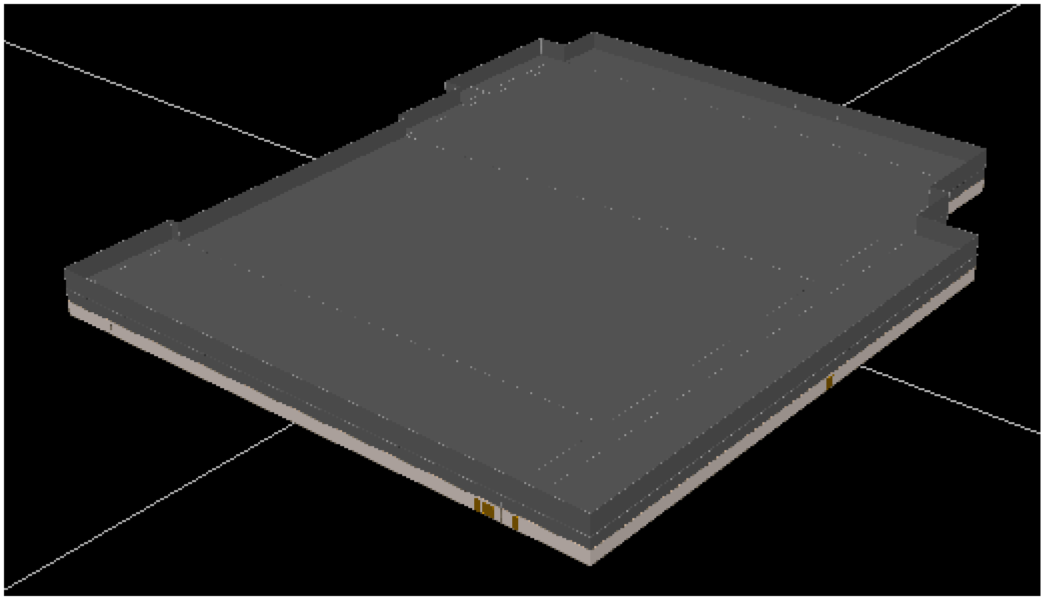


Figure 40: Material information representation of the whole project before conversion

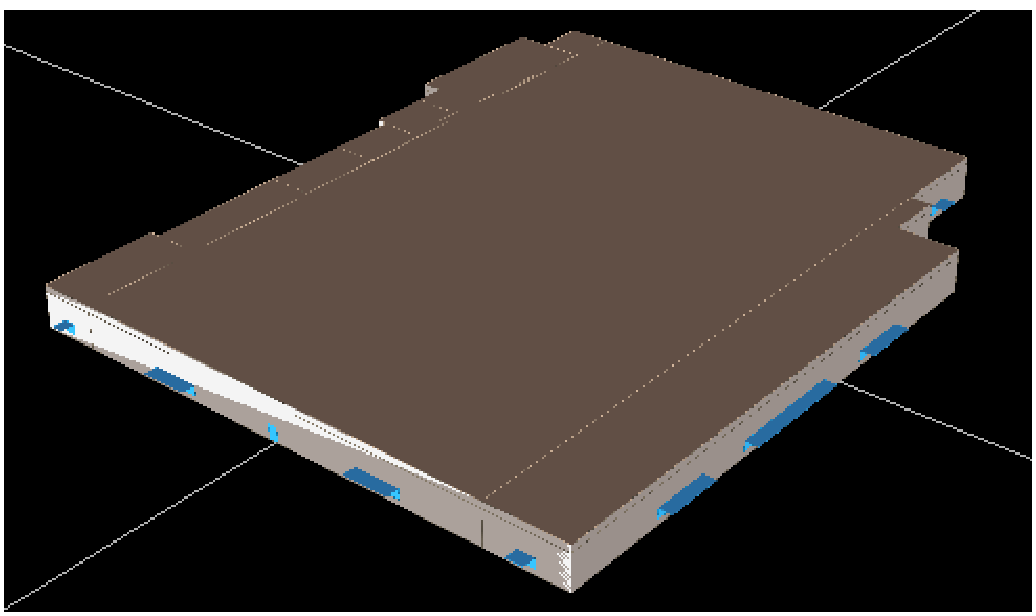


Figure 41: Material information representation of the whole project after conversion

The proposed converter application corrected all the material misrepresentations of the retail store project model.

Table 9: Correction of the Material misrepresentations

Surfaces that presented Material misrepresentations	Results from the proposed converter application solution
Surface Id= "su-9"	Corrected
Surface Id= "su-10"	Corrected
Surface Id= "su-11"	Corrected
Surface Id= "su-12"	Corrected
Surface Id= "su-13"	Corrected
Surface Id= "su-14"	Corrected

Energy Simulation Results

When implementing the proposed converted solution by importing the resulted DOE 2-INP file into eQUEST, energy simulation analyses can be performed in the energy modeling tool. For example, energy simulation analyses performed in the Case Study 3 presented part of the following results:

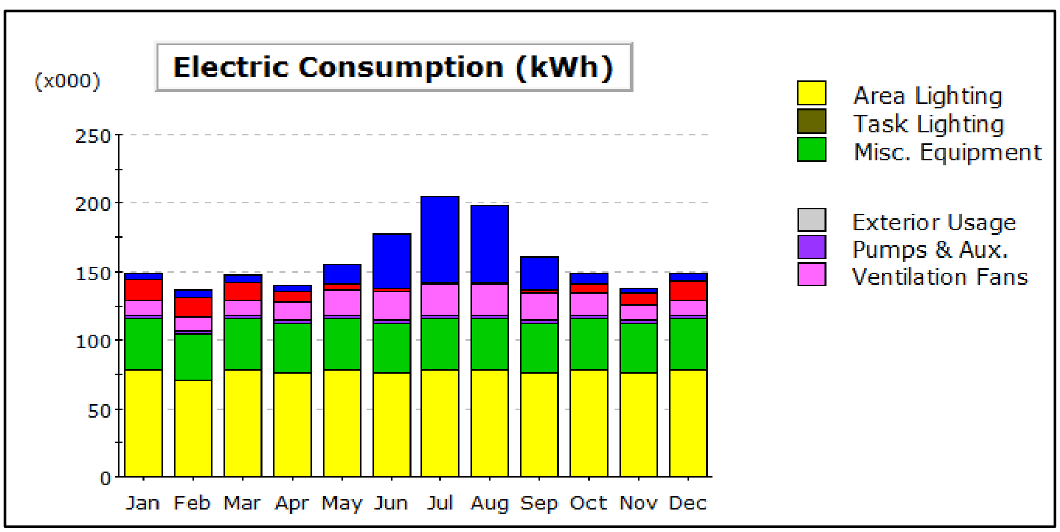


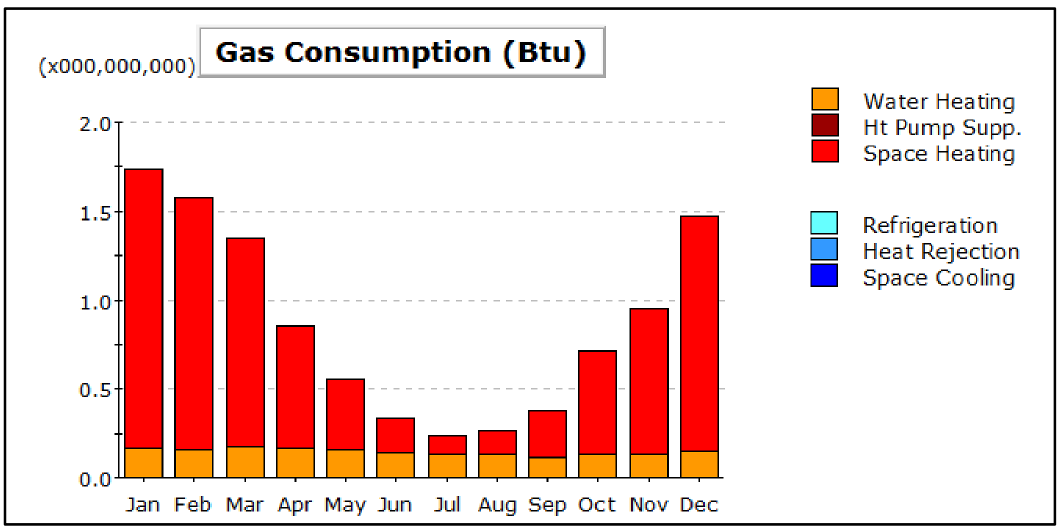
Figure 42: Part of the eQUEST Electricity analysis results from Case Study 3 (a)

Electric Consumption (kWh x000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	4.7	5.6	5.6	4.4	13.5	39.8	62.3	55.6	23.8	8.2	2.6	5.6	231.5
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	16.0	14.7	13.2	8.0	4.7	2.3	1.3	1.6	3.1	6.8	9.5	14.5	95.8
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	10.2	9.6	10.3	13.4	18.5	21.1	23.0	22.6	19.5	15.8	10.7	10.5	185.2
Pumps & Aux.	2.2	2.0	2.2	2.1	2.2	2.1	2.2	2.2	2.1	2.2	2.1	2.2	25.6
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	37.6	33.9	37.6	36.4	37.6	36.4	37.6	37.6	36.4	37.6	36.4	37.6	442.3
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	78.5	70.9	78.5	76.0	78.5	76.0	78.5	78.5	76.0	78.5	76.0	78.5	924.6
Total	149.2	136.7	147.3	140.3	154.9	177.7	204.9	198.0	160.9	149.0	137.2	148.9	1,904.9

Figure 43: Part of the eQUEST Electricity analysis results from Case Study 3 (b)

The retail store facility presented in Case Study 3 uses a total of **1,904,900 kWh** of electricity at a cost of $200.172 for the 12-month period evaluated.



Gas Consumption (Btu x000,000,000)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	1.56	1.42	1.17	0.69	0.40	0.20	0.11	0.13	0.26	0.58	0.81	1.32	8.66
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	0.17	0.16	0.18	0.17	0.16	0.14	0.13	0.13	0.12	0.13	0.14	0.15	1.76
Vent. Fans	-	-	-	-	-	-	-	-	-	-	-	-	-
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	-	-	-	-	-	-	-	-	-	-	-	-	-
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1.73	1.58	1.35	0.86	0.55	0.34	0.24	0.26	0.38	0.71	0.95	1.48	10.42

Figure 44: Part of the eQUEST Gas Consumption analysis results from Case Study 3 (a&b)

CHAPTER FIVE: CONCLUSIONS AND FUTURE WORK

5.1 Conclusions

Over the last few decades, interoperability issues have been acknowledged as an impediment to improve productivity in the Architecture, Engineering and Construction (AEC) industry. The current information exchange between building design and energy models presents numerous problems, including object parametric information deficiencies, geometric misrepresentations and re-input data confusion. These problems inevitably leaded to huge money, time and effort losses for the AEC industry. According to a 2004 study commissioned by the National Institute of Standards and Technology (NIST), interoperability issues presented a cost of $15.8 billion in the year of 2003 alone (Gallaher et al, 2004).

These issues are continue to grow over the years with the introduction of new software tools in the building design and energy modeling process. Efforts towards solving these issues mainly relied in integrated software tools within companies or the creation of open standard schemas. These solutions were determined to be ineffective, costly and limited to solve only a few number of issues. As a result, this dissertation presented a novel open standard converter solution that works towards unified information exchange between building design and energy modeling in building performance. The proposed solution was developed through the creation of a novel Extensible Style-sheet Language Transformation (XSLT) and a software plug-in component inside a building design tool environment. The results of the proposed converter solution demonstrated the overall rectification of most of the geometric and material misrepresentations resulting from the current software interoperability process. For complex projects that presented more than two hundred surfaces in geometric information, an overall correction of 98.8% of the surfaces was achieved.

The main contribution of this study is in the development of a novel open schema converter solution that properly transforms the information from the Green Building XML (gbXML) schema to the DOE-2 INP schema. In addition, the proposed converter solution is expected to reduce the time and effort losses in the AEC industry by automating the current manual process of software integration between building design and energy analysis software tools. Due to the high costs of training, upgrading and implementing BIM and BEM for energy performance, companies are currently reluctant to use these tools only for large projects. However, with the implementation of the proposed converter solution, companies will be able to afford using BIM and BEM tools for small projects as well. Society needs building design and energy modeling in order to achieve sustainability and development. In order to do that, the tools involved in this process must exchange information effortlessly amongst one another. This dissertation presented a new alternative towards the direction of a more sustainable and efficient building performance process.

5.2 Future Work

This thesis presented the creation and implementation of a novel open standard schema converter that will serve as automated solution to solve the interoperability issues between building design and energy modeling tools. The proposed open schema converter solution focused on the conversion of the building location, geometry and material information of the gbXML and DOE-2 INP schemas from Autodesk Revit and eQUEST, respectively. Future work would focus on solving further interoperability issues in the conversion process of these tools in addition to performing additional tests of different case studies examples of building design and energy modeling projects.

Moreover, future work would focus in studying the interoperability issues between other software tools and different open standard schemas. Furthermore, other alternative solutions and additional programming languages than the ones utilized in this study, could be explored in order to determine which one provides the most efficient and accurate solution.

REFERENCES

Augenbroe, G. (1992). Integrated building performance evaluation in early design stages. *Building and Environment*, (p. 27).

Autodesk. (2013, April). *Autodest Ecotect Analysis*. Retrieved from Sustainable Building Design Software: http://usa.autodesk.com/ecotect-analysis/

Autodesk, I. (2005). Building Information Modeling for Sustainable Design. AUTODESK® REVIT® WHITE PAPER.

Autodesk, I. (2009). Energy Analysis Workflows for Sustainability.

Autodesk, I. (2011). *Getting Started with Web Service Tools for Whole Building Analysis.* Autodesk White Papers.

Bao, Y., & Horowitz, E. (1996). A New Approach to Sotfware Tool Interoperability . *ACM.*

Becerik-Gerber, B., & Rice, S. (2010). The perceived value of building information modeling in the US building industry. (pp. 185–201). ITcon 15.

Beck Technology. (2012). *Product-DProfiler*. Retrieved from Beck Technology-Innovation in all Dimensions: http://beck-technology.com/dprofiler.html

California Energy Commission. (2007). *Title 24, Part 6, of the California Code of Regulations: California's Energy Efficiency Standards for Residential and Nonresidential Buildings.* California, USA.

Caneta Research, I. (2007). *Advancing Buildings and Systems*. Retrieved January 2014, from http://www.canetaenergy.com/index.html

Cate, B., Kolaitis, P., & Tan, W.-C. (2013). Schema Mappins and Data examples. *ACM.* Genoa, Italy.

COMIS. (2003). *COMIS, Multizone Air Flow Model Homepage*. Retrieved 2014, from http://www-epb.lbl.gov/comis/

Council, C. G. (2014). *Canada Green Building Council, Programs: Building Performance*. Retrieved January 2014, from http://www.cagbc.org/Content/NavigationMenu/Programs/GREENUP/default.htm

Crawley, D. B., Hand, J. W., Kummert, M., & Griffith, B. T. (2005). Contrasting the Capabilities of Building Energy Performance Simulation Programs. *Proceedings of Building Simulation*, 231-238.

Crotty, R. (2012). *The impact of building information modelling : Transforming construction.* Abingdon, Oxon; New York: Spon.

DOE-2. (n.d.). *Building Energy Use and Cost Analysis Tool*. Retrieved April 2013, from http://doe2.com/DOE2/index.html

Eastman, C. M. (2008). *BIM handbook :A guide to building information modeling for owners, managers, designers, engineers, and contractors.* Hoboken, N.J.: John Wiley & Sons, Inc. .

Gallaher, M. P., O'Connor, A. C., Dettbarn, J. L., & Gilday, L. T. (2004). *Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry.* USA: U.S Department of Commerce. Technology Administration. National Institute of Standards and Technology.

Gauchel, J., & Hovestadt, S. (1992). Building modeling based on concepts of autonomy. *Proceedings of AID 1992.* Pittsburgh, PA.

gbXML org. (2014). *gbXML-Open Green Building XML Schema: a Building Information Modeling Solution for Our Green World*. Retrieved from http://www.gbxml.org/

Granlund. (2007 a). *BSPro Server homepage*. Retrieved 2013, from http://www.granlund.fi/sivukartta/

GRAPHISOFT. (2014). *ArchiCAD*. Retrieved from ArchiCAD: BIM Lives in the Details: http://www.graphisoft.com/archicad/

Green, D., Aksamija, A., Thun, G., Velikov, K., & Tazelaar, R. (2013). SPECIAL ISSUE: NATIONAL SCIENCE FOUNDATION WORKSHOP. Architecture and Engineering of Sustainable Buildings. *Perkins + Will Research Journal/ VOL 05.01*, 25.

Hirsch, J. J. (2009). *DOE-2: Building Energy Use and Cost Analysis Tool*. Retrieved April 2013, from http://doe2.com/DOE2/index.html

Hong, T. (2008). *Comparing Computer Run Time of Building Simulation Programs. Build Simul.* Berkeley: Tsinghua Press and Springer.

IAI, I. (2007). *International Alliance for Interoperability (IAI)-North America-Homepage*. Retrieved from http://www.aisc.org/content.aspx?id=26040

InfoComm, B. (2011). *Building Information Modeling (BIM).* InfoComm BIM Taskforce.

ISO. (1992). *Product data representation and exchange part 1: Overview and Fundamental Principles.*

Jernigan, F. E. (2007). *Big BIM little BIM: the practical approach to building information modeling: integrated practice done the right way!* Salisbury, Maryland: 4Site Press.

Jokela, M., Keinanen, A., Lahtela, H., & Lassila, K. (1997). Integrated Building Simulation Tool-Riuska. *Insinooritoimisto Olof Granlund Oy.*

Krygiel, E. &. (2008). *Green BIM :Successful sustainable design with building information modeling* (1st ed.). Indianapolis, IN: Wiley Publishing.

Kumar, S. (2008). *Interoperability between building information models (BIM) and energy analysis programs.A comparative study.* California: Master Thesis, University of Southern California.

Kymmell, W. (2008). *Building Information Modeling: Planning and Managing Projects with 4D CAD and Simulations.* USA: McGraw Hill Construction.

Lam, K. P., Karaguzel, O. T., Zhang, R., & Zhao, J. (2012). *Identification and Analysis of Interoperability Gaps between Nbims/Open Standards and Building Performance Simulation Tools.* Philadelphia, USA.: Carnegie Mellon University.

Lam, K., Wong, N., & et al. (2004). SEMPER-II: an internet-based multi-domain building performance simulation environment for early design support. *Automation in Construction*, (p. 13 (15)).

McGraw-Hill Construction. (2010). *Green BIM: How Building Information Modeling is Contributing to Green Design and Construction.* Bedford, MA: SmartMarket Report.

McQuiston, F. C., Parker, J. D., & Spitler, J. D. (2005). *Heating, Ventilating and Air Conditioning Analysis and Design.* John Wiley & Sons, Inc.

Models, E. (2010). *eQUEST® Quick Start Pay Back Analysis Case Study*. Retrieved April 2013, from ttp://energy-models.com/training/equest-quick-start/case-study

NBC, N. B. (2011). *National Model Construction Code Documents*. Retrieved 2014, from National Energy Code of Canada for Buildings (NECB): http://www.nationalcodes.ca/eng/necb/index.html

Nemetschek North America. (2010). *Online Store: Vectorworks Architect*. Retrieved December 2013, from Nemetschek North America, Inc.: https://secure.vectorworks.net/estore/

NIBS. (2008). *United States National Building Information Modeling Standard*, version 1—Part 1: Overview, principles, and methodologies. Retrieved from http://nbimsdoc.opengeospatial.org/ Oct. 30, 2009

Owolabi A, Anumba C J and El-Hamalawi A (2003). Architecture for implementing IFC-based online construction product libraries , *ITcon Vol. 8, Special Issue IFC - models for the AEC arena ,* pg. 201-218.

Pauwels P., Meyer De R., Walle de R.V. and Campenhout J.V., (2011). "Linking a game engine environment to architectural information on the Semantic Web", *Journal of Civil Engineering and Architecture,* **5**, 787-798.

Pohi, J., & Rep, I. (1988). An integrated intelligent CAD environment. *4th International Conference on Systems Research, Informatics and Cybernetics.* Baden-Baden, Germany.

Rutherford, J. (1993). KNODES: knowledged-based design decision support. *CADD Future.*

Scheer, D. (2013, March 17). *Advanced Energy Analysis with Green Building Studio DOE2 and EnergyPlus*. Retrieved April 2013, from Building Performance Analysis: http://autodesk.typepad.com/bpa/2013/03/advanced-energy-analysis-with-green-building-studio-doe2-and-energyplus-support.html

Shady Attia, L. B. (July 27-30, 2009). ARCHITECT FRIENDLY": A COMPARISON OF TEN DIFFERENT BUILDING PERFORMANCE SIMULATION TOOLS. *Eleventh International IBPSA Conference.* Glasgow, Scotland.

Smith, D., & Tardif, M. (2009). *Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers, .* NJ: John Wiley and Sons.

SRG, S. R. (1998). *Overview DOE-2.2.* Lawrence Berkeley National Laboratory and James J. Hirsh and Associates.

TARGET®. (2013). *Developer Guide Edition 2.13.* Minneapolis, MN: Property Development, Real State Department.

Trimble. (2013). *SketchUP*. Retrieved from SketchUP: http://www.sketchup.com/?gclid=CLnYxpXf0r0CFa07MgodkjAAbw

Williams, I. (2009). *Beginning XSLT and XPath: Transforming XML Documents and Data.* Indianapolis, Indiana: Wiley Publishing.

APPENDIX A: gbXML Input File from Case Study 1

gbXML file from Case Study 1: Classroom Project


```
<gbXML xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns="http://www.gbxml.org/schema"
xsi:schemaLocation="http://www.gbxml.org/schema xsi.xsd"
temperatureUnit="C" lengthUnit="Meters" areaUnit="SquareMeters"
volumeUnit="CubicMeters" useSIUnitsForResults="true"
version="0.37">
  <Campus id="cmps-1">
    <Location>
      <Name>Trois-Rivieres, PQ Canada</Name>
      <Latitude>46.210000</Latitude>
      <Longitude>-72.350000</Longitude>
    </Location>
    <Building id="bldg-1" buildingType="Office">
      <Area>132.000000</Area>
      <InfiltrationFlow type="Average"/>
      <BuildingStorey id="bldg-stry-1">
        <Name>Level 1</Name>
        <Level>0.000000</Level>
        <PlanarGeometry>
          <PolyLoop>
            <CartesianPoint>
              <Coordinate>-133.910528</Coordinate>
              <Coordinate>6.725957</Coordinate>
              <Coordinate>0.000000</Coordinate>
            </CartesianPoint>
            <CartesianPoint>
              <Coordinate>-84.697930</Coordinate>
              <Coordinate>6.725957</Coordinate>
              <Coordinate>0.000000</Coordinate>
            </CartesianPoint>
            <CartesianPoint>
              <Coordinate>-84.697930</Coordinate>
              <Coordinate>35.597348</Coordinate>
              <Coordinate>0.000000</Coordinate>
            </CartesianPoint>
            <CartesianPoint>
              <Coordinate>-133.910528</Coordinate>
              <Coordinate>35.597348</Coordinate>
              <Coordinate>0.000000</Coordinate>
            </CartesianPoint>
          </PolyLoop>
        </PlanarGeometry>
      </BuildingStorey>
      <Space id="sp-1-Room_1"
      spaceType="ClassroomOrLectureOrTraining" zoneIdRef="zone-
      Default" lightScheduleIdRef="schdl-2"
      equipmentScheduleIdRef="schdl-2" peopleScheduleIdRef="schdl-1"
```

```
conditionType="HeatedAndCooled" buildingStoreyIdRef="bldg-
stry-1">
  <Name>1 Room 1</Name>
  <PeopleNumber unit="NumberOfPeople">43.055917</PeopleNumber>
  <PeopleHeatGain unit="WattPerPerson"
  heatGainType="Total">131.880000</PeopleHeatGain>
  <PeopleHeatGain unit="WattPerPerson"
  heatGainType="Sensible">73.270000</PeopleHeatGain>
  <PeopleHeatGain unit="WattPerPerson"
  heatGainType="Latent">58.610000</PeopleHeatGain>
  <LightPowerPerArea
  unit="WattPerSquareMeter">15.070000</LightPowerPerArea>
  <EquipPowerPerArea
  unit="WattPerSquareMeter">10.760000</EquipPowerPerArea>
  <Area>66.220000</Area>
  <Volume>158.928000</Volume>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-110.288481</Coordinate>
        <Coordinate>7.054041</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-85.026014</Coordinate>
        <Coordinate>7.054041</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-85.026014</Coordinate>
        <Coordinate>35.269264</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-110.288481</Coordinate>
        <Coordinate>35.269264</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <ShellGeometry id="sg-sp-1-Room_1" unit="Meters">
    <ClosedShell>
      <PolyLoop>
        <CartesianPoint>
          <Coordinate>-33.615929</Coordinate>
          <Coordinate>2.150072</Coordinate>
          <Coordinate>0.000000</Coordinate>
        </CartesianPoint>
        <CartesianPoint>
          <Coordinate>-33.615929</Coordinate>
```

```xml
      <Coordinate>10.750072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-25.915929</Coordinate>
      <Coordinate>10.750072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-25.915929</Coordinate>
      <Coordinate>2.150072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
  </PolyLoop>
  <PolyLoop>
    <CartesianPoint>
      <Coordinate>-33.615929</Coordinate>
      <Coordinate>10.750072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-33.615929</Coordinate>
      <Coordinate>10.750072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-25.915929</Coordinate>
      <Coordinate>10.750072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-25.915929</Coordinate>
      <Coordinate>10.750072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
  </PolyLoop>
  <PolyLoop>
    <CartesianPoint>
      <Coordinate>-33.615929</Coordinate>
      <Coordinate>2.150072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-33.615929</Coordinate>
      <Coordinate>2.150072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-33.615929</Coordinate>
      <Coordinate>10.750072</Coordinate>
```

```
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-33.615929</Coordinate>
      <Coordinate>10.750072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
  </PolyLoop>
  <PolyLoop>
    <CartesianPoint>
      <Coordinate>-33.615929</Coordinate>
      <Coordinate>2.150072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-25.915929</Coordinate>
      <Coordinate>2.150072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-25.915929</Coordinate>
      <Coordinate>2.150072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <CartesianPoint> <Coordinate>-33.615929</Coordinate>
      <Coordinate>2.150072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
  </PolyLoop>
  <PolyLoop>
    <CartesianPoint>
      <Coordinate>-25.915929</Coordinate>
      <Coordinate>2.150072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-25.915929</Coordinate>
      <Coordinate>10.750072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-25.915929</Coordinate>
      <Coordinate>10.750072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-25.915929</Coordinate>
      <Coordinate>2.150072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
```

```xml
    </PolyLoop>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-33.615929</Coordinate>
        <Coordinate>2.150072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.615929</Coordinate>
        <Coordinate>10.750072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.915929</Coordinate>
        <Coordinate>10.750072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.915929</Coordinate>
        <Coordinate>2.150072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </ClosedShell>
</ShellGeometry>
<CADObjectId>436021</CADObjectId>
<SpaceBoundary surfaceIdRef="su-1">
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
```

```xml
  </PlanarGeometry>
</SpaceBoundary>
<SpaceBoundary surfaceIdRef="su-2">
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
</SpaceBoundary>
<SpaceBoundary surfaceIdRef="su-3">
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.400000</Coordinate>
```

```
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
</SpaceBoundary>
<SpaceBoundary surfaceIdRef="su-4">
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
</SpaceBoundary>
<SpaceBoundary surfaceIdRef="su-5">
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
```

```
          <Coordinate>2.050072</Coordinate>
          <Coordinate>0.000000</Coordinate>
        </CartesianPoint>
      </PolyLoop>
    </PlanarGeometry>
  </SpaceBoundary>
  <SpaceBoundary surfaceIdRef="su-6">
    <PlanarGeometry>
      <PolyLoop>
        <CartesianPoint>
          <Coordinate>-33.715929</Coordinate>
          <Coordinate>2.050072</Coordinate>
          <Coordinate>0.000000</Coordinate>
        </CartesianPoint>
        <CartesianPoint>
          <Coordinate>-33.715929</Coordinate>
          <Coordinate>2.050072</Coordinate>
          <Coordinate>2.400000</Coordinate>
        </CartesianPoint>
        <CartesianPoint>
          <Coordinate>-33.715929</Coordinate>
          <Coordinate>10.850072</Coordinate>
          <Coordinate>2.400000</Coordinate>
        </CartesianPoint>
        <CartesianPoint>
          <Coordinate>-33.715929</Coordinate>
          <Coordinate>10.850072</Coordinate>
          <Coordinate>0.000000</Coordinate>
        </CartesianPoint>
      </PolyLoop>
    </PlanarGeometry>
  </SpaceBoundary>
</Space>
<Space id="sp-2-Room_2"
spaceType="ClassroomOrLectureOrTraining" zoneIdRef="zone-
Default" lightScheduleIdRef="schdl-2"
equipmentScheduleIdRef="schdl-2" peopleScheduleIdRef="schdl-1"
conditionType="HeatedAndCooled" buildingStoreyIdRef="bldg-
stry-1">
  <Name>2 Room 2</Name>
  <PeopleNumber unit="NumberOfPeople">38.582575</PeopleNumber>
  <PeopleHeatGain unit="WattPerPerson"
  heatGainType="Total">131.880000</PeopleHeatGain>
  <PeopleHeatGain unit="WattPerPerson"
  heatGainType="Sensible">73.270000</PeopleHeatGain>
  <PeopleHeatGain unit="WattPerPerson"
  heatGainType="Latent">58.610000</PeopleHeatGain>
                      <LightPowerPerArea
 unit="WattPerSquareMeter">15.070000</LightPowerPerArea>
```

```
                    <EquipPowerPerArea
unit="WattPerSquareMeter">10.760000&lt;/EquipPowerPerArea&gt;
 &lt;Area&gt;59.340000&lt;/Area&gt;
 &lt;Volume&gt;142.416000&lt;/Volume&gt;
 &lt;PlanarGeometry&gt;
   &lt;PolyLoop&gt;
     &lt;CartesianPoint&gt;
       &lt;Coordinate&gt;-133.582444&lt;/Coordinate&gt;
       &lt;Coordinate&gt;7.054041&lt;/Coordinate&gt;
       &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
     &lt;/CartesianPoint&gt;
     &lt;CartesianPoint&gt;
       &lt;Coordinate&gt;-110.944649&lt;/Coordinate&gt;
       &lt;Coordinate&gt;7.054041&lt;/Coordinate&gt;
       &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
     &lt;/CartesianPoint&gt;
     &lt;CartesianPoint&gt;
       &lt;Coordinate&gt;-110.944649&lt;/Coordinate&gt;
       &lt;Coordinate&gt;35.269264&lt;/Coordinate&gt;
       &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
     &lt;/CartesianPoint&gt;
     &lt;CartesianPoint&gt;
       &lt;Coordinate&gt;-133.582444&lt;/Coordinate&gt;
       &lt;Coordinate&gt;35.269264&lt;/Coordinate&gt;
       &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
     &lt;/CartesianPoint&gt;
   &lt;/PolyLoop&gt;
 &lt;/PlanarGeometry&gt;
 &lt;ShellGeometry id="sg-sp-2-Room_2" unit="Meters"&gt;
   &lt;ClosedShell&gt;
     &lt;PolyLoop&gt;
       &lt;CartesianPoint&gt;
         &lt;Coordinate&gt;-40.715929&lt;/Coordinate&gt;
         &lt;Coordinate&gt;2.150072&lt;/Coordinate&gt;
         &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
       &lt;/CartesianPoint&gt;
       &lt;CartesianPoint&gt;
         &lt;Coordinate&gt;-40.715929&lt;/Coordinate&gt;
         &lt;Coordinate&gt;10.750072&lt;/Coordinate&gt;
         &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
       &lt;/CartesianPoint&gt;
       &lt;CartesianPoint&gt;
         &lt;Coordinate&gt;-33.815929&lt;/Coordinate&gt;
         &lt;Coordinate&gt;10.750072&lt;/Coordinate&gt;
         &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
       &lt;/CartesianPoint&gt;
       &lt;CartesianPoint&gt;
         &lt;Coordinate&gt;-33.815929&lt;/Coordinate&gt;
         &lt;Coordinate&gt;2.150072&lt;/Coordinate&gt;
         &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
```

```
    </CartesianPoint>
  </PolyLoop>
  <PolyLoop>
    <CartesianPoint>
      <Coordinate>-40.715929</Coordinate>
      <Coordinate>10.750072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-40.715929</Coordinate>
      <Coordinate>10.750072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <CartesianPoint> <Coordinate>-33.815929</Coordinate>
      <Coordinate>10.750072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-33.815929</Coordinate>
      <Coordinate>10.750072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
  </PolyLoop>
  <PolyLoop>
    <CartesianPoint>
      <Coordinate>-40.715929</Coordinate>
      <Coordinate>2.150072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-40.715929</Coordinate>
      <Coordinate>2.150072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-40.715929</Coordinate>
      <Coordinate>10.750072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-40.715929</Coordinate>
      <Coordinate>10.750072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
  </PolyLoop>
  <PolyLoop>
    <CartesianPoint>
      <Coordinate>-40.715929</Coordinate>
      <Coordinate>2.150072</Coordinate>
      <Coordinate>0.000000</Coordinate>
```

```
          </CartesianPoint>
          <CartesianPoint>
            <Coordinate>-33.815929</Coordinate>
            <Coordinate>2.150072</Coordinate>
            <Coordinate>0.000000</Coordinate>
          </CartesianPoint>
          <CartesianPoint>
            <Coordinate>-33.815929</Coordinate>
            <Coordinate>2.150072</Coordinate>
            <Coordinate>2.400000</Coordinate>
          </CartesianPoint>
          <CartesianPoint>
            <Coordinate>-40.715929</Coordinate>
            <Coordinate>2.150072</Coordinate>
            <Coordinate>2.400000</Coordinate>
          </CartesianPoint>
        </PolyLoop>
        <PolyLoop>
          <CartesianPoint>
            <Coordinate>-33.815929</Coordinate>
    <Coordinate>2.150072</Coordinate>
    <Coordinate>0.000000</Coordinate>
  </CartesianPoint>
  <CartesianPoint>
    <Coordinate>-33.815929</Coordinate>
    <Coordinate>10.750072</Coordinate>
    <Coordinate>0.000000</Coordinate>
  </CartesianPoint>
  <CartesianPoint>
    <Coordinate>-33.815929</Coordinate>
    <Coordinate>10.750072</Coordinate>
    <Coordinate>2.400000</Coordinate>
  </CartesianPoint>
  <CartesianPoint>
    <Coordinate>-33.815929</Coordinate>
    <Coordinate>2.150072</Coordinate>
    <Coordinate>2.400000</Coordinate>
  </CartesianPoint>
</PolyLoop>
<PolyLoop>
  <CartesianPoint>
    <Coordinate>-40.715929</Coordinate>
    <Coordinate>2.150072</Coordinate>
    <Coordinate>2.400000</Coordinate>
  </CartesianPoint>
  <CartesianPoint>
    <Coordinate>-40.715929</Coordinate>
    <Coordinate>10.750072</Coordinate>
    <Coordinate>2.400000</Coordinate>
  </CartesianPoint>
```

```
      <CartesianPoint>
        <Coordinate>-33.815929</Coordinate>
        <Coordinate>10.750072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.815929</Coordinate>
        <Coordinate>2.150072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </ClosedShell>
</ShellGeometry>
<CADObjectId>436022</CADObjectId>
<SpaceBoundary surfaceIdRef="su-6">
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.000000</Coordinate> <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
</SpaceBoundary>
<SpaceBoundary surfaceIdRef="su-7">
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-40.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-40.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
```

```
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-33.715929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;10.850072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
    &lt;/PolyLoop&gt;
  &lt;/PlanarGeometry&gt;
&lt;/SpaceBoundary&gt;
&lt;SpaceBoundary surfaceIdRef="su-8"&gt;
  &lt;PlanarGeometry&gt;
    &lt;PolyLoop&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-40.815929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-33.715929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt; &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-40.815929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.400000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
    &lt;/PolyLoop&gt;
  &lt;/PlanarGeometry&gt;
&lt;/SpaceBoundary&gt;
&lt;SpaceBoundary surfaceIdRef="su-9"&gt;
  &lt;PlanarGeometry&gt;
    &lt;PolyLoop&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-40.815929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-40.815929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.400000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-40.815929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;10.850072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.400000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-40.815929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;10.850072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
```

```
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
</SpaceBoundary>
<SpaceBoundary surfaceIdRef="su-10">
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-40.815929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-40.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
            </PolyLoop>
          </PlanarGeometry>
        </SpaceBoundary>
        <SpaceBoundary surfaceIdRef="su-11">
          <PlanarGeometry>
            <PolyLoop>
              <CartesianPoint>
                <Coordinate>-40.815929</Coordinate>
                <Coordinate>2.050072</Coordinate>
                <Coordinate>0.000000</Coordinate>
              </CartesianPoint>
              <CartesianPoint>
                <Coordinate>-40.815929</Coordinate>
                <Coordinate>10.850072</Coordinate>
                <Coordinate>0.000000</Coordinate>
              </CartesianPoint>
              <CartesianPoint>
                <Coordinate>-33.715929</Coordinate>
                <Coordinate>10.850072</Coordinate>
                <Coordinate>0.000000</Coordinate>
              </CartesianPoint>
              <CartesianPoint>
                <Coordinate>-33.715929</Coordinate>
                <Coordinate>2.050072</Coordinate>
                <Coordinate>0.000000</Coordinate>
              </CartesianPoint>
            </PolyLoop>
          </PlanarGeometry>
        </SpaceBoundary>
```

```
  </Space>
</Building>
<Surface id="su-1" surfaceType="ExteriorWall"
  constructionIdRef="ASHWL-66"> <Name>N-1-E-W-1</Name>
  <AdjacentSpaceId spaceIdRef="sp-1-Room_1"/>
  <RectangularGeometry>
    <Azimuth>0.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>-25.815929</Coordinate>
      <Coordinate>10.850072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <Tilt>90.000000</Tilt>
    <Height>2.400000</Height>
    <Width>7.900000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <Opening id="su-1-op-1" openingType="NonSlidingDoor"
  constructionIdRef="MDOOR">
    <Name>N-1-E-W-1-D-1</Name>
    <RectangularGeometry>
      <Azimuth>0.000000</Azimuth>
      <CartesianPoint>
        <Coordinate>7.775000</Coordinate>
        <Coordinate>0.000000</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
```

```
    <Tilt>0.000000</Tilt>
    <Height>2.210000</Height>
    <Width>0.125000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.210000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.590929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.210000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.590929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <CADObjectId>M_Single-Panel 3: 0915 x 2134mm
[432787]</CADObjectId> </Opening>
<Opening id="su-1-op-2" openingType="OperableWindow"
windowTypeIdRef="DGL-R-I">
  <Name>N-1-E-W-1-W-2</Name>
  <RectangularGeometry>
    <Azimuth>0.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>4.780000</Coordinate>
      <Coordinate>0.915000</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <Tilt>0.000000</Tilt>
    <Height>1.220000</Height>
    <Width>1.220000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-31.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.915000</Coordinate>
```

```
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-31.815929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;10.850072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.135000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-30.595929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;10.850072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.135000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-30.595929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;10.850072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;0.915000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
    &lt;/PolyLoop&gt;
  &lt;/PlanarGeometry&gt;
  &lt;CADObjectId&gt;M_Casement Dbl with Trim: 1220 x 1220mm
[434831]&lt;/CADObjectId&gt; &lt;/Opening&gt;
<Opening id="su-1-op-3" openingType="OperableWindow"
windowTypeIdRef="DGL-R-I">
  &lt;Name&gt;N-1-E-W-1-W-3&lt;/Name&gt;
  &lt;RectangularGeometry&gt;
    &lt;Azimuth&gt;0.000000&lt;/Azimuth&gt;
    &lt;CartesianPoint&gt;
      &lt;Coordinate&gt;1.760050&lt;/Coordinate&gt;
      &lt;Coordinate&gt;0.915000&lt;/Coordinate&gt;
      &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
    &lt;/CartesianPoint&gt;
    &lt;Tilt&gt;0.000000&lt;/Tilt&gt;
    &lt;Height&gt;1.220000&lt;/Height&gt;
    &lt;Width&gt;1.220000&lt;/Width&gt;
  &lt;/RectangularGeometry&gt;
  &lt;PlanarGeometry&gt;
    &lt;PolyLoop&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-28.795979&lt;/Coordinate&gt;
        &lt;Coordinate&gt;10.850072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;0.915000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-28.795979&lt;/Coordinate&gt;
        &lt;Coordinate&gt;10.850072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.135000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-27.575979&lt;/Coordinate&gt;
        &lt;Coordinate&gt;10.850072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.135000&lt;/Coordinate&gt;
```

```
        </CartesianPoint>
        <CartesianPoint>
          <Coordinate>-27.575979</Coordinate>
          <Coordinate>10.850072</Coordinate>
          <Coordinate>0.915000</Coordinate>
        </CartesianPoint>
      </PolyLoop>
    </PlanarGeometry>
    <CADObjectId>M_Casement Dbl with Trim: 1220 x 1220mm
    [434860]</CADObjectId>
  </Opening>
  <CADObjectId>Basic Wall: Generic - 200mm
[431543]</CADObjectId> </Surface>
<Surface id="su-2" surfaceType="ExteriorWall"
  constructionIdRef="ASHWL-66"> <Name>E-1-E-W-2</Name>
  <AdjacentSpaceId spaceIdRef="sp-1-Room_1"/>
  <RectangularGeometry>
    <Azimuth>90.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>-25.815929</Coordinate>
      <Coordinate>2.050072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <Tilt>90.000000</Tilt>
    <Height>2.400000</Height>
    <Width>8.800000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
```

```
  </PlanarGeometry>
  <Opening id="su-2-op-1" openingType="NonSlidingDoor"
    constructionIdRef="MDOOR"> <Name>E-1-E-W-2-D-1</Name>
    <RectangularGeometry>
      <Azimuth>0.000000</Azimuth>
      <CartesianPoint>
        <Coordinate>4.070000</Coordinate>
        <Coordinate>0.000000</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <Tilt>0.000000</Tilt>
      <Height>1.981000</Height>
      <Width>1.830000</Width>
    </RectangularGeometry>
    <PlanarGeometry>
      <PolyLoop>
        <CartesianPoint>
          <Coordinate>-25.815929</Coordinate>
          <Coordinate>6.120072</Coordinate>
          <Coordinate>0.000000</Coordinate>
        </CartesianPoint>
        <CartesianPoint>
          <Coordinate>-25.815929</Coordinate>
          <Coordinate>7.950072</Coordinate>
          <Coordinate>0.000000</Coordinate>
        </CartesianPoint>
        <CartesianPoint>
          <Coordinate>-25.815929</Coordinate>
          <Coordinate>7.950072</Coordinate>
          <Coordinate>1.981000</Coordinate>
        </CartesianPoint>
        <CartesianPoint>
          <Coordinate>-25.815929</Coordinate>
          <Coordinate>6.120072</Coordinate>
          <Coordinate>1.981000</Coordinate>
        </CartesianPoint>
      </PolyLoop>
    </PlanarGeometry>
    <CADObjectId>M_Double-Glass 2: 1830 x 1981mm
    [433905]</CADObjectId>
  </Opening>
  <CADObjectId>Basic Wall: Generic - 200mm
[431609]</CADObjectId> </Surface>
<Surface id="su-3" surfaceType="ExteriorWall"
  constructionIdRef="ASHWL-66"> <Name>S-1-E-W-3</Name>
  <AdjacentSpaceId spaceIdRef="sp-1-Room_1"/>
  <RectangularGeometry>
    <Azimuth>180.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>-33.715929</Coordinate>
```

```
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;Tilt&gt;90.000000&lt;/Tilt&gt;
      &lt;Height&gt;2.400000&lt;/Height&gt;
      &lt;Width&gt;7.900000&lt;/Width&gt;
    &lt;/RectangularGeometry&gt;
    &lt;PlanarGeometry&gt;
      &lt;PolyLoop&gt;
        &lt;CartesianPoint&gt;
          &lt;Coordinate&gt;-33.715929&lt;/Coordinate&gt;
          &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
          &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
        &lt;/CartesianPoint&gt;
        &lt;CartesianPoint&gt;
          &lt;Coordinate&gt;-25.815929&lt;/Coordinate&gt;
          &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
          &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
        &lt;/CartesianPoint&gt;
        &lt;CartesianPoint&gt;
          &lt;Coordinate&gt;-25.815929&lt;/Coordinate&gt;
          &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
          &lt;Coordinate&gt;2.400000&lt;/Coordinate&gt;
        &lt;/CartesianPoint&gt;
        &lt;CartesianPoint&gt;
          &lt;Coordinate&gt;-33.715929&lt;/Coordinate&gt;
          &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
          &lt;Coordinate&gt;2.400000&lt;/Coordinate&gt;
        &lt;/CartesianPoint&gt;
      &lt;/PolyLoop&gt;
    &lt;/PlanarGeometry&gt;
    <Opening id="su-3-op-1" openingType="NonSlidingDoor"
    constructionIdRef="MDOOR">
      &lt;Name&gt;S-1-E-W-3-D-1&lt;/Name&gt;
      &lt;RectangularGeometry&gt;
        &lt;Azimuth&gt;0.000000&lt;/Azimuth&gt;
        &lt;CartesianPoint&gt;
          &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
          &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
          &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
        &lt;/CartesianPoint&gt;
        &lt;Tilt&gt;0.000000&lt;/Tilt&gt;
        &lt;Height&gt;2.210000&lt;/Height&gt;
        &lt;Width&gt;1.014990&lt;/Width&gt;
      &lt;/RectangularGeometry&gt;
      &lt;PlanarGeometry&gt;
        &lt;PolyLoop&gt;
          &lt;CartesianPoint&gt;
            &lt;Coordinate&gt;-33.715929&lt;/Coordinate&gt;
            &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
```

```
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-32.700939</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-32.700939</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.210000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.210000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <CADObjectId>M_Single-Panel 3: 0915 x 2134mm
[432510]</CADObjectId> </Opening>
<Opening id="su-3-op-2" openingType="OperableWindow"
windowTypeIdRef="DGL-R-I">
  <Name>S-1-E-W-3-W-2</Name>
  <RectangularGeometry>
    <Azimuth>0.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>1.800000</Coordinate>
      <Coordinate>0.915000</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <Tilt>0.000000</Tilt>
    <Height>1.220000</Height>
    <Width>1.220000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-31.915929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.915000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-30.695929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.915000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-30.695929</Coordinate>
        <Coordinate>2.050072</Coordinate>
```

```
        <Coordinate>2.135000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-31.915929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.135000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <CADObjectId>M_Casement Dbl with Trim: 1220 x 1220mm
[434900]</CADObjectId> </Opening>
<Opening id="su-3-op-3" openingType="OperableWindow"
windowTypeIdRef="DGL-R-I">
  <Name>S-1-E-W-3-W-3</Name>
  <RectangularGeometry>
    <Azimuth>0.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>4.800000</Coordinate>
      <Coordinate>0.915000</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <Tilt>0.000000</Tilt>
    <Height>1.220000</Height>
    <Width>1.220000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-28.915929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.915000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-27.695929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.915000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-27.695929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.135000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-28.915929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.135000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
```

```xml
    <CADObjectId>M_Casement Dbl with Trim: 1220 x 1220mm
  [434948]</CADObjectId> </Opening>
  <CADObjectId>Basic Wall: Generic - 200mm
[431678]</CADObjectId> </Surface>
<Surface id="su-4" surfaceType="Roof"
  constructionIdRef="ASHRF28"> <Name>B-1-E-R-4</Name>
  <AdjacentSpaceId spaceIdRef="sp-1-Room_1"/>
  <RectangularGeometry>
    <Azimuth>0.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>-25.815929</Coordinate>
      <Coordinate>2.050072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <Tilt>180.000000</Tilt>
    <Height>8.800000</Height>
    <Width>7.900000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <CADObjectId>Compound Ceiling: 600 x 600mm Grid
[435611]</CADObjectId> </Surface>
<Surface id="su-5" surfaceType="InteriorFloor"
  constructionIdRef="con-c23"> <Name>B-1-1-I-F-5</Name>
  <AdjacentSpaceId spaceIdRef="sp-1-Room_1"/>
  <AdjacentSpaceId spaceIdRef="sp-1-Room_1"/>
  <RectangularGeometry>
    <Azimuth>0.000000</Azimuth>
```

```
    <CartesianPoint>
      <Coordinate>-25.815929</Coordinate>
      <Coordinate>2.050072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <Tilt>180.000000</Tilt>
    <Height>8.800000</Height>
    <Width>7.900000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <CADObjectId>Floor: Generic 300mm
[435319]</CADObjectId> </Surface>
<Surface id="su-6" surfaceType="InteriorWall"
  constructionIdRef="ASHIW23"> <Name>W-1-2-I-W-6</Name>
  <AdjacentSpaceId spaceIdRef="sp-1-Room_1"/>
  <AdjacentSpaceId spaceIdRef="sp-2-Room_2"/>
  <RectangularGeometry>
    <Azimuth>270.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>-33.715929</Coordinate>
      <Coordinate>10.850072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <Tilt>90.000000</Tilt>
    <Height>2.400000</Height>
    <Width>8.800000</Width>
  </RectangularGeometry>
```

```
<PlanarGeometry>
  <PolyLoop>
    <CartesianPoint>
      <Coordinate>-33.715929</Coordinate>
      <Coordinate>2.050072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-33.715929</Coordinate>
      <Coordinate>2.050072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-33.715929</Coordinate>
      <Coordinate>10.850072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-33.715929</Coordinate>
      <Coordinate>10.850072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
  </PolyLoop>
</PlanarGeometry>
<Opening id="su-6-op-1" openingType="NonSlidingDoor"
constructionIdRef="MDOOR">
  <Name>W-1-2-I-W-6-D-1</Name>
  <RectangularGeometry>
    <Azimuth>0.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>7.785000</Coordinate>
      <Coordinate>0.000000</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <Tilt>0.000000</Tilt>
    <Height>2.134000</Height>
    <Width>0.915000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>2.150072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>2.150072</Coordinate>
        <Coordinate>2.134000</Coordinate>
      </CartesianPoint>
```

```
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-33.715929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;3.065072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.134000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-33.715929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;3.065072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
    &lt;/PolyLoop&gt;
  &lt;/PlanarGeometry&gt;
  &lt;CADObjectId&gt;M_Single-Panel 3: 0915 x 2134mm
[432510]&lt;/CADObjectId&gt; &lt;/Opening&gt;
<Opening id="su-6-op-2" openingType="NonSlidingDoor"
constructionIdRef="MDOOR">
  &lt;Name&gt;W-1-2-I-W-6-D-2&lt;/Name&gt;
  &lt;RectangularGeometry&gt;
    &lt;Azimuth&gt;0.000000&lt;/Azimuth&gt;
    &lt;CartesianPoint&gt;
      &lt;Coordinate&gt;0.100000&lt;/Coordinate&gt;
      &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
      &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
    &lt;/CartesianPoint&gt;
    &lt;Tilt&gt;0.000000&lt;/Tilt&gt;
    &lt;Height&gt;2.134000&lt;/Height&gt;
    &lt;Width&gt;0.915000&lt;/Width&gt;
  &lt;/RectangularGeometry&gt;
  &lt;PlanarGeometry&gt;
    &lt;PolyLoop&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-33.715929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;9.835072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-33.715929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;9.835072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.134000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-33.715929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;10.750072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.134000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-33.715929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;10.750072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
```

```
      </PolyLoop>
    </PlanarGeometry>
    <CADObjectId>M_Single-Panel 3: 0915 x 2134mm
   [432787]</CADObjectId> </Opening>
   <CADObjectId>Basic Wall: Generic - 200mm
 [431830]</CADObjectId> </Surface>
 <Surface id="su-7" surfaceType="ExteriorWall"
   constructionIdRef="ASHWL-66"> <Name>N-2-E-W-7</Name>
   <AdjacentSpaceId spaceIdRef="sp-2-Room_2"/>
   <RectangularGeometry>
     <Azimuth>0.000000</Azimuth>
     <CartesianPoint>
       <Coordinate>-33.715929</Coordinate>
       <Coordinate>10.850072</Coordinate>
       <Coordinate>0.000000</Coordinate>
     </CartesianPoint>
     <Tilt>90.000000</Tilt>
     <Height>2.400000</Height>
     <Width>7.100000</Width>
   </RectangularGeometry>
   <PlanarGeometry>
     <PolyLoop>
       <CartesianPoint>
         <Coordinate>-40.815929</Coordinate>
         <Coordinate>10.850072</Coordinate>
         <Coordinate>0.000000</Coordinate>
       </CartesianPoint>
       <CartesianPoint>
         <Coordinate>-40.815929</Coordinate>
         <Coordinate>10.850072</Coordinate>
         <Coordinate>2.400000</Coordinate>
       </CartesianPoint>
       <CartesianPoint>
         <Coordinate>-33.715929</Coordinate>
         <Coordinate>10.850072</Coordinate>
         <Coordinate>2.400000</Coordinate>
       </CartesianPoint>
       <CartesianPoint>
         <Coordinate>-33.715929</Coordinate>
         <Coordinate>10.850072</Coordinate>
         <Coordinate>0.000000</Coordinate>
       </CartesianPoint>
     </PolyLoop>
   </PlanarGeometry>
   <Opening id="su-7-op-1" openingType="NonSlidingDoor"
   constructionIdRef="MDOOR">
     <Name>N-2-E-W-7-D-1</Name>
     <RectangularGeometry>
       <Azimuth>0.000000</Azimuth>
       <CartesianPoint>
```

```
      <Coordinate>0.000000</Coordinate>
      <Coordinate>0.000000</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <Tilt>0.000000</Tilt>
    <Height>2.210000</Height>
    <Width>1.014990</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-34.730919</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-34.730919</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.210000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.210000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <CADObjectId>M_Single-Panel 3: 0915 x 2134mm
[432787]</CADObjectId> </Opening>
<Opening id="su-7-op-2" openingType="OperableWindow"
windowTypeIdRef="DGL-R-I">
  <Name>N-2-E-W-7-W-2</Name>
  <RectangularGeometry>
    <Azimuth>0.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>4.310050</Coordinate>
      <Coordinate>0.915000</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <Tilt>0.000000</Tilt>
    <Height>1.220000</Height>
    <Width>1.220000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
```

```
      <CartesianPoint>
        <Coordinate>-39.245979</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.915000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-39.245979</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.135000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-38.025979</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.135000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-38.025979</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.915000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <CADObjectId>M_Casement Dbl with Trim: 1220 x 1220mm
[435016]</CADObjectId> </Opening>
<Opening id="su-7-op-3" openingType="OperableWindow"
windowTypeIdRef="DGL-R-I"> <Name>N-2-E-W-7-W-3</Name>
  <RectangularGeometry>
    <Azimuth>0.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>1.369950</Coordinate>
      <Coordinate>0.915000</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <Tilt>0.000000</Tilt>
    <Height>1.220000</Height>
    <Width>1.220000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-36.305879</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.915000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-36.305879</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.135000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
```

```
        <Coordinate>-35.085879</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.135000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-35.085879</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>0.915000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <CADObjectId>M_Casement Dbl with Trim: 1220 x 1220mm
 [435219]</CADObjectId> </Opening>
 <CADObjectId>Basic Wall: Generic - 200mm
[431543]</CADObjectId> </Surface>
<Surface id="su-8" surfaceType="ExteriorWall"
 constructionIdRef="ASHWL-66"> <Name>S-2-E-W-8</Name>
 <AdjacentSpaceId spaceIdRef="sp-2-Room_2"/>
 <RectangularGeometry>
  <Azimuth>180.000000</Azimuth>
  <CartesianPoint>
    <Coordinate>-40.815929</Coordinate>
    <Coordinate>2.050072</Coordinate>
    <Coordinate>0.000000</Coordinate>
  </CartesianPoint>
  <Tilt>90.000000</Tilt>
  <Height>2.400000</Height>
  <Width>7.100000</Width>
 </RectangularGeometry>
 <PlanarGeometry>
  <PolyLoop>
    <CartesianPoint>
      <Coordinate>-40.815929</Coordinate>
      <Coordinate>2.050072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-33.715929</Coordinate>
      <Coordinate>2.050072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-33.715929</Coordinate>
      <Coordinate>2.050072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-40.815929</Coordinate>
      <Coordinate>2.050072</Coordinate>
      <Coordinate>2.400000</Coordinate>
```

```
    </CartesianPoint>
  </PolyLoop>
</PlanarGeometry>
<Opening id="su-8-op-1" openingType="NonSlidingDoor"
constructionIdRef="MDOOR">
  <Name>S-2-E-W-8-D-1</Name>
  <RectangularGeometry>
    <Azimuth>0.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>6.975000</Coordinate>
      <Coordinate>0.000000</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <Tilt>0.000000</Tilt>
    <Height>2.210000</Height>
    <Width>0.125000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-33.840929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.210000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.840929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.210000</Coordinate>
      </CartesianP
    oint>
    </PolyLoop>
    </PlanarGeomet
    ry>
  <CADObjectId>M_Single-Panel 3: 0915 x 2134mm
[432510]</CADObjectId> </Opening>
<Opening id="su-8-op-2" openingType="OperableWindow"
windowTypeIdRef="DGL-R-I">
  <Name>S-2-E-W-8-W-2</Name>
  <RectangularGeometry>
    <Azimuth>0.000000</Azimuth>
```

```
    &lt;CartesianPoint&gt;
      &lt;Coordinate&gt;1.500000&lt;/Coordinate&gt;
      &lt;Coordinate&gt;0.915000&lt;/Coordinate&gt;
      &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
    &lt;/CartesianPoint&gt;
    &lt;Tilt&gt;0.000000&lt;/Tilt&gt;
    &lt;Height&gt;1.220000&lt;/Height&gt;
    &lt;Width&gt;1.220000&lt;/Width&gt;
  &lt;/RectangularGeometry&gt;
  &lt;PlanarGeometry&gt;
    &lt;PolyLoop&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-39.315929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;0.915000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-38.095929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;0.915000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-38.095929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.135000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-39.315929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.135000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
    &lt;/PolyLoop&gt;
  &lt;/PlanarGeometry&gt;
  &lt;CADObjectId&gt;M_Casement Dbl with Trim: 1220 x 1220mm
[435088]&lt;/CADObjectId&gt; &lt;/Opening&gt;
<Opening id="su-8-op-3" openingType="OperableWindow"
windowTypeIdRef="DGL-R-I">
  &lt;Name&gt;S-2-E-W-8-W-3&lt;/Name&gt;
  &lt;RectangularGeometry&gt;
    &lt;Azimuth&gt;0.000000&lt;/Azimuth&gt;
    &lt;CartesianPoint&gt;
      &lt;Coordinate&gt;4.580000&lt;/Coordinate&gt;
      &lt;Coordinate&gt;0.915000&lt;/Coordinate&gt;
      &lt;Coordinate&gt;0.000000&lt;/Coordinate&gt;
    &lt;/CartesianPoint&gt;
    &lt;Tilt&gt;0.000000&lt;/Tilt&gt;
    &lt;Height&gt;1.220000&lt;/Height&gt;
    &lt;Width&gt;1.220000&lt;/Width&gt;
  &lt;/RectangularGeometry&gt;
  &lt;PlanarGeometry&gt;
```

```
      <PolyLoop>
        <CartesianPoint>
          <Coordinate>-36.235929</Coordinate>
          <Coordinate>2.050072</Coordinate>
          <Coordinate>0.915000</Coordinate>
        </CartesianPoint>
        <CartesianPoint>
          <Coordinate>-35.015929</Coordinate>
          <Coordinate>2.050072</Coordinate>
          <Coordinate>0.915000</Coordinate>
        </CartesianPoint>
        <CartesianPoint>
          <Coordinate>-35.015929</Coordinate>
          <Coordinate>2.050072</Coordinate>
          <Coordinate>2.135000</Coordinate>
        </CartesianPoint>
        <CartesianPoint>
          <Coordinate>-36.235929</Coordinate>
          <Coordinate>2.050072</Coordinate>
          <Coordinate>2.135000</Coordinate>
        </CartesianPoint>
      </PolyLoop>
    </PlanarGeometry>
    <CADObjectId>M_Casement Dbl with Trim: 1220 x 1220mm
  [435124]</CADObjectId> </Opening>
  <CADObjectId>Basic Wall: Generic - 200mm
[431678]</CADObjectId> </Surface>
<Surface id="su-9" surfaceType="ExteriorWall"
  constructionIdRef="ASHWL-66"> <Name>W-2-E-W-9</Name>
  <AdjacentSpaceId spaceIdRef="sp-2-Room_2"/>
  <RectangularGeometry>
    <Azimuth>270.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>-40.815929</Coordinate>
      <Coordinate>10.850072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <Tilt>90.000000</Tilt>
    <Height>2.400000</Height>
    <Width>8.800000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-40.815929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-40.815929</Coordinate>
```

```xml
      <Coordinate>2.050072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-40.815929</Coordinate>
      <Coordinate>10.850072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <CartesianPoint>
      <Coordinate>-40.815929</Coordinate>
      <Coordinate>10.850072</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
  </PolyLoop>
</PlanarGeometry>
<Opening id="su-9-op-1" openingType="NonSlidingDoor"
constructionIdRef="MDOOR">
  <Name>W-2-E-W-9-D-1</Name>
  <RectangularGeometry>
    <Azimuth>0.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>3.100000</Coordinate>
      <Coordinate>0.000000</Coordinate>
      <Coordinate>0.000000</Coordinate>
    </CartesianPoint>
    <Tilt>0.000000</Tilt>
    <Height>1.981000</Height>
    <Width>1.830000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-40.815929</Coordinate>
        <Coordinate>5.920072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-40.815929</Coordinate>
        <Coordinate>5.920072</Coordinate>
        <Coordinate>1.981000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-40.815929</Coordinate>
        <Coordinate>7.750072</Coordinate>
        <Coordinate>1.981000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-40.815929</Coordinate>
        <Coordinate>7.750072</Coordinate>
        <Coordinate>0.000000</Coordinate>
```

```
        &lt;/CartesianPoint&gt;
      &lt;/PolyLoop&gt;
    &lt;/PlanarGeometry&gt;
    &lt;CADObjectId&gt;M_Double-Glass 2: 1830 x 1981mm
  [433968]&lt;/CADObjectId&gt; &lt;/Opening&gt;
  &lt;CADObjectId&gt;Basic Wall: Generic - 200mm
[431716]&lt;/CADObjectId&gt; &lt;/Surface&gt;
<Surface id="su-10" surfaceType="Roof"
  constructionIdRef="ASHRF28"> &lt;Name&gt;B-2-E-R-10&lt;/Name&gt;
  &lt;AdjacentSpaceId spaceIdRef="sp-2-Room_2"/&gt;
  &lt;RectangularGeometry&gt;
    &lt;Azimuth&gt;0.000000&lt;/Azimuth&gt;
    &lt;CartesianPoint&gt;
      &lt;Coordinate&gt;-33.715929&lt;/Coordinate&gt;
      &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
      &lt;Coordinate&gt;2.400000&lt;/Coordinate&gt;
    &lt;/CartesianPoint&gt;
    &lt;Tilt&gt;180.000000&lt;/Tilt&gt;
    &lt;Height&gt;8.800000&lt;/Height&gt;
    &lt;Width&gt;7.100000&lt;/Width&gt;
  &lt;/RectangularGeometry&gt;
  &lt;PlanarGeometry&gt;
    &lt;PolyLoop&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-40.815929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.400000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-40.815929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;10.850072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.400000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-33.715929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;10.850072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.400000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-33.715929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.400000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
    &lt;/PolyLoop&gt;
  &lt;/PlanarGeometry&gt;
  &lt;CADObjectId&gt;Compound Ceiling: 600 x 600mm Grid
[435611]&lt;/CADObjectId&gt; &lt;/Surface&gt;
<Surface id="su-11" surfaceType="InteriorFloor"
  constructionIdRef="con-c23"> &lt;Name&gt;B-2-2-I-F-11&lt;/Name&gt;
  &lt;AdjacentSpaceId spaceIdRef="sp-2-Room_2"/&gt;
```

```
    <AdjacentSpaceId spaceIdRef="sp-2-Room_2"/>
    <RectangularGeometry>
      <Azimuth>0.000000</Azimuth>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>0.000000</Coordinate>
      </CartesianPoint>
      <Tilt>180.000000</Tilt>
      <Height>8.800000</Height>
      <Width>7.100000</Width>
    </RectangularGeometry>
    <PlanarGeometry>
      <PolyLoop>
        <CartesianPoint>
          <Coordinate>-40.815929</Coordinate>
          <Coordinate>2.050072</Coordinate>
          <Coordinate>0.000000</Coordinate>
        </CartesianPoint>
        <CartesianPoint>
          <Coordinate>-40.815929</Coordinate>
          <Coordinate>10.850072</Coordinate>
          <Coordinate>0.000000</Coordinate>
        </CartesianPoint>
        <CartesianPoint>
          <Coordinate>-33.715929</Coordinate>
          <Coordinate>10.850072</Coordinate>
          <Coordinate>0.000000</Coordinate>
        </CartesianPoint>
        <CartesianPoint>
          <Coordinate>-33.715929</Coordinate>
          <Coordinate>2.050072</Coordinate>
          <Coordinate>0.000000</Coordinate>
        </CartesianPoint>
      </PolyLoop>
    </PlanarGeometry>
    <CADObjectId>Floor: Generic 300mm [435319]</CADObjectId>
  </Surface>
  <Surface id="su-12" surfaceType="Shade">
    <Name>X-S-12</Name>
    <RectangularGeometry>
      <Azimuth>0.000000</Azimuth>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <Tilt>90.000000</Tilt>
      <Height>1.600000</Height>
      <Width>15.000000</Width>
```

```
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-40.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-40.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>4.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>4.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <CADObjectId>Basic Wall: Generic - 200mm
[431543]</CADObjectId> </Surface>
<Surface id="su-13" surfaceType="Shade">
  <Name>X-S-13</Name>
  <RectangularGeometry>
    <Azimuth>90.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>-25.815929</Coordinate>
      <Coordinate>2.050072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <Tilt>90.000000</Tilt>
    <Height>1.600000</Height>
    <Width>8.800000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
```

```
        &lt;Coordinate&gt;2.400000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-25.815929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;10.850072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;4.000000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-25.815929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;4.000000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
    &lt;/PolyLoop&gt;
  &lt;/PlanarGeometry&gt;
  &lt;CADObjectId&gt;Basic Wall: Generic - 200mm
[431609]&lt;/CADObjectId&gt; &lt;/Surface&gt;
&lt;Surface id="su-14" surfaceType="Shade"&gt;
  &lt;Name&gt;X-S-14&lt;/Name&gt;
  &lt;RectangularGeometry&gt;
    &lt;Azimuth&gt;180.000000&lt;/Azimuth&gt;
    &lt;CartesianPoint&gt;
      &lt;Coordinate&gt;-40.815929&lt;/Coordinate&gt;
      &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
      &lt;Coordinate&gt;2.400000&lt;/Coordinate&gt;
    &lt;/CartesianPoint&gt;
    &lt;Tilt&gt;90.000000&lt;/Tilt&gt;
    &lt;Height&gt;1.600000&lt;/Height&gt;
    &lt;Width&gt;15.000000&lt;/Width&gt;
  &lt;/RectangularGeometry&gt;
  &lt;PlanarGeometry&gt;
    &lt;PolyLoop&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-40.815929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.400000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-25.815929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.400000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-25.815929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;4.000000&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;CartesianPoint&gt;
        &lt;Coordinate&gt;-40.815929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;2.050072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;4.000000&lt;/Coordinate&gt;
```

```
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <CADObjectId>Basic Wall: Generic - 200mm
[431678]</CADObjectId> </Surface>
<Surface id="su-15" surfaceType="Shade">
  <Name>X-S-15</Name>
  <RectangularGeometry>
    <Azimuth>90.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>-40.815929</Coordinate>
      <Coordinate>2.050072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <Tilt>90.000000</Tilt>
    <Height>1.600000</Height>
    <Width>8.800000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-40.815929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-40.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-40.815929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>4.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-40.815929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>4.000000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <CADObjectId>Basic Wall: Generic - 200mm
[431716]</CADObjectId> </Surface>
<Surface id="su-16" surfaceType="Shade">
  <Name>X-S-16</Name>
  <RectangularGeometry>
    <Azimuth>90.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>-33.715929</Coordinate>
```

```xml
      <Coordinate>2.050072</Coordinate>
      <Coordinate>2.400000</Coordinate>
    </CartesianPoint>
    <Tilt>90.000000</Tilt>
    <Height>1.600000</Height>
    <Width>8.800000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>2.400000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>10.850072</Coordinate>
        <Coordinate>4.000000</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-33.715929</Coordinate>
        <Coordinate>2.050072</Coordinate>
        <Coordinate>4.000000</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <CADObjectId>Basic Wall: Generic - 200mm
[431830]</CADObjectId> </Surface>
<Surface id="su-17" surfaceType="Shade">
  <Name>X-S-17</Name>
  <RectangularGeometry>
    <Azimuth>270.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>-40.915929</Coordinate>
      <Coordinate>10.950072</Coordinate>
      <Coordinate>4.461880</Coordinate>
    </CartesianPoint>
    <Tilt>30.000000</Tilt>
    <Height>2.598076</Height>
    <Width>9.000000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-40.915929</Coordinate>
```

```
        <Coordinate>1.950072</Coordinate>
        <Coordinate>4.461880</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-36.415929</Coordinate>
        <Coordinate>6.450072</Coordinate>
        <Coordinate>7.059956</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-40.915929</Coordinate>
        <Coordinate>10.950072</Coordinate>
        <Coordinate>4.461880</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <CADObjectId>Basic Roof: Generic - 400mm
[435973]</CADObjectId> </Surface>
<Surface id="su-18" surfaceType="Shade">
  <Name>X-S-18</Name>
  <RectangularGeometry>
    <Azimuth>0.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>-25.715929</Coordinate>
      <Coordinate>10.950072</Coordinate>
      <Coordinate>4.461880</Coordinate>
    </CartesianPoint>
    <Tilt>30.000000</Tilt>
    <Height>3.657818</Height>
    <Width>15.200000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-40.915929</Coordinate>
        <Coordinate>10.950072</Coordinate>
        <Coordinate>4.461880</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-36.415929</Coordinate>
        <Coordinate>6.450072</Coordinate>
        <Coordinate>7.059956</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-30.215929</Coordinate>
        <Coordinate>6.450072</Coordinate>
        <Coordinate>7.059956</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.715929</Coordinate>
        <Coordinate>10.950072</Coordinate>
```

```
        <Coordinate>4.461880</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <CADObjectId>Basic Roof: Generic - 400mm
[435973]</CADObjectId> </Surface>
<Surface id="su-19" surfaceType="Shade">
  <Name>X-S-19</Name>
  <RectangularGeometry>
    <Azimuth>180.000000</Azimuth>
    <CartesianPoint>
      <Coordinate>-40.915929</Coordinate>
      <Coordinate>1.950072</Coordinate>
      <Coordinate>4.461880</Coordinate>
    </CartesianPoint>
    <Tilt>30.000000</Tilt>
    <Height>3.657818</Height>
    <Width>15.200000</Width>
  </RectangularGeometry>
  <PlanarGeometry>
    <PolyLoop>
      <CartesianPoint>
        <Coordinate>-40.915929</Coordinate>
        <Coordinate>1.950072</Coordinate>
        <Coordinate>4.461880</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-25.715929</Coordinate>
        <Coordinate>1.950072</Coordinate>
        <Coordinate>4.461880</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-30.215929</Coordinate>
        <Coordinate>6.450072</Coordinate>
        <Coordinate>7.059956</Coordinate>
      </CartesianPoint>
      <CartesianPoint>
        <Coordinate>-36.415929</Coordinate>
        <Coordinate>6.450072</Coordinate>
        <Coordinate>7.059956</Coordinate>
      </CartesianPoint>
    </PolyLoop>
  </PlanarGeometry>
  <CADObjectId>Basic Roof: Generic - 400mm
[435973]</CADObjectId> </Surface>
<Surface id="su-20" surfaceType="Shade">
  <Name>X-S-20</Name>
  <RectangularGeometry>
    <Azimuth>90.000000</Azimuth>
    <CartesianPoint>
```

```
        &lt;Coordinate&gt;-25.715929&lt;/Coordinate&gt;
        &lt;Coordinate&gt;1.950072&lt;/Coordinate&gt;
        &lt;Coordinate&gt;4.461880&lt;/Coordinate&gt;
      &lt;/CartesianPoint&gt;
      &lt;Tilt&gt;30.000000&lt;/Tilt&gt;
      &lt;Height&gt;2.598076&lt;/Height&gt;
      &lt;Width&gt;9.000000&lt;/Width&gt;
    &lt;/RectangularGeometry&gt;
    &lt;PlanarGeometry&gt;
      &lt;PolyLoop&gt;
        &lt;CartesianPoint&gt;
          &lt;Coordinate&gt;-30.215929&lt;/Coordinate&gt;
          &lt;Coordinate&gt;6.450072&lt;/Coordinate&gt;
          &lt;Coordinate&gt;7.059956&lt;/Coordinate&gt;
        &lt;/CartesianPoint&gt;
        &lt;CartesianPoint&gt;
          &lt;Coordinate&gt;-25.715929&lt;/Coordinate&gt;
          &lt;Coordinate&gt;1.950072&lt;/Coordinate&gt;
          &lt;Coordinate&gt;4.461880&lt;/Coordinate&gt;
        &lt;/CartesianPoint&gt;
        &lt;CartesianPoint&gt;
          &lt;Coordinate&gt;-25.715929&lt;/Coordinate&gt;
          &lt;Coordinate&gt;10.950072&lt;/Coordinate&gt;
          &lt;Coordinate&gt;4.461880&lt;/Coordinate&gt;
        &lt;/CartesianPoint&gt;
      &lt;/PolyLoop&gt;
    &lt;/PlanarGeometry&gt;
    &lt;CADObjectId&gt;Basic Roof: Generic - 400mm
  [435973]&lt;/CADObjectId&gt; &lt;/Surface&gt;
&lt;/Campus&gt;
&lt;Construction id="ASHWL-66"&gt;
  &lt;Name&gt;8 in lightweight concrete block&lt;/Name&gt;
  &lt;Description&gt;8 in (200 mm) lightweight concrete
  block&lt;/Description&gt;
  &lt;LayerId layerIdRef="lay-ASHWL-66"/&gt;
  &lt;U-value unit="WPerSquareMeterK"&gt;0.8108&lt;/U-value&gt;
&lt;/Construction&gt;
&lt;Construction id="MDOOR"&gt;
  &lt;Name&gt;Metal&lt;/Name&gt;
  &lt;Description&gt;Metal door&lt;/Description&gt;
  &lt;LayerId layerIdRef="lay-MDOOR"/&gt;
  &lt;U-value unit="WPerSquareMeterK"&gt;3.7021&lt;/U-value&gt;
&lt;/Construction&gt;
&lt;Construction id="ASHRF28"&gt;
  &lt;Name&gt;4 in lightweight concrete&lt;/Name&gt;
  &lt;Description&gt;4 in (100 mm) lightweight concrete&lt;/Description&gt;
  &lt;LayerId layerIdRef="lay-ASHRF28"/&gt;
  &lt;U-value unit="WPerSquareMeterK"&gt;1.2750&lt;/U-value&gt;
&lt;/Construction&gt;
&lt;Construction id="con-c23"&gt;
```

```
  &lt;Name&gt;Passive floor, no insulation, tile or
  vinyl&lt;/Name&gt; &lt;Description&gt;
    Passive floor, no insulation, tile or vinyl [Source:
  CIBSE] &lt;/Description&gt;
  &lt;LayerId layerIdRef="lay-c23"/&gt;
  &lt;U-value unit="WPerSquareMeterK"&gt;2.9582&lt;/U-value&gt;
&lt;/Construction&gt;
&lt;Construction id="ASHIW23"&gt;
  &lt;Name&gt;Frame partition with 3/4 in gypsum board&lt;/Name&gt;
  &lt;Description&gt;Frame partition with 3/4 in (19 mm) gypsum
  board&lt;/Description&gt; &lt;LayerId layerIdRef="lay-ASHIW23"/&gt;
  &lt;U-value unit="WPerSquareMeterK"&gt;1.4733&lt;/U-value&gt;
&lt;/Construction&gt;
&lt;Layer id="lay-ASHWL-66"&gt;
  &lt;MaterialId materialIdRef="mat-AM13"/&gt;
  &lt;MaterialId materialIdRef="mat-AM13"/&gt;
&lt;/Layer&gt;
&lt;Layer id="lay-MDOOR"&gt;
  &lt;MaterialId materialIdRef="mat-AF08"/&gt;
  &lt;MaterialId materialIdRef="mat-860"/&gt;
  &lt;MaterialId materialIdRef="mat-AF08"/&gt;
&lt;/Layer&gt;
&lt;Layer id="lay-ASHRF28"&gt;
  &lt;MaterialId materialIdRef="mat-AM01"/&gt;
&lt;/Layer&gt;
&lt;Layer id="lay-c23"&gt;
  &lt;MaterialId materialIdRef="mat-AF14"/&gt;
  &lt;MaterialId materialIdRef="mat-842"/&gt;
&lt;/Layer&gt;
&lt;Layer id="lay-ASHIW23"&gt;
  &lt;MaterialId materialIdRef="mat-447"/&gt;
  &lt;MaterialId materialIdRef="mat-AG01"/&gt;
&lt;/Layer&gt;
&lt;Material id="mat-AM13"&gt;
  &lt;Name&gt;8 in lightweight concrete&lt;/Name&gt;
  &lt;Description&gt;8 in (200 mm) lightweight concrete&lt;/Description&gt;
  &lt;Thickness unit="Meters"&gt;0.2032&lt;/Thickness&gt;
  &lt;Conductivity unit="WPerMeterK"&gt;0.53&lt;/Conductivity&gt;
  &lt;Density unit="KgPerCubicM"&gt;1280&lt;/Density&gt;
  &lt;SpecificHeat unit="JPerKgK"&gt;840&lt;/SpecificHeat&gt;
&lt;/Material&gt;
&lt;Material id="mat-AF08"&gt;
  &lt;Name&gt;Metal surface&lt;/Name&gt;
  &lt;Description&gt;Metal surface&lt;/Description&gt;
  &lt;Thickness unit="Meters"&gt;0.0008&lt;/Thickness&gt;
  &lt;Conductivity unit="WPerMeterK"&gt;45.28&lt;/Conductivity&gt;
  &lt;Density unit="KgPerCubicM"&gt;7824&lt;/Density&gt;
  &lt;SpecificHeat unit="JPerKgK"&gt;500&lt;/SpecificHeat&gt;
&lt;/Material&gt;
&lt;Material id="mat-860"&gt;
```

```
    <Name>1 1/2 in wood</Name>
    <Description>1 1/2 in (40 mm) wood</Description>
    <Thickness unit="Meters">0.0376</Thickness>
    <Conductivity unit="WPerMeterK">0.15</Conductivity>
    <Density unit="KgPerCubicM">608</Density>
    <SpecificHeat unit="JPerKgK">1630</SpecificHeat>
  </Material>
  <Material id="mat-AM01">
    <Name>4 in brick</Name>
    <Description>4 in (100 mm) brick</Description>
    <Thickness unit="Meters">0.1016</Thickness>
    <Conductivity unit="WPerMeterK">0.89</Conductivity>
    <Density unit="KgPerCubicM">1920</Density>
    <SpecificHeat unit="JPerKgK">790</SpecificHeat>
  </Material>
  <Material id="mat-AF14">
    <Name>Slate or tile</Name>
    <Description>Slate or tile</Description>
    <Thickness unit="Meters">0.0127</Thickness>
    <Conductivity unit="WPerMeterK">1.59</Conductivity>
    <Density unit="KgPerCubicM">1920</Density>
    <SpecificHeat unit="JPerKgK">1260</SpecificHeat>
  </Material>
  <Material id="mat-842">
    <Name>No insulation</Name>
    <Description>No insulation</Description>
    <R-value unit="SquareMeterKPerW">1</R-value>
  </Material>
  <Material id="mat-447">
    <Name>Minwool batt R11 w/ 2x4 frame</Name>
    <Description>Batt, R-11 including framing factor</Description>
    <R-value unit="SquareMeterKPerW">8.32</R-value>
  </Material>
  <Material id="mat-AG01">
    <Name>5/8 in gyp board</Name>
    <Description>5/8 in (16 mm) gyp board</Description>
    <Thickness unit="Meters">0.0159</Thickness>
    <Conductivity unit="WPerMeterK">0.16</Conductivity>
    <Density unit="KgPerCubicM">800</Density>
    <SpecificHeat unit="JPerKgK">1090</SpecificHeat>
  </Material>
  <WindowType id="DGL-R-I">
    <Name>
      Large double-glazed windows (reflective coating) - industry
    </Name>
    <Description>
      Large double-glazed windows (reflective coating) -
    industry </Description>
    <U-value unit="WPerSquareMeterK">2.9214</U-value>
    <SolarHeatGainCoeff unit="Fraction"
```

```
  solarIncidentAngle="0">0.13</SolarHeatGainCoeff>
  <SolarHeatGainCoeff unit="Fraction"
  solarIncidentAngle="40">0.12</SolarHeatGainCoeff>
  <SolarHeatGainCoeff unit="Fraction"
  solarIncidentAngle="50">0.12</SolarHeatGainCoeff>
  <SolarHeatGainCoeff unit="Fraction"
  solarIncidentAngle="60">0.11</SolarHeatGainCoeff>
  <SolarHeatGainCoeff unit="Fraction"
  solarIncidentAngle="70">0.10</SolarHeatGainCoeff>
  <SolarHeatGainCoeff unit="Fraction"
  solarIncidentAngle="80">0.06</SolarHeatGainCoeff>
  <SolarHeatGainCoeff unit="Fraction">0.11</SolarHeatGainCoeff>
  <Transmittance unit="Fraction"
type="Visible">0.07</Transmittance> </WindowType>
<Schedule id="schdl-1" type="Fraction">
  <Name>School Occupancy - 8 AM to 9 PM</Name>
  <YearSchedule id="yr-schdl-1">
    <BeginDate>2013-01-01</BeginDate>
    <EndDate>2013-12-31</EndDate>
    <WeekScheduleId weekScheduleIdRef="wk-schdl-1"/>
  </YearSchedule>
</Schedule>
<WeekSchedule id="wk-schdl-1" type="Fraction">
  <Day dayType="All" dayScheduleIdRef="dy-schdl-1"/>
</WeekSchedule>
<DaySchedule id="dy-schdl-1" type="Fraction">
  <ScheduleValue>0.000000</ScheduleValue>
  <ScheduleValue>0.000000</ScheduleValue>
  <ScheduleValue>0.000000</ScheduleValue>
  <ScheduleValue>0.000000</ScheduleValue>
  <ScheduleValue>0.000000</ScheduleValue>
  <ScheduleValue>0.000000</ScheduleValue>
  <ScheduleValue>0.000000</ScheduleValue>
  <ScheduleValue>0.050000</ScheduleValue>
  <ScheduleValue>0.750000</ScheduleValue>
  <ScheduleValue>0.900000</ScheduleValue>
  <ScheduleValue>0.900000</ScheduleValue>
  <ScheduleValue>0.800000</ScheduleValue>
  <ScheduleValue>0.800000</ScheduleValue>
  <ScheduleValue>0.800000</ScheduleValue>
  <ScheduleValue>0.800000</ScheduleValue>
  <ScheduleValue>0.450000</ScheduleValue>
  <ScheduleValue>0.150000</ScheduleValue>
  <ScheduleValue>0.050000</ScheduleValue>
  <ScheduleValue>0.150000</ScheduleValue>
  <ScheduleValue>0.200000</ScheduleValue>
  <ScheduleValue>0.200000</ScheduleValue>
  <ScheduleValue>0.100000</ScheduleValue>
  <ScheduleValue>0.000000</ScheduleValue>
  <ScheduleValue>0.000000</ScheduleValue>
```

```xml
</DaySchedule>
<Schedule id="schdl-2" type="Fraction">
  <Name>School Lighting - 7 AM to 9 PM</Name>
  <YearSchedule id="yr-schdl-2">
    <BeginDate>2013-01-01</BeginDate>
    <EndDate>2013-12-31</EndDate>
    <WeekScheduleId weekScheduleIdRef="wk-schdl-2"/>
  </YearSchedule>
</Schedule>
<WeekSchedule id="wk-schdl-2" type="Fraction">
  <Day dayType="All" dayScheduleIdRef="dy-schdl-2"/>
</WeekSchedule>
<DaySchedule id="dy-schdl-2" type="Fraction">
  <ScheduleValue>0.000000</ScheduleValue>
  <ScheduleValue>0.000000</ScheduleValue>
  <ScheduleValue>0.000000</ScheduleValue>
  <ScheduleValue>0.000000</ScheduleValue>
  <ScheduleValue>0.000000</ScheduleValue>
  <ScheduleValue>0.000000</ScheduleValue>
  <ScheduleValue>0.000000</ScheduleValue>
  <ScheduleValue>0.300000</ScheduleValue>
  <ScheduleValue>0.850000</ScheduleValue>
  <ScheduleValue>0.950000</ScheduleValue>
  <ScheduleValue>0.950000</ScheduleValue>
  <ScheduleValue>0.950000</ScheduleValue>
  <ScheduleValue>0.800000</ScheduleValue>
  <ScheduleValue>0.800000</ScheduleValue>
  <ScheduleValue>0.800000</ScheduleValue>
  <ScheduleValue>0.700000</ScheduleValue>
  <ScheduleValue>0.500000</ScheduleValue>
  <ScheduleValue>0.500000</ScheduleValue>
  <ScheduleValue>0.350000</ScheduleValue>
  <ScheduleValue>0.350000</ScheduleValue>
  <ScheduleValue>0.300000</ScheduleValue>
  <ScheduleValue>0.300000</ScheduleValue>
  <ScheduleValue>0.000000</ScheduleValue>
  <ScheduleValue>0.000000</ScheduleValue>
</DaySchedule>
<Zone id="zone-Default">
  <Name>Default</Name>
  <DesignHeatT unit="C">21.111111</DesignHeatT>
  <DesignCoolT unit="C">23.333333</DesignCoolT>
  <CADObjectId>293242</CADObjectId>
  <TypeCode>10</TypeCode>
</Zone>
<DocumentHistory>
  <ProgramInfo id="adesk-rvt-1">
    <CompanyName>Autodesk, Inc.</CompanyName>
    <ProductName>Autodesk Revit MEP 2010</ProductName>
    <Version>2010</Version>
```

```
      &lt;Platform&gt;Microsoft Windows&lt;/Platform&gt;
    &lt;/ProgramInfo&gt;
    &lt;PersonInfo id="adesk-rvt-usr-1"&gt;
      &lt;LastName&gt;Elizabeth&lt;/LastName&gt;
    &lt;/PersonInfo&gt;
    <CreatedBy personId="adesk-rvt-usr-1" programId="adesk-rvt-1"
    date="2013-0930T17:40:48">
      &lt;CADModelId&gt;48be42e2-d33b-4e9d-b92c-
    9e2851604cdd&lt;/CADModelId&gt; &lt;/CreatedBy&gt;
  </Document
History>
&lt;/gbXML&gt;
```

APPENDIX B: DOE-2 INP File Resulted from the Proposed Conversion Process of Case Study 1

DOE-2 INP file resulted from the Proposed Converter Solution in Case Study 1: Classroom Project

```
INPUT
   ..
$ Created by Elizabeth Guzman, 2014.

$ ---------------------------------------------------------
$              Abort, Diagnostics
$ ---------------------------------------------------------
$ ---------------------------------------------------------
$              Global Parameters
$ ---------------------------------------------------------
$ ---------------------------------------------------------
$              Title, Run Periods, Design Days, Holidays
$ ---------------------------------------------------------
TITLE   ..
    "Run Period 1" = RUN-PERIOD-PD
    BEGIN-YEAR       = 2029
    BEGIN-MONTH      = 01
    BEGIN-DAY        = 01
    END-YEAR         = 2029
    END-MONTH        = 12
    END-DAY          = 31
   ..

"c-Weather-45277" = DESIGN-DAY
   TYPE              = COOLING
   MONTH = 6
   DAY = 1
   NUMBER-OF-DAYS = 100
   DRYBULB-HIGH     = 83.7
   WETBULB-AT-HIGH  = 69.6
   DRYBULB-RANGE    = 52.2
      ..
"h-Weather-45277" = DESIGN-DAY
   TYPE              = HEATING
   MONTH = 1
   DAY = 30
   NUMBER-OF-DAYS = 30
   DRYBULB-HIGH     = -3.8
      ..



$ ---------------------------------------------------------
$              Compliance Data
$ ---------------------------------------------------------

"Compliance Data" = COMPLIANCE
   C-PROJ-NAME      = "Project"
   C-CODE-VERSION   = 2
   ..
```

```
$ ---------------------------------------------------------
$              Site and Building Data
$ ---------------------------------------------------------

SITE-PARAMETERS
   LATITUDE         = 46.210000
   LONGITUDE         = -72.350000



   ..
"Standard US Holidays" = HOLIDAYS
   TYPE             = OFFICIAL-US ..
BUILD-PARAMETERS
   AZIMUTH          = 0
   HOLIDAYS         = "Standard US Holidays"
   ..
$ ---------------------------------------------------------
$              Materials / Layers / Constructions
$ ---------------------------------------------------------

$8 in lightweight concrete
"mat-AM13 8 in lightweight concrete" = MATERIAL
   TYPE             = PROPERTIES
   THICKNESS        = 0.66667
   CONDUCTIVITY     = 0.306228334648663
   DENSITY          = 79.9077888
   SPECIFIC-HEAT    = 0.200630553167097
   ..

$4 in brick
"mat-AM01 4 in brick" = MATERIAL
   TYPE             = PROPERTIES
   THICKNESS        = 0.33333
   CONDUCTIVITY     = 0.514232486485491
   DENSITY          = 119.8616832
   SPECIFIC-HEAT    = 0.188688258335722
   ..

$Wood 2in  (HF-B1)
"mat-394 Wood 2in  (HF-B1)" = MATERIAL
   TYPE             = PROPERTIES
   THICKNESS        = 0.1667
   CONDUCTIVITY     = 0.07
   DENSITY          = 37
   SPECIFIC-HEAT    = 0.2
   ..

$Conc HW 140lb 4in  (CC03)
"mat-264 Conc HW 140lb 4in  (CC03)" = MATERIAL
   TYPE             = PROPERTIES
   THICKNESS        = 0.3333
```

```
   CONDUCTIVITY     = 0.7576
   DENSITY          = 140
   SPECIFIC-HEAT    = 0.2
   ..

$GypBd 5/8in  (GP02)
"mat-353 GypBd 5/8in  (GP02)" = MATERIAL
   TYPE             = PROPERTIES
   THICKNESS        = 0.0521
   CONDUCTIVITY     = 0.0926
   DENSITY          = 50
   SPECIFIC-HEAT    = 0.2
   ..

$Air Space
"mat-464 Air Space" = MATERIAL
   TYPE             = RESISTANCE
   RESISTANCE       = 0.619999999999999
   ..

$
"lay-ASHWL-66" = LAYERS
   MATERIAL         = (
    "mat-AM13 8 in lightweight concrete"
  ,
    "mat-AM13 8 in lightweight concrete"
   )
   ..
$
"lay-ASHRF28" = LAYERS
   MATERIAL         = (
    "mat-AM01 4 in brick"
   )
   ..
$
"layer-30" = LAYERS
   INSIDE-FILM-RES  = 0.0001
   MATERIAL         = (
    "mat-394 Wood 2in  (HF-B1)"
   )
   ..
$
"layer-32" = LAYERS
   INSIDE-FILM-RES  = 0.920000000000001
   MATERIAL         = (
    "mat-264 Conc HW 140lb 4in  (CC03)"
   )
   ..
$
"layer-31" = LAYERS
   INSIDE-FILM-RES  = 0.679999999999998
   MATERIAL         = (
    "mat-353 GypBd 5/8in  (GP02)"
  ,
```

```
     "mat-464 Air Space"
   ,
     "mat-353 GypBd 5/8in  (GP02)"
    )
    ..
$8 in lightweight concrete block
"ASHWL-66 8 in lightweight concrete block" = CONSTRUCTION
   TYPE                  = LAYERS
   LAYERS              = "lay-ASHWL-66"

    ..
$4 in lightweight concrete
"ASHRF28 4 in lightweight concrete" = CONSTRUCTION
   TYPE                  = LAYERS
   LAYERS              = "lay-ASHRF28"

    ..
$R2 Default Door
"construction-30 R2 Default Door" = CONSTRUCTION
   TYPE                  = LAYERS
   ABSORPTANCE      = 0.5
   ROUGHNESS             = 4
   LAYERS              = "layer-30"

    ..
$Interior 4in Slab Floor
"construction-32 Interior 4in Slab Floor" = CONSTRUCTION
   TYPE                  = LAYERS
   ABSORPTANCE      = 0
   ROUGHNESS             = 4
   LAYERS              = "layer-32"

    ..
$R0 Metal Frame Wall
"construction-31 R0 Metal Frame Wall" = CONSTRUCTION
   TYPE                  = LAYERS
   ABSORPTANCE      = 0.7
   ROUGHNESS             = 4
   LAYERS              = "layer-31"

    ..
$ ---------------------------------------------------------
$              Glass Types
$ ---------------------------------------------------------

$Large double-glazed windows (reflective coating) - industry
"DGL-R-I Large double-glazed windows (reflective coat" = GLASS-TYPE
   TYPE             = SHADING-COEF

   GLASS-CONDUCT    = 0.514488593336691
   SHADING-COEF     = 0.14942528735632185
   VIS-TRANS        = 0.07

   ..
```

```
$ ---------------------------------------------------------
$              Window Layers
$ ---------------------------------------------------------

$ ---------------------------------------------------------
$              Lamps / Luminaries / Lighting Systems
$ ---------------------------------------------------------

$ ---------------------------------------------------------
$              Day Schedules
$ ---------------------------------------------------------

$
"dy-schdl-1"  = DAY-SCHEDULE
   TYPE              = FRACTION
   HOURS             = (1, 24)
   VALUES            = ( 0.000000,
                         0.000000,
                         0.000000,
                         0.000000,
                         0.000000,
                         0.000000,
                         0.000000,
                         0.050000,
                         0.750000,
                         0.900000,
                         0.900000,
                         0.800000,
                         0.800000,
                         0.800000,
                         0.800000,
                         0.450000,
                         0.150000,
                         0.050000,
                         0.150000,
                         0.200000,
                         0.200000,
                         0.100000,
                         0.000000,
                         0.000000 )
   ..

$
"dy-schdl-2"  = DAY-SCHEDULE
   TYPE              = FRACTION
   HOURS             = (1, 24)
   VALUES            = ( 0.000000,
                         0.000000,
                         0.000000,
                         0.000000,
                         0.000000,
                         0.000000,
                         0.000000,
```

```
                          0.300000,
                          0.850000,
                          0.950000,
                          0.950000,
                          0.950000,
                          0.800000,
                          0.800000,
                          0.800000,
                          0.700000,
                          0.500000,
                          0.500000,
                          0.350000,
                          0.350000,
                          0.300000,
                          0.300000,
                          0.000000,
                          0.000000 )
   ..

$
"ds-351-Equip"  = DAY-SCHEDULE
   TYPE             = FRACTION
   HOURS            = (1, 24)
   VALUES           = ( 0.305,
                          0.275,
                          0.295,
                          0.29,
                          0.315,
                          0.45,
                          0.72,
                          0.905,
                          0.935,
                          0.92,
                          0.915,
                          0.915,
                          0.905,
                          0.905,
                          0.905,
                          0.875,
                          0.79,
                          0.64,
                          0.565,
                          0.545,
                          0.535,
                          0.47,
                          0.44,
                          0.385 )
   ..

$
"ds-352-Equip"  = DAY-SCHEDULE
   TYPE             = FRACTION
   HOURS            = (1, 24)
   VALUES           = ( 0.25,
```

```
                          0.26,
                          0.28,
                          0.29,
                          0.29,
                          0.38,
                          0.41,
                          0.475,
                          0.495,
                          0.49,
                          0.495,
                          0.495,
                          0.495,
                          0.48,
                          0.48,
                          0.475,
                          0.465,
                          0.46,
                          0.42,
                          0.395,
                          0.37,
                          0.35,
                          0.35,
                          0.335 )
   ..

$
"ds-353-Equip"  = DAY-SCHEDULE
   TYPE             = FRACTION
   HOURS            = (1, 24)
   VALUES           = ( 0.215,
                          0.225,
                          0.235,
                          0.245,
                          0.245,
                          0.305,
                          0.305,
                          0.36,
                          0.37,
                          0.375,
                          0.375,
                          0.375,
                          0.36,
                          0.36,
                          0.36,
                          0.355,
                          0.345,
                          0.35,
                          0.32,
                          0.31,
                          0.295,
                          0.275,
                          0.275,
                          0.275 )
   ..
```

```
$ Infiltration -
"ds-150-FanINF"  = DAY-SCHEDULE
   TYPE              = FRACTION
   HOURS             = (1, 24)
   VALUES            = ( 0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25 )
   ..


$
"ds-150-Fan"  = DAY-SCHEDULE
   TYPE              = ON/OFF/FLAG
   HOURS             = (1, 24)
   VALUES            = ( 1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
```

```
                      1,
                      1,
                      1,
                      1,
                      1,
                      1 )
   ..

$ Infiltration -
"ds-128-FanINF"  = DAY-SCHEDULE
   TYPE             = FRACTION
   HOURS            = (1, 24)
   VALUES           = ( 0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25,
                        0.25 )
   ..


$
"ds-128-Fan"  = DAY-SCHEDULE
   TYPE             = ON/OFF/FLAG
   HOURS            = (1, 24)
   VALUES           = ( 1,
                        1,
                        1,
                        1,
                        1,
                        1,
                        1,
                        1,
                        1,
                        1,
                        1,
```

```
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1 )
   ..

$ Infiltration -
"ds-139-FanINF"  = DAY-SCHEDULE
   TYPE              = FRACTION
   HOURS             = (1, 24)
   VALUES            = ( 0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25,
                         0.25 )
   ..


$
"ds-139-Fan"  = DAY-SCHEDULE
   TYPE              = ON/OFF/FLAG
   HOURS             = (1, 24)
   VALUES            = ( 1,
                         1,
                         1,
                         1,
```

```
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1,
                         1 )
   ..

$
"ds-150-Temp-On-21.7-Off-20.6"  = DAY-SCHEDULE
   TYPE             = TEMPERATURE
   HOURS            = (1, 24)
   VALUES           = ( 71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0,
                        71.0 )
   ..

$
"ds-128-Temp-On-21.7-Off-20.6"  = DAY-SCHEDULE
```

```
   TYPE              = TEMPERATURE
   HOURS             = (1, 24)
   VALUES            = ( 71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0 )
   ..

$
"ds-139-Temp-On-21.7-Off-20.6"  = DAY-SCHEDULE
   TYPE              = TEMPERATURE
   HOURS             = (1, 24)
   VALUES            = ( 71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
                         71.0,
```

```
                        71.0,
                        71.0 )
   ..

$
"ds-150-Temp-On-23.3-Off-23.3"  = DAY-SCHEDULE
   TYPE              = TEMPERATURE
   HOURS             = (1, 24)
   VALUES            = ( 74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0 )
   ..

$
"ds-128-Temp-On-23.3-Off-23.3"  = DAY-SCHEDULE
   TYPE              = TEMPERATURE
   HOURS             = (1, 24)
   VALUES            = ( 74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
                        74.0,
```

```
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0 )
   ..

$
"ds-139-Temp-On-23.3-Off-23.3"  = DAY-SCHEDULE
   TYPE              = TEMPERATURE
   HOURS             = (1, 24)
   VALUES            = ( 74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0,
                         74.0 )
   ..

$
"ds-150-Occ"  = DAY-SCHEDULE
   TYPE              = FRACTION
   HOURS             = (1, 24)
   VALUES            = ( 0.22,
                         0.19,
                         0.19,
                         0.18,
                         0.24,
                         0.33,
                         0.67,
                         0.88,
                         0.88,
                         0.9,
```

```
                         0.91,
                         0.91,
                         0.9,
                         0.9,
                         0.92,
                         0.87,
                         0.77,
                         0.59,
                         0.49,
                         0.47,
                         0.45,
                         0.37,
                         0.36,
                         0.27 )
   ..

$
"ds-128-Occ"  = DAY-SCHEDULE
   TYPE              = FRACTION
   HOURS             = (1, 24)
   VALUES            = ( 0.17,
                         0.17,
                         0.17,
                         0.17,
                         0.19,
                         0.28,
                         0.33,
                         0.4,
                         0.41,
                         0.44,
                         0.45,
                         0.46,
                         0.45,
                         0.43,
                         0.43,
                         0.44,
                         0.43,
                         0.37,
                         0.33,
                         0.3,
                         0.27,
                         0.24,
                         0.24,
                         0.22 )
   ..

$
"ds-139-Occ"  = DAY-SCHEDULE
   TYPE              = FRACTION
   HOURS             = (1, 24)
   VALUES            = ( 0.14,
                         0.14,
                         0.14,
                         0.15,
```

```
                        0.17,
                        0.21,
                        0.22,
                        0.26,
                        0.27,
                        0.31,
                        0.31,
                        0.32,
                        0.3,
                        0.3,
                        0.3,
                        0.31,
                        0.31,
                        0.29,
                        0.27,
                        0.25,
                        0.22,
                        0.19,
                        0.19,
                        0.18 )
    ..

$ ------------------------------------------------------------
$              Week Schedules
$ ------------------------------------------------------------

$
"wk-schdl-1"  = WEEK-SCHEDULE
    TYPE             = FRACTION
      (ALL) "dy-schdl-1"
        ..

$
"wk-schdl-2"  = WEEK-SCHEDULE
    TYPE             = FRACTION
      (ALL) "dy-schdl-2"
        ..

$24/7 Week - Lighting and Equipment
"ws-62-Equip"  = WEEK-SCHEDULE
    TYPE             = FRACTION
      (MON, FRI) "ds-351-Equip"
    (SAT) "ds-352-Equip"
    (SUN) "ds-353-Equip"
    (HDD) "ds-353-Equip"
    (CDD) "ds-351-Equip"
    (HOL) "ds-353-Equip"
        ..

$ Infiltration - 24/7 Week - Occupancy-Fan
"ws-61-FanINF"  = WEEK-SCHEDULE
    TYPE             = FRACTION
    (MON, FRI) "ds-150-FanINF"
    (SAT) "ds-128-FanINF"
```

```
    (SUN) "ds-139-FanINF"
    (HDD) "ds-139-FanINF"
    (CDD) "ds-150-FanINF"
    (HOL) "ds-139-FanINF"
        ..

$24/7 Week - Occupancy-Fan
"ws-61-Fan"  = WEEK-SCHEDULE
    TYPE             = ON/OFF/FLAG
      (MON, FRI) "ds-150-Fan"
    (SAT) "ds-128-Fan"
    (SUN) "ds-139-Fan"
    (HDD) "ds-139-Fan"
    (CDD) "ds-150-Fan"
    (HOL) "ds-139-Fan"
        ..

$24/7 Week - Occupancy-Temperature
"ws-61-Temp-On-21.7-Off-20.6"  = WEEK-SCHEDULE
    TYPE             = TEMPERATURE
      (MON, FRI) "ds-150-Temp-On-21.7-Off-20.6"
    (SAT) "ds-128-Temp-On-21.7-Off-20.6"
    (SUN) "ds-139-Temp-On-21.7-Off-20.6"
    (HDD) "ds-139-Temp-On-21.7-Off-20.6"
    (CDD) "ds-150-Temp-On-21.7-Off-20.6"
    (HOL) "ds-139-Temp-On-21.7-Off-20.6"
        ..

$24/7 Week - Occupancy-Temperature
"ws-61-Temp-On-23.3-Off-23.3"  = WEEK-SCHEDULE
    TYPE             = TEMPERATURE
      (MON, FRI) "ds-150-Temp-On-23.3-Off-23.3"
    (SAT) "ds-128-Temp-On-23.3-Off-23.3"
    (SUN) "ds-139-Temp-On-23.3-Off-23.3"
    (HDD) "ds-139-Temp-On-23.3-Off-23.3"
    (CDD) "ds-150-Temp-On-23.3-Off-23.3"
    (HOL) "ds-139-Temp-On-23.3-Off-23.3"
        ..

$24/7 Week - Occupancy
"ws-61-Occ"  = WEEK-SCHEDULE
    TYPE             = FRACTION
      (MON, FRI) "ds-150-Occ"
    (SAT) "ds-128-Occ"
    (SUN) "ds-139-Occ"
    (HDD) "ds-139-Occ"
    (CDD) "ds-150-Occ"
    (HOL) "ds-139-Occ"
        ..

$ ---------------------------------------------------------
$             Annual Schedules
$ ---------------------------------------------------------
```

```
$School Occupancy - 8 AM to 9 PM
"schdl-1" = SCHEDULE
   TYPE              = FRACTION
  THRU              DEC 31 "wk-schdl-1"
   ..
$School Lighting - 7 AM to 9 PM
"schdl-2" = SCHEDULE
   TYPE              = FRACTION
  THRU              DEC 31 "wk-schdl-2"
   ..
$LtgEquip - Typical 24/7
"EquipSched-35" = SCHEDULE
   TYPE              = FRACTION
  THRU              DEC 31 "ws-62-Equip"
   ..
$ Infiltration - Occupancy-Typical 24/7-Fan
"FanSch-34INF" = SCHEDULE
     TYPE              = FRACTION

  THRU              DEC 31 "ws-61-FanINF"
   ..

$Occupancy-Typical 24/7-Fan
"FanSch-34" = SCHEDULE
   TYPE              = ON/OFF/FLAG
  THRU              DEC 31 "ws-61-Fan"
   ..
$Occupancy-Typical 24/7-Temperature
"Heatsched-7" = SCHEDULE
   TYPE              = TEMPERATURE
  THRU              DEC 31 "ws-61-Temp-On-21.7-Off-20.6"
   ..
$Occupancy-Typical 24/7-Temperature
"Coolsched-7" = SCHEDULE
   TYPE              = TEMPERATURE
  THRU              DEC 31 "ws-61-Temp-On-23.3-Off-23.3"
   ..
$Occupancy-Typical 24/7
"DHWSchedule-34" = SCHEDULE
   TYPE              = FRACTION
  THRU              DEC 31 "ws-61-Occ"
   ..
$ Always On
"Sch_OnHrR" = SCHEDULE  TYPE = ON/OFF
      THRU DEC 31 (ALL) (1, 24) VALUES = (1)..

$ Always On Fraction
"Sch_On" = SCHEDULE  TYPE = FRACTION
      THRU DEC 31 (ALL) (1, 24) VALUES = (1)..

$ Always Off Fraction
"Sch_Off" = SCHEDULE  TYPE = FRACTION
      THRU DEC 31 (ALL) (1, 24) VALUES = (0)..
```

```
$ ----------------------------------------------------------
$              Polygons
$ ----------------------------------------------------------

$N-1-E-W-1
"su-1GEOM"= POLYGON

  V1        = ( 25.9186351706, 0.00000000 )

  V2        = ( 25.9186351706, 13.074015748 )

  V3        = ( 0.00000000, 13.074015748 )

  V4        = ( 0.00000000, 0.00000000 )

   ..
$E-1-E-W-2
"su-2GEOM"= POLYGON

  V1        = ( 0.00000000, 0.00000000 )

  V2        = ( 28.8713910761, 0.00000000 )

  V3        = ( 28.8713910761, 13.074015748 )

  V4        = ( 0.00000000, 13.074015748 )

   ..
$S-1-E-W-3
"su-3GEOM"= POLYGON

  V1        = ( 0.00000000, 0.00000000 )

  V2        = ( 25.9186351706, 0.00000000 )

  V3        = ( 25.9186351706, 13.074015748)

  V4        = ( 0.00000000, 13.074015748)

   ..
$B-1-E-R-4
"su-4GEOM"= POLYGON

  V1        = ( 0.00000000, 0.00000000 )

  V2        = ( 28.8713910761, 0.00000000 )

  V3        = ( 28.8713910761, 25.9186351706 )

  V4        = ( 0.00000000, 25.9186351706 )
..

$B-1-I-R-5
"su-5GEOM"= POLYGON
```

```
  V1        = ( 0.00000000, 0.00000000 )

  V2        = ( 28.8713910761, 0.00000000 )

  V3        = ( 28.8713910761, 25.9186351706 )

  V4        = ( 0.00000000, 25.9186351706 )

..

$B-1-I-R-6
"su-6GEOM"= POLYGON

  V1        = ( 0.00000000, 0.00000000 )

  V2        = ( 28.8713910761, 0.00000000 )

  V3        = ( 28.8713910761, 23.2939632546 )

  V4        = ( 0.00000000, 23.2939632546 )


   ..
$N-2-E-W-7
"su-7GEOM"= POLYGON

  V1        = ( 23.2939632546, 0.00000000 )

  V2        = ( 23.2939632546, 13.074015748 )

  V3        = ( 0.00000000, 13.074015748 )

  V4        = ( 0.00000000, 0.00000000 )

   ..
$S-2-E-W-8
"su-8GEOM"= POLYGON

  V1        = ( 0.00000000, 0.00000000 )

  V2        = ( 23.2939632546, 0.00000000 )

  V3        = ( 23.2939632546, 13.074015748 )

  V4        = ( 0.00000000, 13.074015748 )

   ..
$W-2-E-W-9
"su-9GEOM"= POLYGON

  V1        = ( 28.8713910761, 0.00000000 )

  V2        = ( 28.8713910761, 13.074015748 )
```

```
  V3        = ( 0.00000000, 13.074015748 )

  V4        = ( 0.00000000, 0.00000000 )

   ..
$B-2-E-R-10
"su-10GEOM"= POLYGON

  V1        = ( 0.00000000, 0.00000000 )

  V2        = ( 28.8713910761, 0.00000000 )

  V3        = ( 28.8713910761, 23.2939632546 )

  V4        = ( 0.00000000, 23.2939632546 )

..
$W-2-E-R-17
"su-17GEOM" = POLYGON

  V1        = ( 0.00000000, 0.00000000)

  V2        = ( 28.8713910761, 0.00000000 )

  V3        = ( 14.43569553805, 17.048 )

 ..
$W-2-E-R-20
"su-20GEOM" = POLYGON

  V1        = ( 0.00000000, 0.00000000)

  V2        = ( 28.8713910761, 0.00000000 )

  V3        = ( 14.43569553805, 17.048 )

..
$W-2-E-R-19
"su-19GEOM" = POLYGON

  V1        = ( 50.00, 0.00000000)

  V2        = ( 35.10, 17.048 )

  V3        = ( 15.00, 17.048 )

  V4        = ( 0.00000000, 0.00000000)

..

$W-2-E-R-18
"su-18GEOM" = POLYGON
```

```
  V1        = (  0.00000000, 0.00000000 )

  V2        = ( 15.00, 17.048 )

  V3        = ( 35.10, 17.048)

  V4        = ( 50.00, 0.00000000 )

..


$Level 1
"bldg-stry-1GEOM"= POLYGON

  V1        = ( -133.9088910761, 6.7258759843 )

  V2        = ( -84.6968930446, 6.7258759843 )

  V3        = ( -84.6968930446, 35.5969127297 )

  V4        = ( -133.9088910761, 35.5969127297 )

   ..
$ ---------------------------------------------------------
$              Wall Parameters
$ ---------------------------------------------------------
$ ---------------------------------------------------------
$              Fixed and Building Shades
$ ---------------------------------------------------------

$X-S-16
"su-16_depx_1" = BUILDING-SHADE

    TILT              = 90.0
    AZIMUTH           = 90.0
    X                 = -110.6165649606
    Y                 = 6.7259580052
    Z                 = 7.874015748
    HEIGHT              = 5.249
   WIDTH                   = 28.871
..


$ ---------------------------------------------------------
$              Misc Cost Related Objects
$ ---------------------------------------------------------
BASELINE
   ..
$ *********************************************************
$ **                                                    **
$ **      Floors / Spaces / Walls / Windows / Doors      **
$ **                                                    **
$ *********************************************************
```

```
$Level 1
"bldg-stry-1" = FLOOR

    SHAPE              = POLYGON
    POLYGON            = "bldg-stry-1GEOM"
    SPACE-HEIGHT     = 7.874
    FLOOR-HEIGHT     = 7.874
   ..


$2_Room_2
$2007 ASHRAE 90.1 SCHOOL/UNIVERSITY Default
"S~zone-Default"= SPACE

   NUMBER-OF-PEOPLE  = 81.6
   PEOPLE-HG-SENS  = 250.0
   PEOPLE-HG-LAT  = 200.0
   LTG-SPEC-METHOD   = POWER-DEFINITION
   LIGHTING-W/AREA   = ( 1.4 )
   EQUIPMENT-W/AREA  = ( 0.9996 )
   VOLUME            = 10641.856
   AZIMUTH           = 0.0
   X                 = 0.0
   Y                 = 0.0
   Z                 = 0.0

   SHAPE             = NO-SHAPE
   AREA              = 1351.517
   C-SUB-AREA        = 1351.517
   C-OCC-TYPE        = 10


   ZONE-TYPE         = CONDITIONED
   LIGHTING-SCHEDULE = "schdl-2"
   PEOPLE-SCHEDULE   = "schdl-1"
        DAYLIGHTING = NO

      MIN-POWER-FRAC = 0.300000
      MIN-LIGHT-FRAC = 0.100000
      LIGHT-SET-POINT1 = 30.000000
      ZONE-FRACTION1 = 0.648100
      LIGHT-REF-POINT1 = (-121.9354625984,
                           25.7909186352,
                           2.4999704724)

    EQUIP-SCHEDULE    = ("schdl-2")

   TEMPERATURE = 70.0
   INF-METHOD     = AIR-CHANGE

   AIR-CHANGES/HR = 0.25
       INF-SCHEDULE = "FanSch-34INF"
```

```
..


$N-1-E-W-1
"su-1" = EXTERIOR-WALL
   POLYGON            = "su-1GEOM"


    CONSTRUCTION     =    "ASHWL-66 8 in lightweight concrete block"

    TILT              = 90.0
    AZIMUTH           = .0
    X                 = -84.69792979
    Y                 = 35.5973490814
    Z                 = 0.00000000
   ..

$N-1-E-W-1-D-1
"su-1-op-1" = DOOR
    CONSTRUCTION     =    "construction-30 R2 Default Door"
   X                 = 25.5085301837
   Y                 = 0.00000000
   HEIGHT            = 7.251
   WIDTH             = 0.41
   ..

$N-1-E-W-1-W-2
"su-1-op-2" = WINDOW
   C-PRODUCT-TYPE   = 0
   C-FRAME-TYPE     = 0

   GLASS-TYPE        ="DGL-R-I Large double-glazed windows
(reflective coat"
   C-UFACTOR-METHOD  = 0
   C-SHGC-METHOD     = 0

   X                 = 15.6824146982
   Y                 = 3.0019685039
   HEIGHT            = 4.003
   WIDTH             = 4.003
   ..

$N-1-E-W-1-W-3
"su-1-op-3" = WINDOW
   C-PRODUCT-TYPE   = 0
   C-FRAME-TYPE     = 0

   GLASS-TYPE        ="DGL-R-I Large double-glazed windows
(reflective coat"
   C-UFACTOR-METHOD  = 0
   C-SHGC-METHOD     = 0

   X                 = 5.7744422572
```

```
   Y                  = 3.0019685039
   HEIGHT             = 4.003
   WIDTH              = 4.003
   ..



$E-1-E-W-2
"su-2" = EXTERIOR-WALL
   POLYGON             = "su-2GEOM"


    CONSTRUCTION      =    "ASHWL-66 8 in lightweight concrete block"

    TILT               = 90.0
    AZIMUTH            = 90.0
    X                  = -84.69792979
    Y                  = 6.7259580052
    Z                  = 0.00000000
   ..

$E-1-E-W-2-D-1
"su-2-op-1" = DOOR
    CONSTRUCTION      =    "construction-30 R2 Default Door"
   X                  = 13.3530183727
   Y                  = 0.00000000
   HEIGHT             = 6.499
   WIDTH              = 6.004
   ..



$S-1-E-W-3
"su-3" = EXTERIOR-WALL
   POLYGON             = "su-3GEOM"


    CONSTRUCTION      =    "ASHWL-66 8 in lightweight concrete block"

    TILT               = 90.0
    AZIMUTH            = 180.0
    X                  = -110.6165649606
    Y                  = 6.7259580052
    Z                  = 0.00000000
   ..

$S-1-E-W-3-D-1
"su-3-op-1" = DOOR
    CONSTRUCTION      =    "construction-30 R2 Default Door"
   X                  = 0.00000000
   Y                  = 0.00000000
   HEIGHT             = 7.251
   WIDTH              = 3.33
   ..
```

```
$S-1-E-W-3-W-2
"su-3-op-2" = WINDOW
   C-PRODUCT-TYPE   = 0
   C-FRAME-TYPE     = 0

   GLASS-TYPE        ="DGL-R-I Large double-glazed windows
(reflective coat"
   C-UFACTOR-METHOD  = 0
   C-SHGC-METHOD     = 0

   X                 = 5.905511811
   Y                 = 3.0019685039
   HEIGHT            = 4.003
   WIDTH             = 4.003
   ..

$S-1-E-W-3-W-3
"su-3-op-3" = WINDOW
   C-PRODUCT-TYPE   = 0
   C-FRAME-TYPE     = 0

   GLASS-TYPE        ="DGL-R-I Large double-glazed windows
(reflective coat"
   C-UFACTOR-METHOD  = 0
   C-SHGC-METHOD     = 0

   X                 = 15.7480314961
   Y                 = 3.0019685039
   HEIGHT            = 4.003
   WIDTH             = 4.003
   ..



$B-1-E-R-4
"su-4" = ROOF
   POLYGON            = "su-4GEOM"


    CONSTRUCTION     =    "ASHRF28 4 in lightweight concrete"

    TILT              = 180.0
    AZIMUTH           = 90.0
    X                 = -110.6165649606
    Y                 = 6.7259580052
    Z                 = 7.874015748
   ..

$B-1-I-R-5
"su-5" = ROOF
   POLYGON            = "su-5GEOM"
```

```
    CONSTRUCTION     =   "construction-32 Interior 4in Slab Floor"

    TILT              = 180.0
    AZIMUTH           = 90.0
    X                 = -110.6165649606
    Y                 = 6.7259580052
    Z                 = 0
   ..

$B-1-I-R-6
"su-6" = ROOF
   POLYGON           = "su-6GEOM"


    CONSTRUCTION     =   "construction-32 Interior 4in Slab Floor"

    TILT              = 180.0
    AZIMUTH           = 90.0
    X                 = -133.9105282152
    Y                 = 6.7259580052
    Z                 = 0

   ..

$N-2-E-W-7
"su-7" = EXTERIOR-WALL
   POLYGON           = "su-7GEOM"


    CONSTRUCTION     =    "ASHWL-66 8 in lightweight concrete block"

    TILT              = 90.0
    AZIMUTH           = .0
    X                 = -110.6165649606
    Y                 = 35.5973490814
    Z                 = 0.00000000
   ..

$N-2-E-W-7-D-1
"su-7-op-1" = DOOR
    CONSTRUCTION     =    "construction-30 R2 Default Door"
   X                 = 0.00000000
   Y                 = 0.00000000
   HEIGHT            = 7.251
   WIDTH             = 3.33
   ..

$N-2-E-W-7-W-2
"su-7-op-2" = WINDOW
   C-PRODUCT-TYPE   = 0
   C-FRAME-TYPE     = 0

   GLASS-TYPE        ="DGL-R-I Large double-glazed windows
(reflective coat"
```

```
   C-UFACTOR-METHOD  = 0
   C-SHGC-METHOD     = 0

   X                 = 14.1405839895
   Y                 = 3.0019685039
   HEIGHT            = 4.003
   WIDTH             = 4.003
   ..

$N-2-E-W-7-W-3
"su-7-op-3" = WINDOW
   C-PRODUCT-TYPE   = 0
   C-FRAME-TYPE     = 0

   GLASS-TYPE        ="DGL-R-I Large double-glazed windows
(reflective coat"
   C-UFACTOR-METHOD  = 0
   C-SHGC-METHOD     = 0

   X                 = 4.4945866142
   Y                 = 3.0019685039
   HEIGHT            = 4.003
   WIDTH             = 4.003
   ..



$S-2-E-W-8
"su-8" = EXTERIOR-WALL
   POLYGON            = "su-8GEOM"


    CONSTRUCTION     =    "ASHWL-66 8 in lightweight concrete block"

    TILT              = 90.0
    AZIMUTH           = 180.0
    X                 = -133.9105282152
    Y                 = 6.7259580052
    Z                 = 0.00000000
   ..

$S-2-E-W-8-D-1
"su-8-op-1" = DOOR
    CONSTRUCTION     =    "construction-30 R2 Default Door"
   X                 = 22.8838582677
   Y                 = 0.00000000
   HEIGHT            = 7.251
   WIDTH             = 0.41
   ..

$S-2-E-W-8-W-2
"su-8-op-2" = WINDOW
   C-PRODUCT-TYPE   = 0
   C-FRAME-TYPE     = 0
```

```
   GLASS-TYPE         ="DGL-R-I Large double-glazed windows
(reflective coat"
   C-UFACTOR-METHOD  = 0
   C-SHGC-METHOD     = 0

   X                 = 4.9212598425
   Y                 = 3.0019685039
   HEIGHT            = 4.003
   WIDTH             = 4.003
   ..

$S-2-E-W-8-W-3
"su-8-op-3" = WINDOW
   C-PRODUCT-TYPE   = 0
   C-FRAME-TYPE     = 0

   GLASS-TYPE         ="DGL-R-I Large double-glazed windows
(reflective coat"
   C-UFACTOR-METHOD  = 0
   C-SHGC-METHOD     = 0

   X                 = 15.0262467192
   Y                 = 3.0019685039
   HEIGHT            = 4.003
   WIDTH             = 4.003
   ..



$W-2-E-W-9
"su-9" = EXTERIOR-WALL
   POLYGON            = "su-9GEOM"


    CONSTRUCTION     =    "ASHWL-66 8 in lightweight concrete block"

    TILT              = 90.0
    AZIMUTH           = 270.0
    X                 = -133.9105282152
    Y                 = 35.5973490814
    Z                 = 0.00000000
   ..

$W-2-E-W-9-D-1
"su-9-op-1" = DOOR
    CONSTRUCTION     =    "construction-30 R2 Default Door"
   X                 = 10.1706036745
   Y                 = 0.00000000
   HEIGHT            = 6.499
   WIDTH             = 6.004
   ..
```

```
$B-2-E-R-10
"su-10" = ROOF
   POLYGON           = "su-10GEOM"


    CONSTRUCTION     =    "ASHRF28 4 in lightweight concrete"

    TILT              = 180.0
    AZIMUTH           = 90.0
    X                 = -133.9105282152
    Y                 = 6.7259580052
    Z                 = 7.874015748
   ..

$W-2-E-R-17
"su-17" = ROOF
   POLYGON           = "su-17GEOM"


    CONSTRUCTION     =    "ASHRF28 4 in lightweight concrete"


    TILT              = 30.0
    AZIMUTH           = 270.0
    X                 = -133.9105282152
    Y                 = 35.5973490814
    Z                 = 13.3387139108
   ..

$W-2-E-R-20
"su-20" = ROOF
   POLYGON           = "su-20GEOM"


    CONSTRUCTION     =    "ASHRF28 4 in lightweight concrete"


    TILT              = 30.0
    AZIMUTH           = 90.0
    X                 = -84.3698458005
    Y                 = 6.3978740157
    Z                 = 13.3387139108
..


$W-2-E-R-19
"su-19" = ROOF
   POLYGON           = "su-19GEOM"


    CONSTRUCTION     =    "ASHRF28 4 in lightweight concrete"

    TILT              = 30.0
```

```
    AZIMUTH           = 180.0
    X                 = -134.2386122047
    Y                 = 6.3978740157
    Z                 = 13.3387139108
..

$W-2-E-R-18
"su-18" = ROOF
   POLYGON           = "su-18GEOM"


    CONSTRUCTION     =    "ASHRF28 4 in lightweight concrete"

    TILT              = 30.0
    AZIMUTH           = .0
    X                 = -84.3698458005
    Y                 = 35.9254330709
    Z                 = 13.3387139108

..


$ ---------------------------------------------------------
$              Master Meters
$ ---------------------------------------------------------
MASTER-METERS
   MSTR-ELEC-METER  = "EM1"
   MSTR-FUEL-METER  = "FM1"
   ..
$ *********************************************************
$ **                                                     **
$ **      HVAC Circulation Loops / Plant Equipment       **
$ **                                                     **
$ *********************************************************
$ ---------------------------------------------------------
$              Curve Fits
$ ---------------------------------------------------------

$ ---------------------------------------------------------
$              Pumps
$ ---------------------------------------------------------

$ ---------------------------------------------------------
$              Circulation Loops
$ ---------------------------------------------------------

"HydLoop-4" = CIRCULATION-LOOP
    TYPE           = DHW
    PIPE-HEAD      = 2.5005919182325997
    PROCESS-FLOW   = 0.468218518882
    PROCESS-SCH    = "DHWSchedule-34"
    ..

$ ---------------------------------------------------------
```

```
$              Chillers
$ ---------------------------------------------------------

$ ---------------------------------------------------------
$              Boilers
$ ---------------------------------------------------------

$ ---------------------------------------------------------
$              Domestic Water Heaters
$ ---------------------------------------------------------

$Domestic HW Heater
$50 gallon residential/light commercial unit  (50 gal., 0.575 Energy
Factor)
   "HydLoop-4-Equip-34" = DW-HEATER
        TYPE           = GAS

        DHW-LOOP       = "HydLoop-4"

    HEAT-INPUT-RATIO = 1.25
..


$ *********************************************************
$ **                                                     **
$ **               HVAC Systems / Zones                  **
$ **                                                     **
$ *********************************************************

$Air loop
$North exterior system using schedule 'FanSch-34' on the top floor
"North1" = SYSTEM
        TYPE             = PSZ

          FURNACE-AUX      = 0

   HEAT-SOURCE      = FURNACE
   COOLING-EIR      = 0.2747
   FURNACE-HIR      = 1.2804
   DRYBULB-LIMIT    = 70.0
   ECONO-LOW-LIMIT  = 46.4
   MIN-OUTSIDE-AIR  = 0.15
   COOL-CONTROL     = CONSTANT
    MIN-SUPPLY-T     = 52.0
   HEAT-CONTROL     = CONSTANT
   MAX-SUPPLY-T     = 120.0
   FAN-SCHEDULE     = "FanSch-34"
   SUPPLY-STATIC    = 2.7026
   CONTROL-ZONE     = "zone-Default"

   REHEAT-DELTA-T   = 0
   ..

$Default
```

```
"zone-Default"= ZONE

   TYPE              = CONDITIONED
   HEAT-TEMP-SCH     = "Heatsched-7"
   COOL-TEMP-SCH     = "Coolsched-7"
   DESIGN-HEAT-T     = 70.0
   DESIGN-COOL-T     = 74.0
   OA-FLOW/PER       = 14.20
    OA-FLOW/AREA     = .21
    OA-CHANGES     = .00


  SPACE            = "S~zone-Default"
   FLOW/AREA         = 0.75

   THERMOSTAT-TYPE  = PROPORTIONAL
   THROTTLING-RANGE = 2
   ..


$ ---------------------------------------------------------
$              THE END
$ ---------------------------------------------------------

END ..
COMPUTE ..
STOP ..
```