Method and Procedure for developing a Database of green Building Technologies for residential Building through systematic case studies

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Abstract:
This Paper tries to develop on the method that is present for the commercial building given by Zhi Gao in his paper "A Unified Method and Procedure for Developing Green Building Technology Database through Case-studies" to be implement in a residential building. The technologies are identified through literature review and then categorized according to "Virtual Design Studio (VDS)" performance assessment system for the modularization. The technology once identified are assessed using forward and backward analysis in Designbuilder and compared the technology with the reference building for the specific climate zone. The method and procedure are verified through its implementation in various case study for different climate zone as specified in ASHRAE 169. Once analyzed the data are stored in the database using MySQL and can be used as a module in the green design studio.

Keywords: *Green Building Technology, Virtual Design Studio, Database*

1. Introduction:

Building energy consumption, in 2015 showed that about 40% of total U.S. energy consumption was consumed in residential and commercial buildings[1]. Additionally, an energy consumption survey performed by the United states Department of energy (DOE) found that residential heating and air conditioning account for 49% of all the residential energy usage in the United states[2]. Over the time we have seen many standards and many technologies are been implemented to reduce energy consumption. Like the passive house standard developed in 1990's aimed at designing house by particular constraints so that the construction used less energy compared to the conventional construction[3].

Generally, in green building design process the person integrates different green technologies based on previous experience with sole purpose to minimize the energy consumption. We can find all this technology through literature review. However, there are cons to not choosing appropriate technology or integration of different technology without having any idea of how much energy the technology can save and its limitation. Like technology have different impacts in different climate zone. They also can differ from orientation, shape as well as from building to building. Its hard to analyze impact of single technologies on the building when it is integrated with different technologies. Understanding all of this con made us understand that we need to have a systematic approach to analysis of green building technology and then having a database for providing a direct reference of technology itself for building design.

The goal of this paper is to identify technologies through case studies and then put it into a database and in process develop a standard process. This would be shown in this paper as follow, in section 2 we will have a brief description of the procedure. In section 3 we will implement it through a case study. In section 4 we will have a detail explanation of the database and how can we implement in green design studio.

2. Procedure

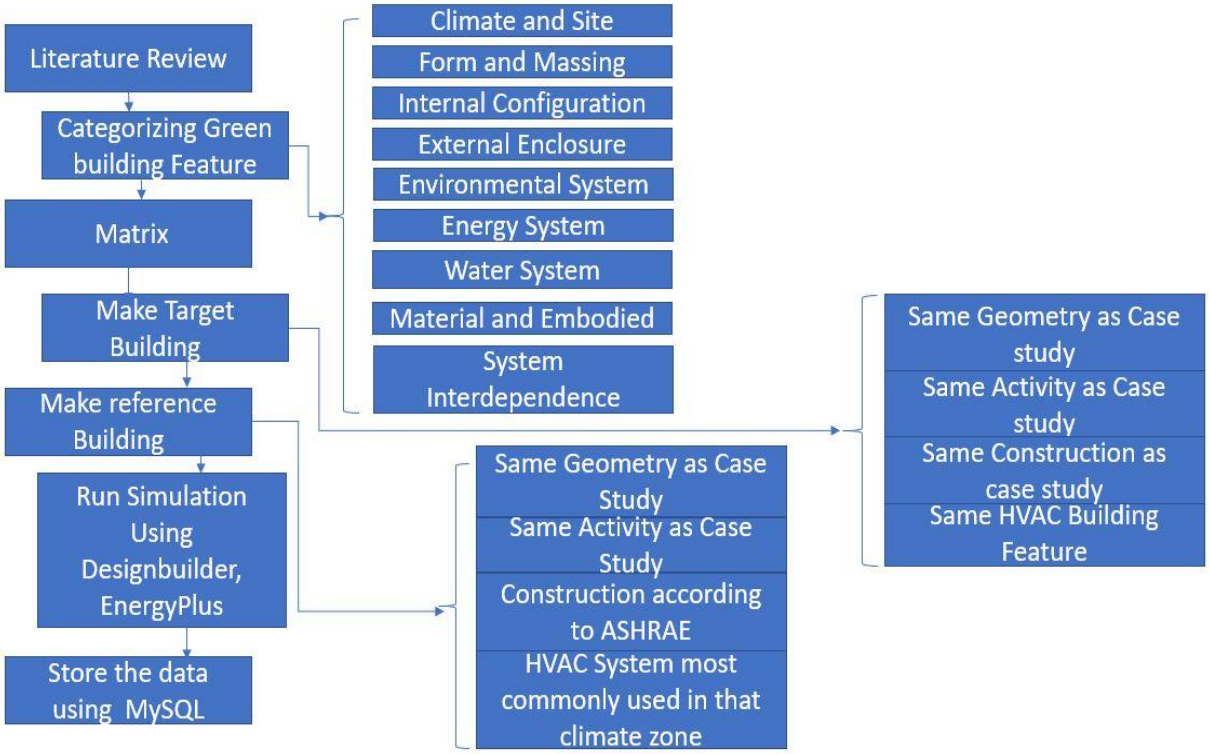


Figure 1. The above figure shows the procedure that is being developed for green building database

2.1 Literature Review: This step is the first step in identifying the case studies we need to simulate. Papers were searched using keywords such as green residential building, low residential building, passive house, residential building, thermal performance etc. to filter the papers. Reading paper tittle and looking for words such as residential house, low energy simulation etc. in title helped us finding right paper for the database. Minimum criteria were established for selecting the papers for database:

1. Paper should be about low energy residential house.
2. Paper should include green building technology.
3. Paper should include geometry of the house
4. Paper should include the description of the construction, activity and specifications of the technologies

2.2 Categorizing Green Building Feature: There are many green building rating systems like LEED, ASHRAE 198.1, BREEAM etc., which have their own method to categorize green features[3]. For green building design and analysis from the building itself the category of the green building technologies need to be relatively independent. Which is been accounted in VDS assessment system. The green technology can be classified in following categories:

1. Climate and Site: Example- site density, microclimate, site orientation, solar path and prevailing winds, ground conditions etc.,
2. Form and massing: Example- existing site context, proposed surface to volume ratio etc.,
3. Internal Configuration: Example- zoning related to building orientation and massing aspects.
4. External Enclosure: Example- Thermal properties, direct and indirect solar gain, air tightness, day lighting, R-value, etc.,
5. Environmental System: Example- active, passive and hybrid HVAC systems
6. Water System: Example- supply and waste water management, local water collection, ground sources, etc.,
7. Energy System: Example- grid management, active, passive and hybrid energy and lighting systems etc.,
8. Material use and embodied energy: Example- Building life cycle.
9. System Interdependence: Example- Overall system efficiencies related to individual subsystems and their coordination, integration and operation

   Once identified green technology it should be categorized in one of the above categories like natural ventilation should go into Climate and Site, green roof should go into External Enclosure and henceforth.

2.3 Matrix:

Feature/Technology	Climate and Site	Form and Massing	Internal Configuration	External Enclosure	Environmental System	Water System	Energy System	Lighting and Daylighting	Material and Embodied Energy	System Interdependece
Heat Recovery Ventilator					2a,9, 11					
Low-e Double Glazing,								2b		
Automatically Used By-pass ventilation Heat recovery					2b					
Stratergy of heat and humidity Recovery					2c,2e					
Humidity recovery with thermal and hygral					2d					
Automated Ventilation Control combined with medium thermal inertia					4					
Ventilated Active Façade				5						
Latent Thermal Energy Storage							6			
Thermoelctrci Cooling and Heaating Unit		5								
Energy Recovery Ventilator							2f			
MVHR					7					
High Performance Cooling system					7					
Fan Forced ventilation					7					
venetian blind shading								7		
PCM				9						
High performance envelope				11						
Solar DHW System						11,12	11,12			
UnderFloor Heating system					12					
Renewable Electricity System			12							

Figure 2. Matrix for Green technology to the Green Building Feature

The above figure shows on one side technologies and on the other side category of technologies. The number we see in this matrix are the paper which we found with the technology and was added to the category as shown in the above matrix. More technologies can be added to the above matrix as we do more literature review.

2.4 Target Building: Having identified the green features from a building and get them categorized, we select a case study from the database and run the simulation. We call it as a target building. Rules for making target house can be described as follows:

- Target house has the same geometry as mentioned in the case study
- It should also have same activity, occupancy schedule and loads
- We use the same construction material as mentioned in the case study
- HVAC technology are used with same specifications as mentioned in the paper.

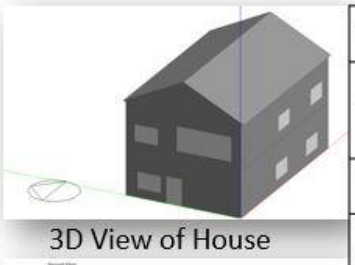
2.5 Reference Building: In order to compare and analyze the contribution of target green features, we need to establish reference for the target building and the reference is called as reference building. The rules of building reference building are described by Zhi Gao in his paper "A Unified Method and Procedure for Developing Green Building Technology Database through Case-studies" are as follows:

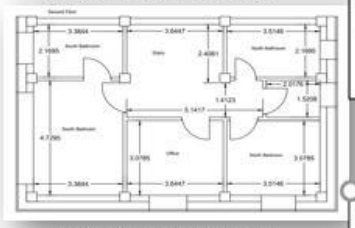
- Reference building has the same climate, cite and geometry as the target building (except for Site or Form & Massing analysis);
- For enclosure, lighting and IEQ requirements, reference building has default values from ASHRAE 90.1 which is widely accepted by government & industry as baseline;
- For schedules (occupancy, activity, internal heat gain, etc.), density parameters (people density, lighting density, etc.) and other heat source, reference building has the exact properties based on the target building's function;
- For HVAC, reference building uses ideal system to embody basic heating & cooling energy consumption;
- Materials & construction assemblies are defined in accordance with the requirements in the local building code or an established model building standard (e.g., the reference building defined in ASHRAE 90.1). In the case studies here, we extracted the material properties and enclosure assembly designs from the EnergyPlus input files of the DOE baseline building prototypes for residential buildings.

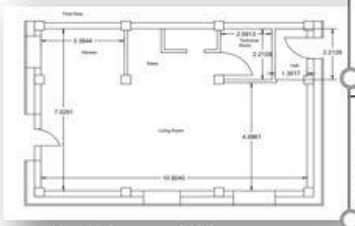
2.6 Run simulation using Designbuilder and EnergyPlus: In this step we do forward analysis and backward analysis using Designbuilder and evaluate each technology individually as well as integrated with each other and comparison study is made on the energy consumption of the house. It will be explained better in section 3 with an example.

2.7 Store data using MySQL: We use relational database between different entities and store the database for different green buildings using MySQL. This database is explained further in this paper in section 4.

3. **Case Study**:
Case Description: Passive House at Bucharest, Romania.







Name	Bucharest Passive House
Location	Bucharest, Romania Climate Zone – 5A
Building Area	140 m2
Building Description	Living Room, Technical Room, Hall, 2 Bathroom,2 Bedroom, Kitchen, Store Room

Basic Information

Main Green Features	High R value [External enclosure] Earth Air Heat Exchanger [External enclosure] PV Panels [External enclosure]
Energy Consumption by Reference	98.31 kWh/m2 year

Green Table

Figure 1. Basic information and green feature table of Bucharest Passive House

3.1 Green Feature Impact analysis and results

1. High R value:
In the green building category it falls into External Enclosure. The R-value of the external wall is high as compared to the reference house external wall. The target house external wall combines of materials as interior plaster of thickness 22mm, cellular concrete Ytong of thickness 250mm and mineral wool of thickness 300 mm (from exterior to interior). They combine to give R-value of 12.698 versus reference house which combines to give an R-value of 0.598. As seen from the table below for two simulation one with reference house external wall and one with target house external wall we can see that the heating load increases by at least 450%. And cooling load decreases by 40%.

Simulation/Load	Heating load (kWh/m^2) year	Cooling load (kWh/m^2) year
Target House with EAHX and High R-value	26.96989	9.20071
Target House with reference House external wall material	133.45	3.706

Table1. With and Without High R value simulation for heating and cooling load

2. Earth Air Heat Exchanger (EAHX):
   The EAHX is a pipeline that has 38 m in length and is buried at 2.5 m deep. The air that enters in the house is cooled or heated depending on the season, using the temperature of the ground. Also, the pipeline has a thermal conductivity of 0.28 W/m/K for an efficient heat transfer between the air and the ground. As we can see from the table the cooling load and heating load increases without Earth Air Heat Exchanger. There is increase of heating load without EAHX by 220% and but for the cooling load simulation results are approximately the same.

Simulation/Load	Heating load (kWh/m^2) year	Cooling load (kWh/m^2) year
Target House with EAHX and High R-value	26.96989	9.20071
Target House without EAHX	60.229	9.1752

Table2. With and Without EAHX simulation for heating and cooling load

3. PV- Panels:
   Electricity from photovoltaic panel is a clean source of energy, environmentally friendly as well as sustainable source. In this target house there is a renewable source of energy being provided by the photovoltaic panels installed on the roof of the house. These solar panels are made of polycrystalline Si having an output power of about 3kW. This renewable source of connected to an inverter that transform the direct current (DC) to alternate current (AC). The amount of electricity generated from this PV panels account for approximately 85% of the energy consumed by the whole house as we can see from the following table.

Simulation/Energy	Electricity Generated by PV Panels (kWh)	Electricity consumed by the house (kWh)
Target House	2031	2374

Table3. PV panel simulation

3.2 Case Conclusion:

As we can see from the below table, there is a summary of annual energy consumption for each green technology being compared between the reference house, target house without High R-value and one where there is no EAHX. From this we can say that High R-value is major contributor among the below technologies as without it there is an increase in annual energy consumption by approximately 400%. Without EAHX there is an increase in energy consumption by 125%.

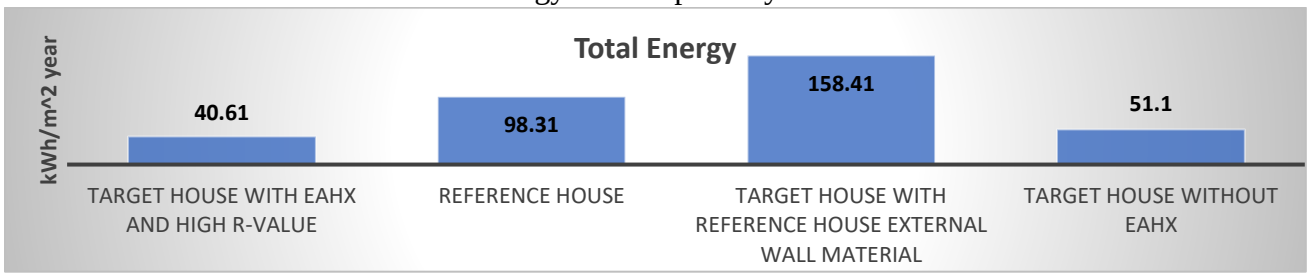


Figure 4. Comparison of annual energy consumption between reference building and proposed building of Bucharest

4. Database:

In this part we are trying to make relational database management system, so that we can store the green technologies and can be used in the green design studio. We will be discussing the methods used in developing the database.

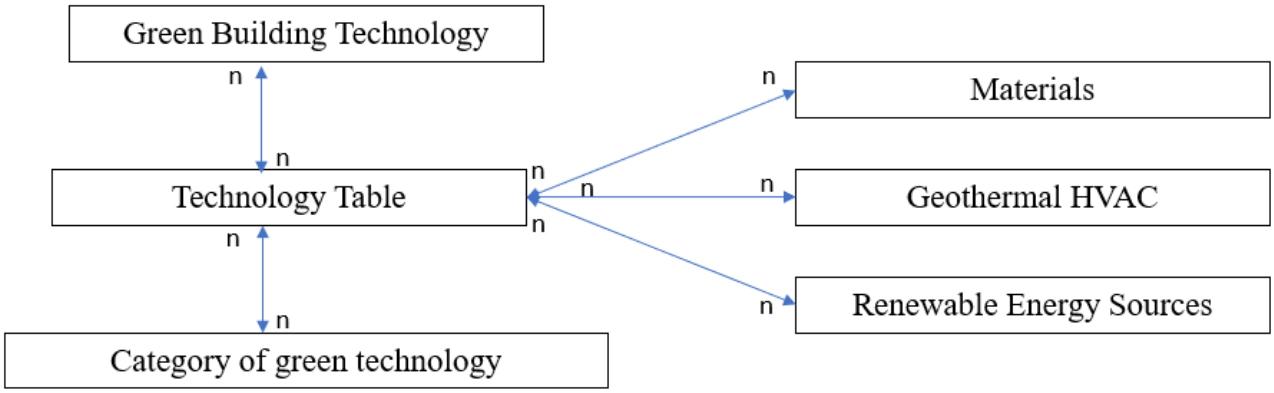


Figure 5. Relational Database for Green technologies

From above figure we can see that Green building Technology table has many to many relationships with the technology table and technology table has many to many relationships with category of green technology. Technology table has further many to many relationships with materials library, geothermal HVAC, renewable Energy Sources.

Properties of Database entities:

No	Entity name	Properties
1	Green Building Technology	Green Building Id Green building Name
2	Technology Table	Technology Id Technology Name Description Features Heating load (kWh/m2) Cooling load (kWh/m2) Annual Load (kWh/m2)
3	Category of green technology	Category Id Category name
4	Materials	Material Id Name of Material Thickness (mm) Density (kg/m3) Conductivity (W/mK) Specific Heat (J/kgK) Thermal Absorptance Solar Absorptance Visible Absorptance

5	Geothermal HVAC	Id Name Design Flow Rate (m3/s) Minimum zone Temperature when heating (Celsius) Maximum zone temperature when cooling (Celsius)
6	Renewable Energy Sources	Id Name Energy Generated (KWh) Energy Saved in percentage (%)

For the case study of Bucharest, we have 3 technologies and it is added to the database. For example, technology EAHX falls into geothermal energy source. This table stores all the required specifications of the EAHX. The Id of this technology is linked to the technology table. The technology table gives you required data regarding how much annual load, heating load or cooling load it takes. The technology Id is then linked to the category entities where we have 9 categories and accordingly EAHX is been added to the External Enclosure. At the same time the technology Id is also linked to the Green building Table which has green building Id associated to the technology. In this way a query can be generated, or a green technology can be searched in green design studio.

With more technologies being simulated more table can be added to the technology table. Like for our case we had 3 technologies one was related to the material, the other one to the geothermal HVAC and the last one to the renewable energy sources. In future for example if someone as Heat Remover as a green technology it can be added as a separate entity and connected to the technology table. Similarly, if someone run a simulation about VATE is a green technology, it can also form a separate entities and cane be linked to the technology table. Similarly, we can analyze and store more data in future with more case studies.

5. Conclusion:

This report talks about house in Bucharest which falls into climate zone 5A. We found three green technology for this climate zone which are then categorized using “Virtual Design Studio” Assessment. When added to the building can have an impact on the outcome of the consumption of energy. We also analyzed each technology individually giving us an idea of how much energy can be consumed by technology individually as well as when integrated with the system. We then went on to make a database where we added this technology so that we can have a searchable database in green design studio for the users. Users can add this technology as a module into their own design and analyze its performance for their design. As we move further, we would like to run more simulations with different climate zone. So that user can also search the database with respect to the climate zone. This method can help us identify more green building technology and then following the procedure we can analyze each technology individually as well as integrated with each other. Additional works required to determine other sub-aspects of performance indicators that have not been quantified in this report.

Acknowledgment:

I would like to personally thank Dr. Jianshun Zhang who is a Mechanical and Aerospace Engineering Professor for giving me this project. It enlightened me with new technologies that I wasn't aware of. Additionally, I would like to thank Mr. Jialei Shen who is a PhD. Student and Cyrus Farr who is a Senior Mechanical Engineering Student. Without their help we won't be able to complete the initial phase of this project.

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