Complete Solution of HVAC for family House Building in Indonesia

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Master thesis
2015

Tomas Bata University in Zlín
Faculty of Applied Informatics

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ABSTRAKT

Tato diplomová práce obsahuje návrh řešení rodinného domu. Budova se nachází v Indonésii, jihovýchodní asijské zemi. Hlavní cíl práce je navrhnout systém chlazení pomocí reverzibilního tepelného čerpadla uvnitř domu tak, aby bylo dosaženo podmínek pohody prostředí pro obyvatele domu. Chladicí systém je součást vzduchotechnického systému a bude navržen jako pasivní chlazení. Budova je navržena tak, aby splňovala podmínky standardů kladené na tzv. zelené budovy. Součástí řešení je i návrh elektroinstalace a osvětlovací soustavy. Součástí řešení je i návrh zabezpečovacího zařízení a systém řízení a monitorování tepelných stavů. Jako obnovitelný zdroj je navrženo využití fotovoltaiky s návazností na venkovní elektrické sítě. V projektu je pozornost věnována i ohřevu teplé vody pomocí solárních panelů as využitím odpadního tepla z tepelného čerpadla. Všechny systémy jsou začleněny do jednoho komunikačního distribuovaného protokolu BACnet sítě formou SCADA pro účelné správy budovy. Diplomová práce je rozdělena na teoretickou část, ve které jsou uvedeny podklady nutné pro vypracování praktické části a praktickou část podle obsahu.

Klíčová slova: automatizace budov systém, facility management, inteligentní domácnost, inteligentní budovy, zelená budova, informační modelování budov, tepelné čerpadlo, bezpečnostní systém, fotovoltaický panel

ABSTRACT

This master thesis contains the solution design of single family house building located in Indonesia, South East Asian country. The mainly purpose of the thesis is to design cooling system using reversible heat pump inside the house to reach comfortable temperature for the occupants. Along with the cooling system include the ventilation design as the passive cooling, also observation of the feasibility material building properties to support optimization of the house design approaching green building standard. Electrical installation such as lighting design combine with other electrical fixtures in security and communication systems by using the collaboration of utility grid and photovoltaic panel as the renewable power source. Plumbing system are include reviewed withal domestic hot water supply associated by means of heat waste from the heat pump and solar water heating system. All systems are obligatory to be integrated in one communication distributed control BACnet protocol network platform by way of SCADA solution in order to manage the energy efficiency as well as its economic evaluation of the house. Thesis' contents are divided into theoretical groundwork and the practical part.

Keywords: building automation system, facility management, smart home, intelligent building, green building, building information modelling, heat pump, security system, photovoltaic panel, HVAC, BACnet, SCADA

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This master's thesis work should be viewed as collaboration of knowledge, expertise opinions and the learning process development in the field of the civil, informatics, electrical and mechanical engineering with specialization in modern residential building. Research and designing of the house model have been carried out between December 2014 and June 2015 based on real family house located in Medan city, Indonesia.

I want to thankful for the blessing from my God Jesus Christ, the One that allowed me to study in Europe until to this point, with His Faithfulness escort me through all the obstacles and my poor health condition. Then, I would like to thank to my Mom in Heaven who was in her life gave me full supported and motivated, convince me to face all the problems and always being responsible to finish what I have started. Also, for Dad in his retirement and loneliness but never tire to keep supportive providing many things for my education. Finally, my sincere gratitude to my supervisor Ing. Martin Zalesak, CSc for the guidance, advice and the patience to teach me while my study process in Tomas Bata University in Zlin as well as towards all the people in Faculty of Applied Informatics who were helped me during the study period.

But seek ye first the kingdom of God, and his righteousness; and all these things shall be added unto you ~ Matthew 6 : 33

I hereby declare that the print version of my master's thesis and the electronic version of my thesis deposited in the IS/STAG system are identical.

Medan, July 2015

Artambo Benjamin Pangaribuan

Student number: A12856

CONTENTS

INTRODUCTION

The global issues around the world these days are mostly relate to energy and environment problems as well as the attempt to create better solution way which are already developed and being developed. Many things in variety of industrial and technology producers proclaim their new product as the energy savings, low energy, environmental friendly (eco-friendly), smart and intelligence. It could be from small products such as smartphone, smart glasses, smart card, intelligent / smart key, until bigger products like smart car, smart gate, smart toll, intelligent transport system, smart home / intelligent building, even smart city.

All these labelling are actually try to attract the consumer to use their products or concepts as the main purpose and then to sustain the earth environment comes next. Of course, in the industrial and technology business, profit must be gain to make the companies keep rolling in the business. Then come up the skeptical question in mind about the standard of all these proclaims, is the product really could make the world sustain or otherwise even make it worsen. As some products could be well-matched in some places, but not in other places, it depends on many factors.

Property business in all around the world always be the major player parallel with the economic growth of a country, human put house as primary needs to their life from generation to generation, even some people could be have more than one house for the investment reason because the price always increase from time to time. Consequently, it cannot be denied that housing contributes large portion of either energy consumption or energy waste everywhere. In order to decrease this problem, many solutions have been developed years ago until now.

The term ‘intelligence’ and ‘smart’ put into the building, peculiarly residential building is to add the spirit into the building so it seems could managed itself to control and monitor what and when exactly it need to consume the energy and make the occupants inside feel comfortable. This spirit term called automation, and must be in the system form. In the end, building automation system in the residential house should make the members of the family safe, secure and convenience.

This thesis’ content try to simulate the useful guidelines by the author to fulfill the most probable requirements and expectations could come up nowadays and near future in local area in the manner of all aspects and real nature condition applied. Based on the observation and ASHRAE standards, prior to designing and managing the building automation system, determine the building physics properties that suitable for approaching the best material in tropical location, treat what kind of technology would be appropriate for the user, ensure the durability in the future function as well as the economic point of view, compatibility of the appliances that will be used and also the accessibility of the system. .

Methodology being used in the thesis for theoretical part primarily based on the various literature views. If any part of the literature has ambiguous, the gaps have been solved by taking comparison with the real time (currently) condition. For practical part is based on Building Information Modelling (BIM) software, in this case is Autodesk Revit MEP 2015. Almost all the calculated result also included from the software, meanwhile the input data that are needed for whole design systems come from the observation at the field, standard codes and literatures. Third party energy analysis web based software in beta version (Autodesk Green Building Studio) which affiliated with the Revit software also being used to simulate the energy of the house design. Other supported software being used is Microsoft Visio 2013 and Climate Consultant 6.0 beta version.

I. THEORY

1 ENERGY EFFICIENT HOUSE

A house can be said being energy efficient while all the systems and sub systems working properly as needed according to the respectively function with lower operating cost than appropriate current standard conventional regulations. The systems could be structure, electricity, mechanical, plumbing, security and information. And the sub systems e.g. ventilation, heating, cooling, sprinkles, communication, etc.

Now days, the trend to construct new building include house with highly energy efficiency level become increase drastically. Most modern civilizations believe conserving the energy will reduce their spending on bills and also have a good long term investment to their property(ies).

Several factors affect the energy level of efficiency of the house building are the location, surrounding climate conditions, government regulations, and also could be the socio-culture (habits) in the area.

1.1 Climate Conditions in Indonesia

There are several aspects to be considered for categorizing worldwide climatic condition. Temperature, humidity, precipitation, wind, and atmospheric pressure are the variables that affect the climate. These variables measured and observed in long term pattern conditions.

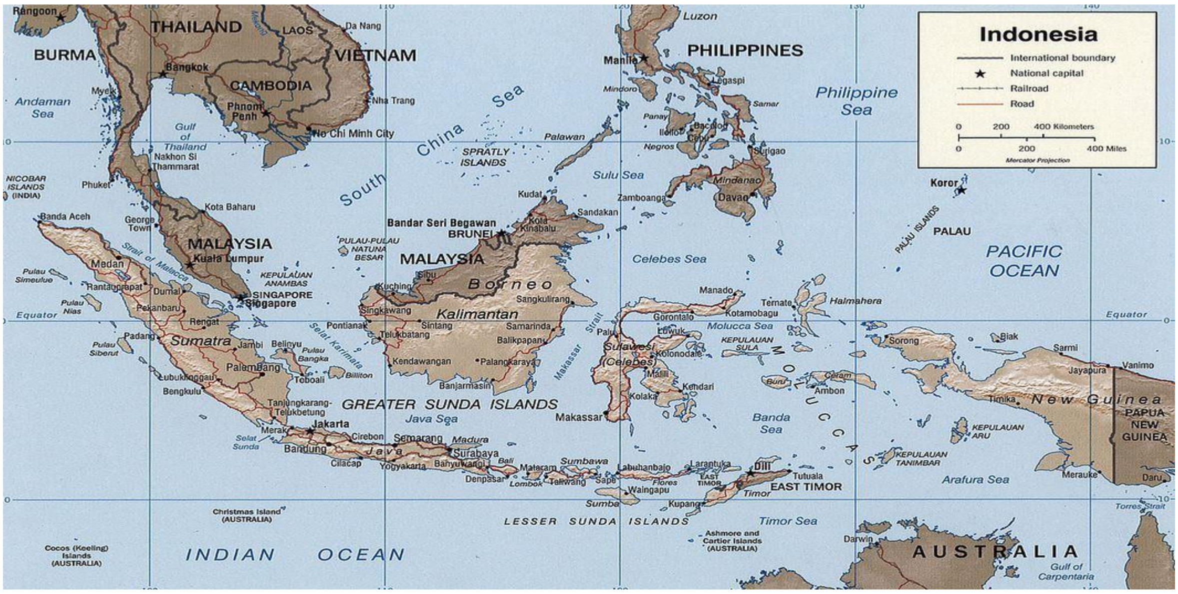

Figure 1 Topography of Indonesia

Indonesia is the biggest archipelago nation in the world and tropical country, located between two continents Asia and Australia, also skirt the equator. This geographical location influence the seasonal pattern of rain and wind. In general, most of the regions are hot and humid (relative humidity between 80-90%).

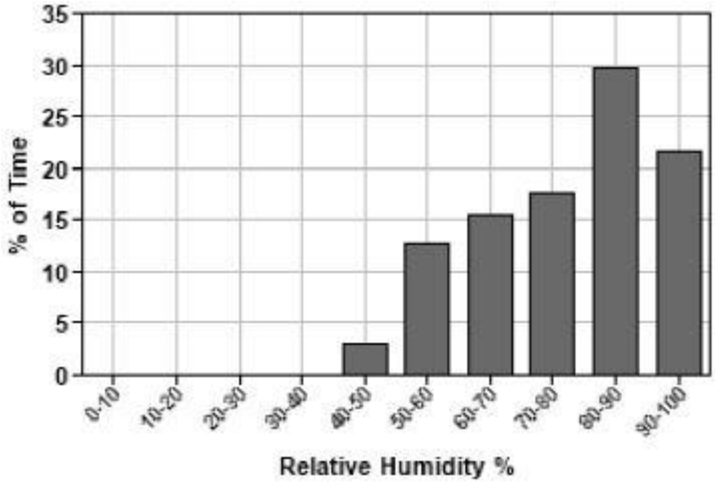

Figure 2 Relative Humidity Frequency Distribution in Indonesia

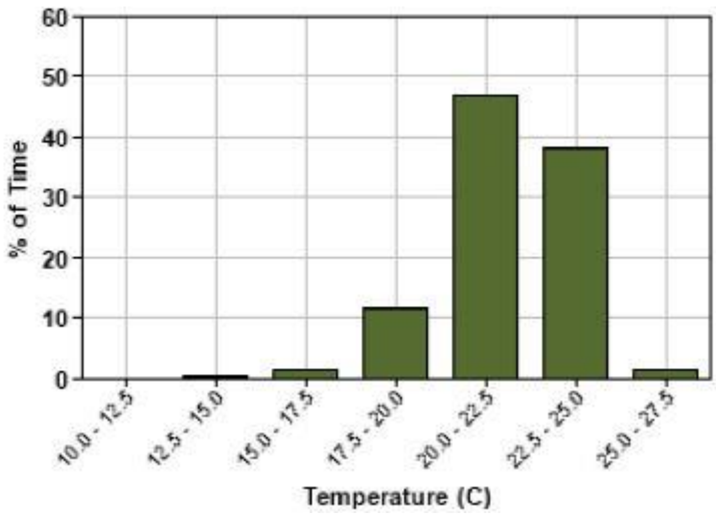

Figure 3 Dew point[1] Frequency Distribution in Indonesia

[1] The temperature at which the air can no longer hold all of the water vapor which is mixed with it and always lower than (or equal to) the air temperature.

Main factor for Indonesia's climate is the precipitation, this is related to the monsoons. Monsoon is the phenomenon of the climate changes occur due to the changes in air pressure in the Indian Ocean and Indian subcontinent. It is generally blow in from east and south in the middle of June and September, from northwest in the middle of December and March. The annual average temperature is around 28 - 29 °C, it is relatively constant. Winds are fairly moderate (range around 1.3-6.3 m/s, according to National Institute of Aeronautics and Space).

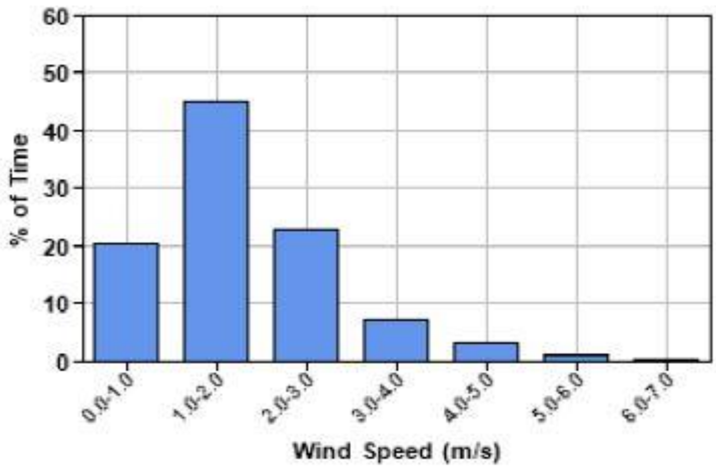

Figure 4 Annual Wind Speed Frequency Distribution in Indonesia

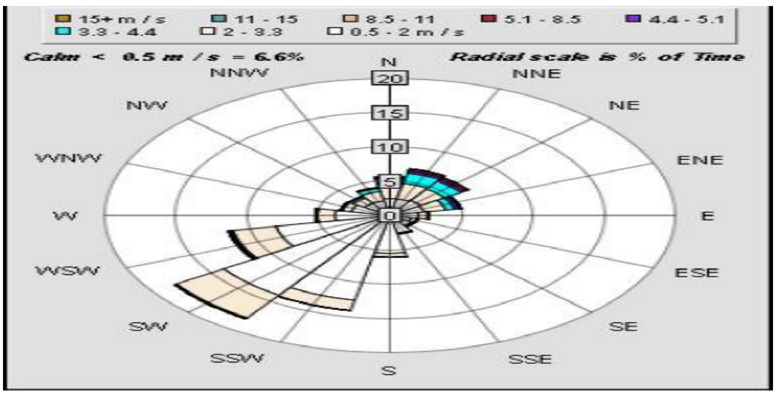

Figure 5 Annual Wind Rose[2] plot in Indonesia

[2] A circular display of how wind speed and direction are distributed at a given location for a certain time period

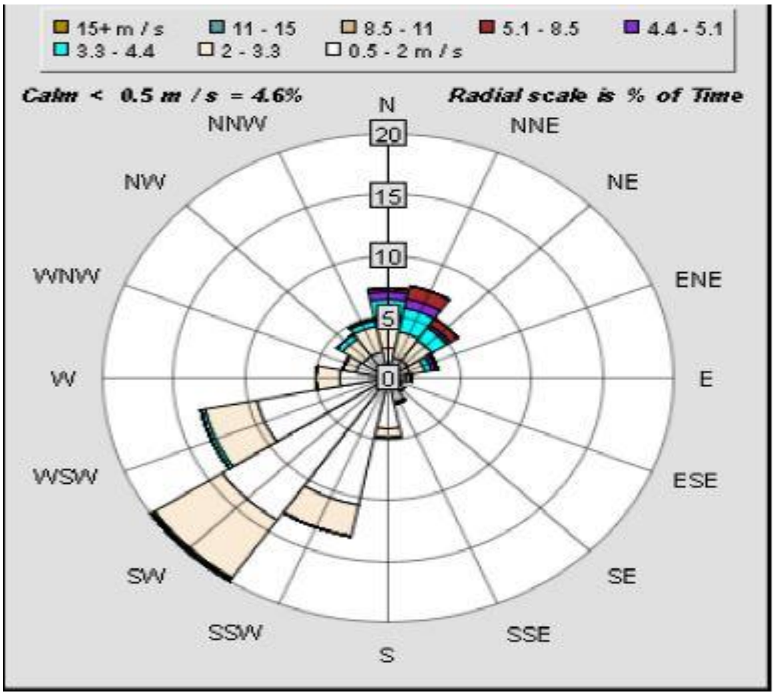

Figure 6 Wind Rose plot (January – March) in Indonesia

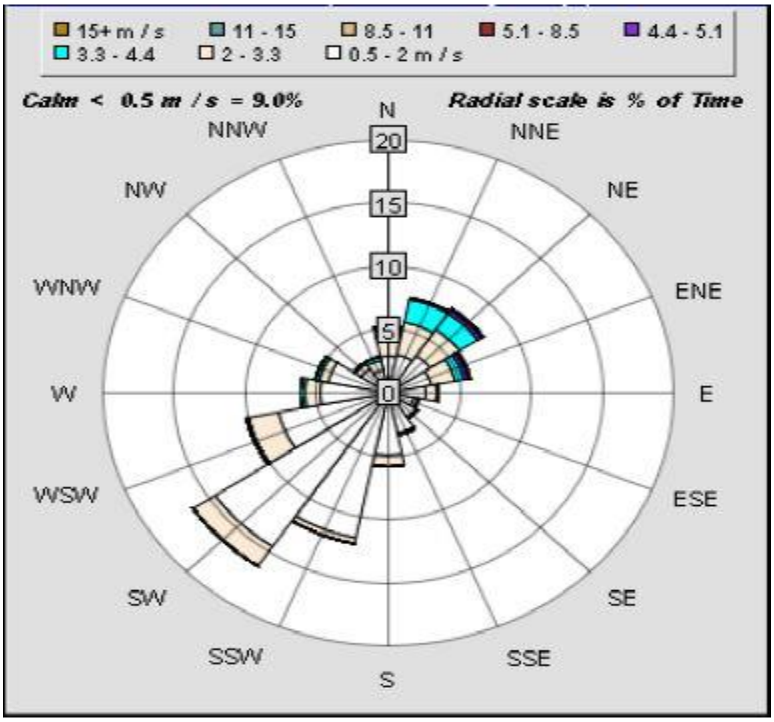

Figure 7 Wind Rose plot (July – September) in Indonesia

There are two seasons in Indonesia, dry season (between June - September) caused by the Australian continental air masses, and rainy season (between December – March) affected by air masses from Pacific Ocean and Asian continent. Average annual rainfall in Indonesia is about 2,702 mm. [1]

Air temperature changes only a little bit from every seasons, roughly temperature drop is 1°C per 90 meters in every escalation of the elevation from sea level. In some highland regions, the hoarfrost occur at the night.

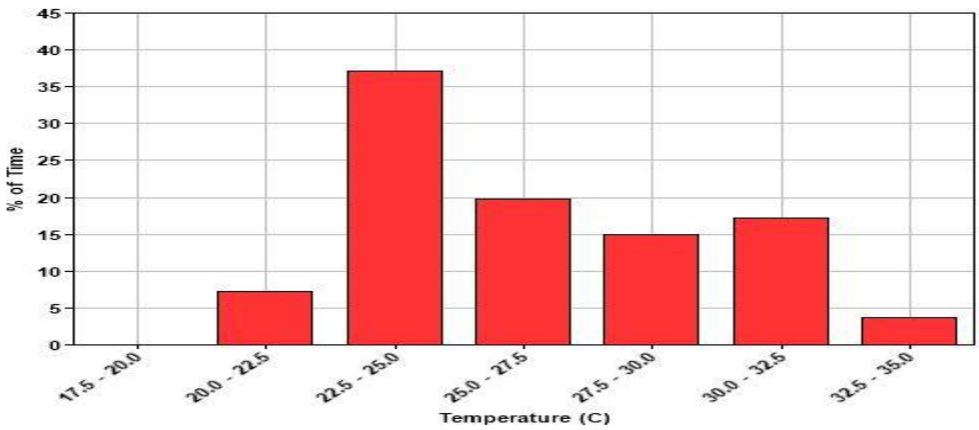

Figure 8 Dry Bulb Temperature Frequency Distribution in Indonesia

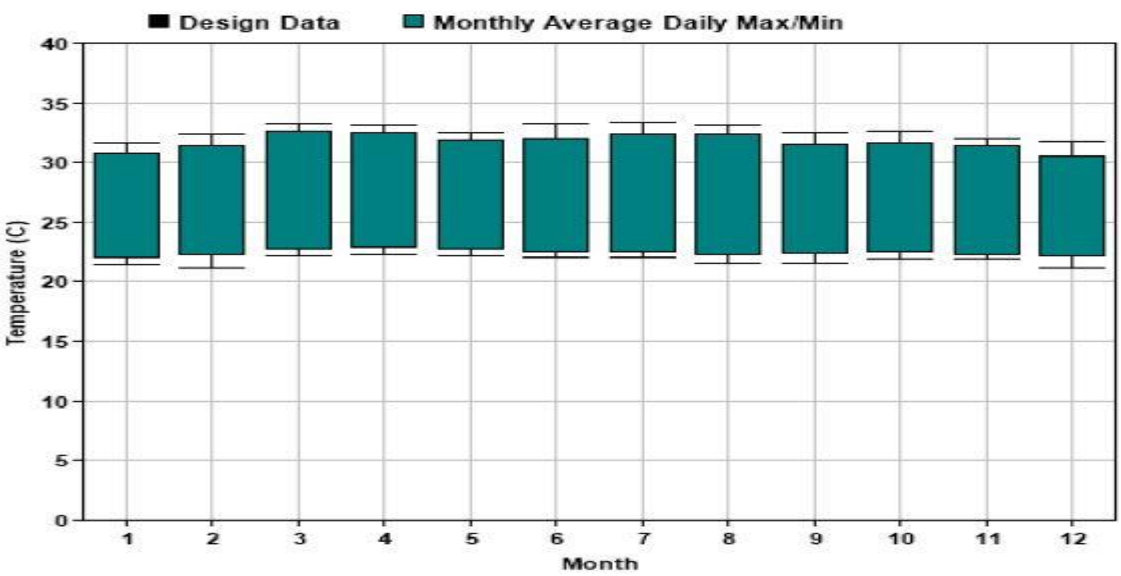

Figure 9 Annual Average Temperature in Indonesia

1.2 Low Energy Residential Building Properties

The idea of low energy residential building is the concept of building could satisfy all the energy obsecration with low-cost, renewable sources, non-polluted, and locally available.[2]

Based on the idea, the definition can be defined by several means, depends on the boundary. Presently the low energy house's parameter is the less calculated heat loss of the building compare with the heat loss of the national building regulation. In other word, the building should be very efficient since it established. Certainly, the starting point to consider for establishing a building are design and material.

1.2.1 Building Envelope

Study about the building envelope is discuss about the physical and structural material of the building. It is very important to choose the right choice material to build a structure. There are many kinds of materials available on the market with various specification and price. Beside the quality, endurance and the aesthetics, the engineer or the designer must take attention to the level of thermal conductivity[3] (k), thermal resistance[4] (R), overall coefficient of heat flow[5] (U-factor) and conductance[6] (C). These thermal properties influence how a house physically consume the energy.

The U-value or U-factor plays important role in heat transfer process between interior and exterior of the building. It is the total coefficient of the heat transfer of all material which are assembled for making a building. It formulated as the reverse of total resistance;

$$U = \frac{1}{\sum R} \quad (1)$$

$$\sum R = \frac{1}{h_i} + \frac{1}{h_e} + \frac{x}{k} \quad (2)$$

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[3] The rate of heat flow through a unit thickness of a homogeneous material(W/m °C)

[4] A measure of resistance to heat flow (m^2 °C/W)

[5] The rate of heat flow through an assembly bounded by air on both sides (W/m^2 °C)

[6] Rate of heat flow through a specific nonhomogeneous object (W/m^2 °C)

where;

h_i = inner side convection heat transfer coefficient, W/m^2 K

h_e = outer side convection heat transfer coefficient, W/m^2 K

k = thermal conductivity of material, W/m K

x = wall thickness, m

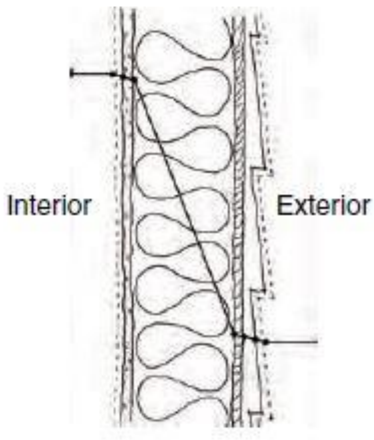

Figure 10 Thermal Gradient by Wall Assembly [3]

Likewise the structure foundation depth must be precise measured to avoid the building collapse, especially in some regions in the world that frequently tend to get earthquakes. Indonesia is one of the countries that most often get earthquakes. Normally the foundation depth for single family house buildings in Indonesia between 1 - 3 m under the ground and the pile thickness 0.7 m.

According to ASHRAE Standard 90.1-2007 (SI Edition), building envelope requirements are categorized based on climate zone. There are 8 (eight) climate zones in the world to distinguish the specifications range of the building assemblies due to the building energy conservation. Indonesia belonging into climate zone 1 (one) upon the standard as seen on Table 1.

Table 1 Indonesia climate zone [4]

Country	City (Province or Region)	Zone	Country	City (Province or Region)	Zone	Country	City (Province or Region)	Zone	Country	City (Province or Region)	Zone
Argentina			Finland			Japan			(Russia cont.)		
	Buenos Aires/Ezeiza	3		Helsinki/Seutula	7		Fukaura	5		RostovNaDonu	5
	Cordoba	3	France				Sapporo	5		Vladivostok	6
	Tucuman/Pozo	2		Lyon/Satolas	4		Tokyo	3		Volgograd	6
Australia				Marseille	4	Jordan			Saudi Arabia		
	Adelaide (SA)	4		Nantes	4		Amman	3		Dhahran	1
	Alice Springs (NT)	2		Nice	4	Kenya				Riyadh	1
	Brisbane (AL)	2		Paris/Le Bourget	4		Nairobi Airport	3	Senegal		
	Darwin Airport (NT)	1		Strasbourg	5	Korea				Dakar/Yoff	1
	Perth/Guildford (WA)	3	Germany				Pyonggang	5	Singapore		
	Sydney/KSmith (NSW)	3		Berlin/Schoenfeld	5		Seoul	4		Singapore/Changi	1
Azores (Terceira)				Hamburg	5	Malaysia			South Africa		
	Lajes	3		Hannover	5		Kuala Lumpur	1		Cape Town/D F Malan	4
Bahamas				Mannheim	5		Penang/Bayan Lepas	1		Johannesburg	4
	Nassau	1	Greece			Mexico				Pretoria	3
Belgium				Souda (Crete)	3		Mexico City (Distrito Federal)	3	Spain		
	Brussels Airport	5		Thessalonika/Mikra	4		Guadalajara (Jalisco)	1		Barcelona	4
Bermuda			Greenland				Monterrey (Nuevo Laredo)	3		Madrid	4
	St. Georges/Kindley	2		Narssarssuaq	7		Tampico (Tamaulipas)	1		Valencia/Manises	3
Bolivia			Hungary				Veracruz (Veracruz)	4	Sweden		
	La Paz/El Alto	5		Budapest/Lorinc	5		Merida (Yucatan)	1		Stockholm/Arlanda	6
Brazil			Iceland			Netherlands			Switzerland		
	Belem	1		Reykjavik	7		Amsterdam/Schiphol	5		Zurich	5
	Brasilia	2	India			New Zealand			Syria		
	Fortaleza	1		Ahmedabad	1		Auckland Airport	4		Damascus Airport	3
	Porto Alegre	2		Bangalore	1		Christchurch	4	Taiwan		
	Recife/Curado	1		Bombay/Santa Cruz	1		Wellington	4		Tainan	1
	Rio de Janeiro	1		Calcutta/Dum Dum	1	Norway				Taipei	2
	Salvador/Ondina	1		Madras	1		Bergen/Florida	5	Tanzania		
	Sao Paulo	2		Nagpur Sonegaon	1		Oslo/Fornebu	6		Dar es Salaam	1
Bulgaria				New Delhi/Safdarjung	1	Pakistan			Thailand		
	Sofia	5	Indonesia				Karachi Airport	1		Bangkok	1
Chile				Djakarta/Halimperda (Java)	1	Papua New Guinea			Tunisia		
	Concepcion	4		Kupang Penfui (Sunda Island)	1		Port Moresby	1		Tunis/El Aouina	3
	Punta Arenas/Chabunco	6		Makassar (Celebes)	1	Paraguay			Turkey		
	Santiago/Pedahuel	4		Medan (Sumatra)	1		Asuncion/Stroessner	1		Adana	3
China				Palembang (Sumatra)	1	Peru				Ankara/Etimesgut	4
	Shanghai/Hongqiao	3		Surabaja Perak (Java)	1		LimaCallao/Chavez	2		Istanbul/Yesilkoy	4

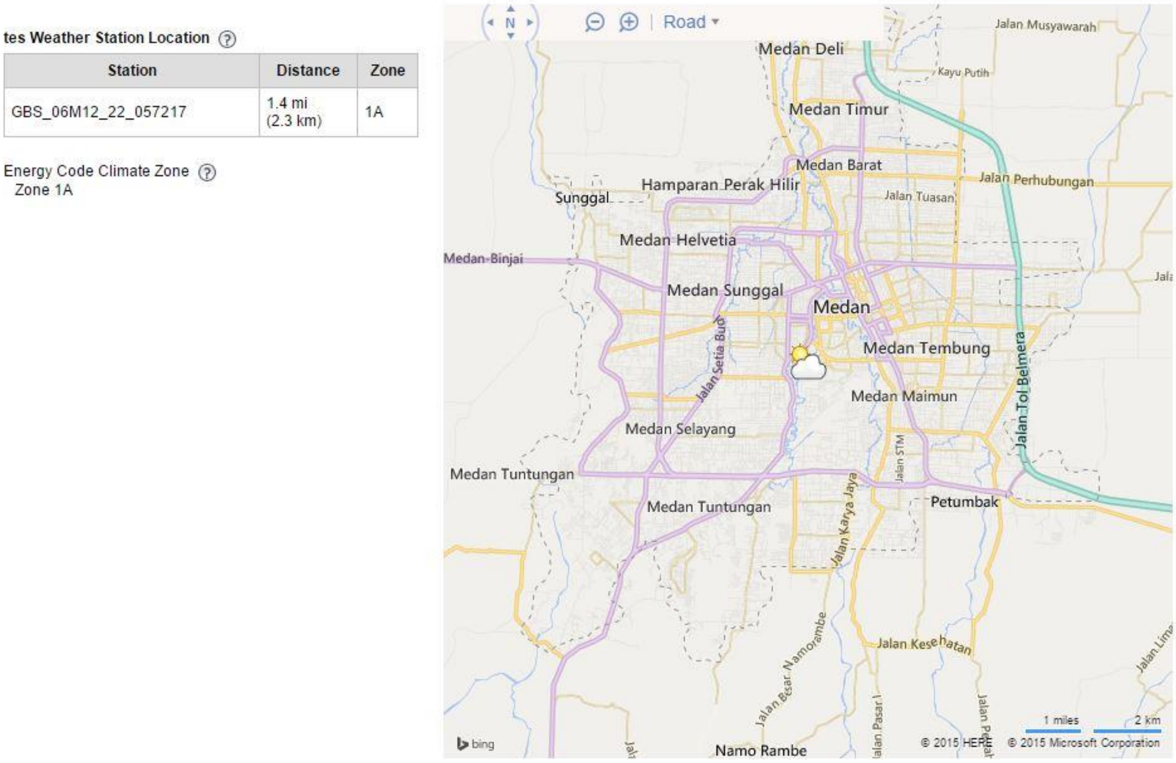

Figure 11 Weather Station with Climate Zone 1A in Medan, Indonesia

The standard elements of single family residential buildings consists of roofs, walls, basement walls (if any), floors, slab floors, doors and windows (fenestrations). Insulation will much help to reduce the heat flow among the elements, the higher R-value the better the thermal insulation. For the glass windows, the parameter value being used is solar heat gain coefficient (SHGC) which is the ratio of the solar gain entering the space through the window to the incident solar radiation, it is dimensionless and the value for the real products in the market is between 0.2 until 0.9. Lower SHGC means has good thermal resistance and vice versa.

Slabs floor using different value factor with floors, if floors using U-value, slab floors measured with F-factor which expressed per linear meter of building perimeter. This factor is prepared for unheated and heated slab floors.

In table 2 can be view the range value of thermal properties for building physics standard in order to help conserve the energy. NR means no insulation requirement.

Table 2 Building Envelope Requirements for Climate Zone 1 [4]

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value	Assembly Maximum	Insulation Min. R-Value
Roofs						
Insulation Entirely above Deck	U-0.360	R-2.6 c.i.	U-0.273	R-3.5 c.i.	U-1.240	R-0.7 ci
Metal Building	U-0.369	R-3.3	U-0.369	R-3.3	U-7.268	NR
Attic and Other	U-0.192	R-5.3	U-0.153	R-6.7	U-0.459	R-2.3
Walls, Above-Grade						
Mass	U-3.293	NR	U-0.857[a]	R-1.0 c.i.[a]	U-3.293	NR
Metal Building	U-0.642	R-2.3	U-0.642	R-2.3	U-6.700	NR
Steel-Framed	U-0.705	R-2.3	U-0.705	R-2.3	U-1.998	NR
Wood-Framed and Other	U-0.504	R-2.3	U-0.504	R-2.3	U-1.660	NR
Walls, Below-Grade						
Below-Grade Wall	C-6.473	NR	C-6.473	NR	C-6.473	NR
Floors						
Mass	U-1.825	NR	U-1.825	NR	U-1.825	NR
Steel-Joist	U-1.986	NR	U-1.986	NR	U-1.986	NR
Wood-Framed and Other	U-1.599	NR	U-1.599	NR	U-1.599	NR
Slab-On-Grade Floors						
Unheated	F-1.264	NR	F-1.264	NR	F-1.264	NR
Heated	U-1.766	R-1.3 for 300 mm	F-1.766	R-1.3 for 300 mm	F-1.766	R-1.3 for 300 mm
Opaque Doors						
Swinging	U-3.975		U-3.975		U-3.975	
Nonswinging	U-8.233		U-8.233		U-8.233	
Fenestration	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**	**Assembly Max. U**	**Assembly Max. SHGC**
Vertical Glazing, 0%–40% of Wall						
Nonmetal framing (all)[b]	U-6.81	SHGC-0.25 all	U-6.81	SHGC-0.25 all	U-6.81	SHGC-NR all
Metal framing (curtainwall/storefront)[c]	U-6.81		U-6.81		U-6.81	
Metal framing (entrance door)[c]	U-6.81		U-6.81		U-6.81	
Metal framing (all other)[c]	U-6.81		U-6.81		U-6.81	
Skylight with Curb, Glass, % of Roof						
0%–2.0%	U_{all}-11.24	$SHGC_{all}$-0.36	U_{all}-11.24	$SHGC_{all}$-0.19	U_{all}-11.24	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-11.24	$SHGC_{all}$-0.19	U_{all}-11.24	$SHGC_{all}$-0.16	U_{all}-11.24	$SHGC_{all}$-NR
Skylight with Curb, Plastic, % of Roof						
0%–2.0%	U_{all}-10.79	$SHGC_{all}$-0.34	U_{all}-10.79	$SHGC_{all}$-0.27	U_{all}-10.79	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-10.79	$SHGC_{all}$-0.27	U_{all}-10.79	$SHGC_{all}$-0.27	U_{all}-10.79	$SHGC_{all}$-NR
Skylight without Curb, All, % of Roof						
0%–2.0%	U_{all}-7.72	$SHGC_{all}$-0.36	U_{all}-7.72	$SHGC_{all}$-0.19	U_{all}-7.72	$SHGC_{all}$-NR
2.1%–5.0%	U_{all}-7.72	$SHGC_{all}$-0.19	U_{all}-7.72	$SHGC_{all}$-0.19	U_{all}-7.72	$SHGC_{all}$-NR

1.2.2 Building Regulations

In each country, there is national regulations regard to building standard policy. Even though it is common found inside a nation has different regulations between the municipalities. For international scope, there are several trusted standard codes which could be taken as references to be adopted in both national and municipality rules. Some familiar standard codes name are ASHRAE, ANSI, CEN, and APEC building codes.

Indonesia has three basic national building legislations, these are (1) building permit IMB (*Izin Mendirikan Bangunan*), (2) location permit (*Izin lokasi*), (3) advice planning permit IPPT (*Izin Perubahan Penggunaan Tanah*). This permit must be owned before someone starting to construct any permanent building. The material products standard been regulated with SNI (*Standar Nasional Indonesia*)[7], however the district or regency governments have optional authority to refuse or implemented if any point in codes and regulations are suitable or not suitable in the local region. In 2011, about 70 percent of district and regency governments had developed their own codes but still in the corridor of national law. The official national government develop the entire regulations and standards assisted by some parties such as academicians and private sector.

The other mandatory regulations to consider prior to either build or renovate any facilities are (1) industry permits, (2) environmental reviews AMDAL (*Analisis Dampak Lingkungan*), (3) nuisance permits HO (*Hinder Ordonnantie*). The Indonesian Building Code was legislated in order to socialize compulsory standards in building and construction industry these are IMB National Regulation Law 28 of 2002 and Regulation 36 of 2005. Law 28 disposes building functions, building requirements, building processes, the role of the community, the role of government, and sanctions for noncompliance. Regulation 36 of 2005 is about implementing regulations of Law 28 of 2002.

[7] Indonesian National Standard agency owned by central government

Table 3 Indonesia Status of Compulsory Building Codes among APEC members [5]

Economy	Code	Buildings Covered	Reference Standards	Green Features			Adoption, Evolution, Enforcement (Details in Table 4)
				Coverage	Actors	Development Timeline	
Chile	National building code- General Law of Urban Planning and Construction	Housing and commercial	Mainly Normas Chilenas INN	Standards addressing aspects of sustainability (energy efficiency)	Energy efficiency and other sustainable aspects in the built environment are incorporated in the technical standards.	N/A	Code adoption is local through regional secretariat ministries. The Ministry of Housing and Urban Development supervises laws, regulations, administrative and technical requirements for construction and urbanization and interprets provisions of land zoning tools.
People's Republic of China	National Construction Law leading to development of many codes (45 for structures and hundreds of building codes)	Building uses, height etc.	Standards are not referenced but incorporated directly into the documents	Energy efficiency, water efficiency, waste management, lighting, light pollution have been integrated into existing codes.	Centrally by the Ministry.	N.A.	See Table 4.
Hong Kong, China	Building Ordinance and Buildings Dept.'s codes of practice	Building use	BS, AS/NZS, JIS, American Standards, EU standards, Chinese standards	None	Mostly government, but private sector and professional orgs have been developing and promoting rating systems. One of the few economies where a government green rating system runs hand in hand with a privately run rating system.	Government green building rating has existed since 2004, and the private rating system since 2008.	Enforced and administered by the Buildings Department. There are only four divisions in the department.
Indonesia	Law 28, Law 29, Regulation 36, Regulation 76, Land and building control are integrated (mandatory)	Building use	National Standards Institute	Environmental protection and requirements are integrated into Law 29 (land planning) and thus are part of the building regulatory control system	At this time, no government effort to develop green codes and standards. Private sector (Green Building Institute of Indonesia) has a rating system called GREENSHIP.	N.A.	Laws by the central government are passed by the parliament, and enforced in all central government jurisdictions. The central government also passes laws for regional governments, and assists them in developing codes, even though regional and local governments tend to develop their own codes. Regional and local codes mostly contain punishment and payment information, rarely technical information. The authority handling the law is the Building Department.

1.2.3 Regulations Enforcement

As the member of APEC economic community, Indonesia follows the APEC Building Codes, Regulations, and Standards. Still, among the members do not have the same standards each other. Based on executive summary reports issued in 2013 by APEC publications SCSC[8], Indonesia does not have green building home standard nor green home features in the national building regulations. Currently, the rating system (named GREENSHIP) is made voluntarily by one private and nonprofit organization GBCI[9]. The credit points consists of energy efficiency, environmental management, site development, material resources and cycle, indoor air quality, and water conservation. This assessment made for the purpose to educate Indonesian people especially architects, developers, contractors, mass media, building materials industries and government.

Table 4 Parameters of GREENSHIP Homes [6]

Category	Number of Criteria			Scores	
	Prerequisite	Credits	Bonus	Credits	Bonus
Site development	2	6	-	13	-
Energy efficiency	2	5	1	15	2
Water conservation	-	5	-	13	-
Material resources	1	8	-	11	-
Indoor air quality	1	6	-	13	-
Environmental management	1	7	1	11	2
Total benchmarks	7	38	2	77	4

[8] Subcommittee on Standards and Conformance, an APEC publications committee

[9] Green Building Council of Indonesia, http://www.gbcindonesia.org/

Site development parameter has several sub appropriate prerequisites to fulfill in order to get points in GREENSHIP standard, they are: site management policy, motor vehicle reduction policy, access to community, site landscaping, bicycle, heat island effect, water management, site management, and building neighborhood. Detail points of site development section shown in table 5.

Table 5 Prerequisites of Site Development Section [6]

CODE	RATING		BENCMARK	POINT	MAX POINT
APPROPRIATE SITE DEVELOPMENT					16
P 1	Site Management Policy		The availability of a written statement containing the commitment from top management regarding the exterior building maintenance, integrated pest management (IPM), and weeds and also habitat management around the site using non-toxic materials.	P	P
P 2	Motor Vehicle Reduction Policy		The availability of a written statement containing the commitment from top management to perform various actions to achieve the reduction of private vehicles, such as car pooling, feeder buses, public transportation vouchers and discrimination of parking fares.	P	P
			The availability of a campaign which includes the positive impact from the reduction of private vehicles with a minimum installation campaign is permanently written on every floor, such as sticker, poster, email.	P	
ASD 1	Community Accessibility	1	There are at least 5 types of public facilities within a distance of achieving the main road as far as 1500 m from the site.	1	2
		2	Provide pedestrian facilities which are safe, comfortable and free from crossover vehicle access to connect at least 3 public facilities above and / or by mass transportation stations.	1	
		3A	The availability of public transport stops or stations within 300 m from the gate outside the building with the calculation exclude pedestrian bridge and ramp.	1	
			OR		
		3B	Provide a shuttle bus for the building users to reach the public transportation stations or car pooling which is integrated with the shuttle bus. Minimum numbers of bus are 2 units.	1	
			OR		
		3C	Provide pedestrian facilities within the the building area to reach the bus stop or the nearest public transport station, safely and a comfortably in accordance with Minister of Public Works' Decree No 30/PRT/M/2006 Chapter 2B.	1	
ASD 2	Motor Vehicle Reduction		The availability of the implementation for one of the options: car pooling, feeder buses, public transportation vouchers, and discrimination of parking fares.	1	1

ASD 3	Bicycle	1	The availability of a secure bicycle parking, 1 unit per 30 building users	1	2
		2	If point 1 above is met and provide special changing room and bathroom for bicycle users for every 25 bicycle parking lots.	1	
ASD 4	Site Landscaping	1	The presence of vegetation landscape area (softscape) which is free from the park (hardscape) located on the upper surface of the land area of at least 30% of the total land area. The area calculated include park above the basement, roof garden, terrace garden and wall garden. Formation of plants in accordance to the Ministry of Public Works' Decree No. 5/PRT/M/2008 of green open space of Article 2.3.1 of the Criteria for Yard Vegetation.	1	3
		2	Addition of 1 point for each additional 10% of site area for the use of landscaping areas.	1-2	
		3	The use of local plants from local nursery with a maximum distance of 1000 km and productive plants.	1	
ASD 5	Heat Island Effect	1A	Using materials with the average albedo value of at least 0.3 according to the calculation of area for pavement covered- roof	1	2
			OR		
		1B	Using a green roof at 50% of roof area which is not used for electrical mechanical (ME), calculated from the broad canopy.	1	
		2	Using materials with the average albedo value of at least 0.3 according to the calculation of area for pavement-covered non-roof.	1	
ASD 6	Storm Water Management	1A	Reducing the load volume of rainwater runoff from the land area into the city drainage network by 50% of daily rainfall total volume, calculated from the discharge of rain water in rainy months.	1	2
			OR		
		1B	Reducing the load volume of rainwater runoff from the land area into the city drainage network by 75% of daily rainfall total volume, calculated from the discharge of rain water in rainy months.	2	
ASD 7	Site Management	1	Having and applying the SOP control of crop pests and weeds using non-toxic materials.	1	2
		2	Provision of non-domesticated animal habitat at least 5% of the total building footprint area based on animal activity areas (home range).	1	
ASD 8	Building Neighbourhood	1	Improving the quality of community life around the building by doing one of the following actions: improved sanitation, provision of places of worship, public toilets, street vendors and community development training.	1	2

Energy efficiency criteria contains nine conditions to concern about, they are: (1) policy and energy management plan, (2) minimum building energy performance, (3) optimized efficiency building energy performance, (4) testing, recommissioning or retro-commissioning, (5) system energy performance, (6) energy & monitoring control, (7) operation

& maintenance, (8) on site renewable energy, and (9) less energy emission. The comprehensive description of these criteria explained in table 6.

Table 6 Criteria of Energy and Conservation Section [6]

ENERGY EFFICIENCY & CONSERVATION					36
P 1	Policy and Energy Management Plan		The availability of a written statement that includes a commitment from top management which covers: the energy audit, savings targets and specific term action plans by the energy team.	P	P
			The availability of a campaign which includes the positive impact from energy savings with a minimum installation campaign is permanently written on every floor, such as sticker, poster, email.	P	
P 2	Minimum Building Energy Performance	1A	Shows the intensity of electric energy consumption during the last 6 months to less than standard intensity of electric energy consumption which is determined by GBC Indonesia (250 kWh/m2.year for Office, 450 kWh/m2.year for mall, and hotel or apartment of 350 kWh/m2.year).	P	P
			OR		
		1B	Shows the energy savings of 5% or more in the last 6 months.	P	
EEC 1	Optimized Efficiency Building Energy Performance	1A	4 Points awarded if the intensity of energy consumption from the building showed 5% less than the 120% intensity of electric energy consumption from the standard reference in the last 6 month. Furthermore, each multiplication will get an additional 1 point with a maximum of 8 points.	4-8	16
		1B	9 Points awarded if the intensity of energy consumption from the building showed 3% less than the 100% intensity of electric energy consumption from the standard reference in the last 6 month. Furthermore, each multiplication will get an additional 1 point with a maximum of 16 points.	9-16	
			OR		
		2	If the intensity of energy consumption from the building showed more than 120% intensity of electric energy consumption from the standard reference, then any decrease of 10% within the last 6 months will get 1 point with a maximum of 3 points.	1-3	
EEC 2	Testing, Recommissioning or Retro-	1A	Have done the re-commissioning or retrokomisioning on MVAC (Mechanical ventilation and air conditioning) (eg chillers) major equipment in the period a year earlier;	1	2

Table 6 (continued)

<table>
<tr><td></td><td>commissioning</td><td></td><td>OR</td><td></td><td></td></tr>
<tr><td></td><td></td><td>1B</td><td>The presence of periodic continuous commissioning within a maximum of 3 years.</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td>2</td><td>If the points above are met then there are additional points for testing, re-commissioning or retrokomisioning on MVAC System (AHU, pumps, cooling tower) as a whole.</td><td>1</td><td></td></tr>
<tr><td>EEC 3</td><td>System Energy Performance</td><td colspan="2">EEC 3-1 Lighting Control</td><td>2</td><td>12</td></tr>
<tr><td></td><td></td><td>1</td><td>Conduct saving (Economize) by using a lamp which has 20% more-efficient lighting power, compared to the lighting power listed in the 2003 Indonesia National Standards (SNI) No 6197-2000 on Energy Conservation in Lighting Systems *.</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td>2A</td><td>Using a minimum of 50% of high-frequency ballasts (electronic) in the general workspace.</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td></td><td>OR</td><td></td><td></td></tr>
<tr><td></td><td></td><td>2B</td><td>Using a minimum of 80% of high-frequency ballasts (electronic) in the general workspace.</td><td>2</td><td></td></tr>
<tr><td></td><td></td><td></td><td>*SNI Refer to attachment 1</td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="2">EEC 3-2 Mechanical Ventilation Air Conditioning (MVAC)</td><td>10</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Efficiency in equipment that uses air conditioning system operated with electricity, then the minimum efficiency according to GBC INDONESIA and its savings business are as follows:
<table>
<tr><th>AC System</th><th>Type of equipment</th><th>Minimum Efficiency (kW/TR)</th><th>2 points for every savings efforts*</th></tr>
<tr><td>Water cooled</td><td>Recip/screw chiller</td><td>0.881</td><td>0.03</td></tr>
<tr><td></td><td>Centrifugal chiller</td><td>0.656</td><td>0.03</td></tr>
<tr><td>Aircooled</td><td>Recip/screw chiller</td><td>1.270</td><td>0.05</td></tr>
<tr><td>Unitary</td><td>Split</td><td>1.436</td><td>0.02</td></tr>
<tr><td></td><td>VRV</td><td>1.034</td><td>0.03</td></tr>
</table>
* for each savings efforts with improved efficiency savings for each number "saving efforts" which is specified, will get 2 points with a maximum of 10 points

Note: Authentication is done by an actual Site Performance Test.</td><td></td><td></td></tr>
<tr><td>EEC 4</td><td>Energy Monitoring & Control</td><td>1A</td><td>Provision of kWh meter which includes:
• System of air,
• Systems lighting and sockets,
• System for other expenses,
• Space which is not excluded or conditioned</td><td>1</td><td>3</td></tr>
<tr><td></td><td></td><td>1B</td><td>The presence of monthly routine record which consist of results from monitoring and data collection on the kWh meters. The recording is made during the last 6 months minimum.</td><td>1</td><td></td></tr>
</table>

		1C	Appreciate the use of energy in the form of Energy Display placed in public areas by displaying information in bar graph; on the comparison of total energy use within 12 months of the previous year with total energy usage in the year took place in year to date.	1	
			OR		
		2	Applying technological support for building equipment monitoring and controlling	3	
EEC 5	Operation and Maintenance	1	Operation and maintenance manual for the whole air conditioning system (chiller, Air Handling Units, cooling tower).	1	3
		2	If point 1 is met, then added with the operation and maintenance manual on a regular basis for the whole other equipment systems (transportation systems in buildings, clean and soiled (pump) water distribution system and power backup.	1	
		3	Monthly reports for a minimum of the last 6 months for the building systems' operation and maintenance activities, in accordance with the format specified in the operation and maintenance manual.	1	
EEC 6	On Site Renewable Energy	1	If 0.25% of the maximum power demand generated by renewable energy or 2 kWp of installed renewable energy *	1	5 B
			OR		
		2	If 0.5% of the maximum power demand generated by renewable energy or 5 kWp of installed renewable energy *	2	
			OR		
		3	If 1,0% of the maximum power demand generated by renewable energy or 10 kWp of installed renewable energy *	3	
			OR		
		4	If 1,5% of the maximum power demand generated by renewable energy or 20 kWp of installed renewable energy *	4	
			OR		
		5	If 2,0% of the maximum power demand generated by renewable energy or 40 kWp of installed renewable energy *	5	
			* to meet each of the above benchmarks, the representative of the building are asked to choose a higher rate between the percentage or amount of kWp renewable energy installed		
EEC 7	Less Energy Emission		CO_2 Emission Reduction Measures		3 B
		1A	0.25 % CO_2 reduction from the original emission,	1	
			OR		
		1B	0.5 % CO_2 reduction from the original emission,	2	
			OR		
		1C	1.0 % CO_2 reduction from the original emission,	3	

In water conservation part has also nine preconditons to take attention, they are: (1) water management policy, (2) water sub-metering, (3) water monitoring control, (4) fresh water efficiency, (5) water quality, (6) recycled water, (7) potable water, (8) deep well reduction, and (9) water tap efficiency. In table 7 displayed some descriptions of these items.

Table 7 Criteria of Water Conservation Section [6]

WATER CONSERVATION					20
P 1	Water Management Policy		The availability of a written statement that includes a commitment from top management which covers: water audit, saving targets and specific terms action plans by water conservation team.	P	P
			The availability of a campaign which includes the positive impact from water conservation with a minimum installation campaign is permanently written on every floor, such as sticker, poster, email.	P	
WAC 1	Water Sub-Metering		The availability of sub-meter water consumption in the system of public areas, commercial areas and utility buildings.	1	1
WAC 2	Water Monitoring Control		The availability of standard operating procedures and its implementation for the maintenance and periodic inspection of plumbing system to prevent leakage and wastage of water by showing the water balance in the last 6 months for initial certification *.	2	2
			(*) For the following certification, reports every 6 months in the last 3 years based on annual reports are required.		
WAC 3	Fresh Water Efficiency		This assessment is only for buildings that have maximum water consumption 20% greater than National Standard (SNI 03-7065-2005 on Procedures of Plumbing System Implementation *.		8
		1	For buildings with water consumption 20% above the SNI, each reduction of 10% receives 1 point to reach the SNI with a maximum of 2 points.	1-2	
		2	If point 1 is fulfilled, then any effort to reduce water consumption by 3% from the SNI gets 1 point. Maximum value is 6 points.	3-8	
			*SNI Refer to attachment 2		
WAC 4	Water Quality		Showing the last 6 months of laboratory evidence for primary sources of water in accordance with the criteria of clean water at least once within 6 months for initial certification *.	1	1
			(*) For the following certification, reports every 6 months in the last 3 years based on annual reports are required.		
			* Regulation Refer to attachment 3		
WAC 5	Recycled Water	1A	Using recycled water with sufficient capacity for the needs of make-up water cooling towers. Benchmark applies only to buildings that use a cooling tower on the refrigeration system.	1	5
			OR		
		1B	100% irrigation needs is not originating from the primary water source of the building (Local Water Enterprise / PDAM and groundwater).	1	

Table 7 (Continued)

		2	Using recycled water with sufficient capacity for the needs of flushing toilets, in accordance with WHO standards for medium contact (<100 fecal coliform / 100 ml).	2	
		3	Having a water recycling system where the output is equivalent to the standard of clean water in accordance to the Minister of Health Decree No.416/1990 of Water Quality Requirements and Monitoring to meet the needs of of clean water.	2	
WAC 6	Potable Water		Using a filtration system that produces drinking water in accordance with Minister of Health Decree No. 492/2010 of Drinking Water Quality Requirements * Minimum in every kitchen or pantry.	1	1
			* Regulation Refer to attachment 4		
WAC 7	Deep Well Reduction	1A	Consumption of water which use deep well with a maximum of 20% of overall water consumption.	1	2
			OR		
		1B	Consumption of water which use deep well with a maximum of 10% of overall water consumption.	2	
WAC 8	Water Tap Efficiency	1A	50% use of tap water in a public area using the auto-stop feature.	1	2 B
			OR		
		1B	80% use of tap water in a public area using the auto-stop feature.	2	

For material resources, it has eight aspects to consider getting the points such as: (1) fundamental refrigerant, (2) material purchasing policy, (3) waste management policy, (4) non ODS usage, (5) material purchasing practice, (6) waste management practice, (7) hazardous waste management, and (8) management of used good. In table 8 described each item of prerequisite.

Table 8 Criteria of Material Resources Section [6]

MATERIAL RESOURCES AND CYCLE					12
P 1	Fundamental Refrigerant	1A	Using non-CFC refrigerant and cleaner materials that have a small value of Ozone Depleting Potential (ODP), <1	P	P
			OR		
		1B	If still using the CFCs as a refrigerant, it is necessary to conduct audit and phase out plan for the use of CFCs as refrigerants in the next 3 years and reduce consumption of CFCs from refrigeration leaks and damages set forth in the Refrigerant Management System or RMS Plan Plan.	P	
P 2	Material Purchasing Policy		The availability of a written statement that includes top management policies which prioritize expenditures/use for green materials in the list below: a. Regional production b. Certified SNI / ISO / Ecolabel c. Materials that can be recycled (recycable) d. Used Materials (reused) e. Renewable material (renewable) f. Modular or pre fabricated material g. Certified wood h. Lights that do not contain mercury i. Insulation that does not contain styrene j. Plafond or partition that does not contain asbestos k. Composite wood products and low formaldehyde emission agrifiber l. Paint products and low VOC-emitting carpet		P
P 3	Waste Management Policy		The availability of a written statement that includes top management policies regulating waste management based on the segregation between: a. Organic waste, b. Inorganic waste, and c. Hazardous waste	P	P
			The availability of a campaign which includes the positive impact from waste management based on the segregation with a minimum installation campaign is permanently written on every floor, such as sticker, poster, email.	P	
MRC 1	Non ODS Usage		Using the entire air conditioning system with refrigerant materials that have ODP = 0 (non-CFC and non-HCFC).	2	2
MRC 2	Material Purchasing Practice		List of environmentally friendly material: a. 80% of regional production based on the total expenditures the overall material b. 30% SNI / ISO / Ecolabel certified, based on the total expenditures the overall material c. 5% recycled material, based on the total expenditures the overall material d. 10% reused material, based on the total expenditures the overall material e. 2% Renewable Materials, based on the total expenditures the overall material f. 30% modular or pre fabricated materials based on the total expenditures the overall material g. 100% Wood-certified wood materials based on total expenditures overall woodmaterial h. 2.5% lights do not contain mercury, of total expenditures lamp units i. Insulation that does not contain styrene j. Plafond or partition that does not contain asbestos k. Composite wood products and low formaldehyde emission agrifiber l. Low VOC-emitting carpet and paint products		3
		1A	The availability of documents which explain the expenditures of material according to the policies in the prerequisite 2; at least 3 of the material specified in the list of environmentally friendly materials with the purchase amount as mentioned in the "purpose" in the last 6 months for initial certification *.	1	
			OR		
		1B	The availability of documents which explain the expenditures of material according to the policies in the prerequisite 2; at least 5 of the material specified in the list of environmentally friendly materials with the purchase amount as mentioned in the "purpose" in the last 6 months for initial certification *.	2	

Table 8 (continued)

			OR		
		1C	The availability of documents which explain the expenditures of material according to the policies in the prerequisite 2; at least 7 of the material specified in the list of environmentally friendly materials with the purchase amount as mentioned in the "purpose" in the last 6 months for initial certification *.	3	
			(*) For the following certification, reports every 6 months in the last 3 years based on annual reports are required.		
MRC 3	Waste Management Practice	1	The availability of standard operating procedures, training and reports to collect and sort the waste based on organic and inorganic types, in the last 6 month for the inaugural certification *.	1	4
			(*) For the following certification, reports every 6 months in the last 3 years based on annual reports are required.		
		2	If the organic and inorganic waste has been seperated, conduct organic waste processing independently or in cooperation with official agencies of organic waste treatment.	1	
		3	If the organic and inorganic waste has been seperated, conduct inorganic waste processing independently or in cooperation with official agencies of inorganic waste treatment who has principles of 3R (*Reduce, Reuse, Recycle*).	1	
		4	Efforts of Packaging waste reduction which are made of Styrofoam and non-food grade plastic.	1	
		5	An effort for dealing with waste from renovation activity to a third party at least 10% from the the total renovation budget in the last 6 months for initial certification *. (*) For the Following certification, reports every 6 months in the last 3 years based on annual reports are required.	1	
MRC 4	Hazardous Waste Management	1	The availability of standard operating procedures, training and management of hazardous waste management such as: lamps, batteries, printer ink and packaging from cleaning materials in the past 6 months for initial certification *.	2	2
			(*) For the following certification, reports every 6 months in the last 3 years based on annual reports are required.		
MRC 5	Management of Used Good		The availability ofstandard operating procedures and report for the distribution of used items which still can be recovered such as furniture, electronics and spare parts through donations or secondhand goods market in the last 6 months for initial certification *.	1	1

The indoor air quality (health and comfort) section consists of nine things to evaluate, they are: (1) no smoking campaign, (2), outdoor air introduction, (3) environmental tobacco smoke control, (4) CO2 & CO monitoring, (5) physical and chemical pollutants, (6) biological pollutant, (7) visual comfort, (8) acoustic level, and (9) building user survey. In table 9 shows the detail description of each item.

Table 9 Criteria of Indoor Air Quality Section [6]

INDOOR HEALTH AND COMFORT					20
P 1	No Smoking Campaign		The availability of a written statement containing the commitment from top management to perform various actions to achieve the reduction of smoking activity inside the building.	P	p
			The availability of a non-smoking campaign which includes the negative impact from the smoking to us and the environment with a minimum installation campaign is permanently written on every floor, such as sticker, poster, email.	P	
IHC 1	Outdoor Air Introduction		Indoor air quality which shows a minimum introduction of outside air based on SNI No 03-6572-2001of Procedures for Ventilation and Air Conditioning Systems in Buildings building *.	2	2
			*SNI refer to attachment 5A and 5B		
IHC 2	Environmental Tobacco Smoke Control		Smoking is prohibited in all areas of the building and does not provide smoking area within the building. If smoking areas are provided outside the building, it must be located minimum 5 m from the entrance, where the entry of fresh air and window openings; with a follow-up monitoring procedures, documentation and responsive system towards smoking prohibition.	2	2
IHC 3	CO_2 and CO Monitoring	1A	For rooms with high density (such as ballroom / multipurpose room, public meeting rooms, general office, supermarket) equipped with gas sensors installation of carbon dioxide (CO2), which has a mechanism to regulate the amount of outside air ventilation so that the CO2 concentration inside the room is no more than 1,000 ppm. The sensor is placed 1.5 m above the floor near the water return grille.	2	2
			OR		
		1B	For closed parking spaces inside the building, is equipped with gas sensors installation of carbon monoxide (CO) which has a mechanism to regulate the amount of outside air ventilation so that the concentration of CO inside the room is no more than 23 ppm. The sensor is placed 50 cm above the floor near the exhaust grille.	2	
IHC 4	Physical and Chemical Pollutants		Indoor air quality measurements performed randomly, with the sample points in the main lobby, work space or a room rented by tenants. Measurements are taken with a minimum of 1 sample point per 1000 m^2 or the maximum number of samples is 25 point for a single building.		6

Table 9 (continued)

<table>
<tr><td></td><td></td><td>1</td><td>If the measurement results for indoor air quality meets the standards of pollutant gases in Table 1:

Table 1. Gas Pollution for the Office Workplace
<table>
<tr><td>No</td><td>Parameter</td><td colspan="2">Maximum Concentration</td></tr>
<tr><td></td><td></td><td>mg/m_3</td><td>ppm</td></tr>
<tr><td>1</td><td>Sulfide Acid (H2S)</td><td>1</td><td>-</td></tr>
<tr><td>2</td><td>Ammonia (NH3)</td><td>17</td><td>-</td></tr>
<tr><td>3</td><td>Carbon monoxide (CO)</td><td>-</td><td>8</td></tr>
<tr><td>4</td><td>Nitrogen dioxide(NO2)</td><td>5.6</td><td>3</td></tr>
<tr><td>5</td><td>Sulfur dioxide(SO2)</td><td>5.2</td><td>2</td></tr>
</table>
Source: Minister of Health Decree No 1405/Menkes/SK/XI/2002 of Environmental Health Standards in the Office and Industrial Work. (Annex I, Chapter 3, A.3. Pollution gases) Governor of Jakarta Regulation No.54/2008 of Indoor Air Quality Standards</td><td>2</td><td></td></tr>
<tr><td></td><td></td><td>2</td><td>Concentration of Total Dust is based on Minister of Health Decree No 1405/Menkes/SK/XI/2002 of Environmental Health Standards in the Office and Industrial Work. (Annex I, Chapter 3, A.2. Total Dust)*.</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td></td><td>Indoor air pollution sources:</td><td></td><td></td></tr>
<tr><td></td><td></td><td>3</td><td>Concentration Volatile Organic Compound (VOC) is based on SNI 19-0232-2005 of Threshold Limit Values for Chemical Substances in Workplace Air *.</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td>4</td><td>If points 1, 2 and 3 are met; and the concentration of formaldehyde in accordance with SNI 19-0232-2005 *.</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td>5</td><td>If points 1, 2 and 3 are met; and the concentration of asbestos in accordance with Minister of Health Decree No. 1405/Menkes/SK/XI/2002 *.</td><td>1</td><td></td></tr>
<tr><td></td><td></td><td></td><td>* SNI and Regulation refer to attachment 6.</td><td></td><td></td></tr>
<tr><td>IHC 5</td><td>Biological Pollutant</td><td>1</td><td>Cleaning filters, cooling coil and VAC (ventilation and air conditioning) tools in accordance with the schedule of regular maintenance to prevent the formation of mold and fungus as the growing place for microorganisms. Schedule maintenance is based on the standard factory guidelines.</td><td>1</td><td>3</td></tr>
<tr><td></td><td></td><td>2</td><td>Take measurements for number of bacterias,with a maximum amount of bacteria colony of 700 / m3 air and free of pathogenic germs in the room which is determined by GBC INDONESIA (based on Minister of Health Decree No 1405/Menkes/SK/XI/2002 of Environmental Health Standards in the Office and Industrial Work)</td><td>2</td><td></td></tr>
<tr><td>IHC 6</td><td>Visual Comfort</td><td></td><td>The measurement results show the level of lighting (illumination) in every workspace in accordance with the SNI No 03-6197-2000 of Energy Conservation in Lighting Systems *.
*SNI refer to attachment 7</td><td>1</td><td>1</td></tr>
</table>

Table 9 (continued)

IHC 7	Acoustic Level		The measurement results show the sound level in workspace in accordance with the SNI No 03-6386-2000 of Specification for Sound Level and Time of hum for Building and Housing (Recommended Design Criteria) *.	1	1
			Measurements are taken randomly, as many as five points a minimum every one space per two floors. Sound level depends on the type of occupancy. Measurements are taken when it is unoccupied and in a condition of building equipment (such as ventilation systems, elevators, plumbing and lighting system) is operating.		
			*SNI refer to attachment 8		
IHC 8	Building User Survey	1	Conduct building user comfort surveys which include air temperature, lighting levels, sound comfort, and building hygiene pest control. Minimum respondents are 30% from the total users of the building.	1	3
		2A	Meet point 1, and if the results of the survey stated that 60% of the total respondents are comfortable.	1	
			OR		
		2B	Meet point 1, and if the results of the survey stated that 80% of the total respondents are comfortable.	2	
		3	If point 1 is met, and the results of the first survey claimed less than 60% of respondents are comfortable, but do follow the improvements and then conduct a second survey which result at least 80% of total respondents are comfortable.	1	

Building environment management for GREENSHIP rating has six issues to take note, i.e. (1) operation and maintenance policy, (2) innovations, (3) design intent and owner's project requirement, (4) green operational and maintenance team, (5) green lease, and (6) operation and maintenance training. Table 10 shown the description of every issue.

Table 10 Criteria of Building Environment Management Section [6]

BUILDING ENVIRONMENT MANAGEMENT					13
P 1	Operation & Maintenance Policy		The presence of operation & maintenance plan which supports the goal for the achievement of GREENSHIP-EB rating, which focused on: mechanical & electrical systems, plumbing systems and water quality, exterior & interior maintenance, purchasing and waste management Includes: Organizational structure, Standard Operating Procedures and training, work programs, budgets, periodic reports at least every 3 months.	P	P
BEM 1	Innovations	1	Application of innovation with the building quality improvement quantitatively, for example: ASD 4, EEC 1, WAC 3, and IHC 4 so there is an increase in efficiency which exceeds the limit set in the relevant rating.	1-2	5
		2	Application of innovation with the management approach, such as behaviour changes encouragement, for examples in ASD ASD 2 and 8 and MRC 2, 3 and 4, resulting in increased efficiency in other ratings.	1-3	
BEM 2	Design Intent & Owner's Project Requirement	1	Availability of Design Intent document and Owner's Project, also following the changes which occurred during the period of revitalization and operational.	1	2
		2	Availability of As Built Drawing (a minimum of single line drawings) document, technical specifications and manuals for operation and maintenance of equipment (generators, transportation in buildings, air conditioners and cooling towers), also following the changes which occurred during the period of revitalization and operational.	1	
BEM 3	Green Operational & Maintenance Team	1	The presence of an integrated structure inside the operational structure of the building that is in charge of maintaining the application of sustainability / green building principles.	1	2
		2	A minimum of one Greenship Professionals involved in operational & maintenance who works full time	1	
BEM 4	Green Occupancy/Lease	1A	For commercial buildings: a Lease Agreement contains clauses that theTenant will meet a minimum of 1 criteria in GREENSHIP EB for each category of ASD, EEC, WAC, IHC and the MRC.	2	2
			OR		
		1B	For buildings which is used personally, has the SOP and Training which includes the efforts to meet these criteria in GREENSHIP EB with a minimum of 1 rating in each category of ASD, EEC, WAC, IHC and the MRC.	2	
BEM 5	Operation and Maintenance Training	1	The availability of minimum periodic schedule every 6 months and training programs in the operation and maintenance for site, energy, water, materials and HSES (Health Safety Environmental and Security).	1	2
		2	Evidence of operation and maintenance training implementation for site, energy, water, materials and programs along with evaluation from the HSES training.	1	

Regardless APEC has committed to support the green building program, Indonesia is still far from the expectation in practical way. Many local regulations still use old standard or even with no standards.

Table 11 Indonesia Status of Green Building Codes among APEC Members [5]

Economy	Green Code/Rating System	Green Features in Mandatory Code	Implementation Status	Evolution	Code is Part of National Building Code System
Australia	No code. Green Star is the rating system.	No	Voluntary	Green Building Council of Australia administers Green Star. Inputs and suggestions from stakeholders and general public are administered by Green Star Review Committee. Standards are adopted from various Australian and Australia/New Zealand Standards, and the environmental acts and regulations of the Department of Sustainability, Environment, Water, Population and Communities.	No
Brunei Darussalam	Green Building Initiative	Per website, may become national code	Still at implementation stage	Just started; no details provided.	No
Canada	No code. BOMA BESt, BREEAM, CSA, LEED, EnerGuide, GreenGlobe are rating systems.	No	Mostly voluntary, however, NBC has included similar standards in NBC	LEED and BOMA BESt managed by their respective non-profit organizations.	Separate green building code not on the radar but code has many of green features.
Chile	No code.	No	N/A	Development of different standards addressing sustainability issues in the built environment is notes. Important efforts on EE.	No.
People's Republic of China	JGJ/T229-2010 (green design for civil buildings)	Green features are in hundreds of codes.	Mandatory.	Not sure.	Yes.
Hong Kong, China	No code. CEPAS and BEAM Plus are rating systems.	No	Voluntary at this time. CEPAS is maintained by the Buildings Department and BEAM is private and nonprofit	CEPAS is maintained and managed by the Buildings Department. It does not set a timeline for updates and is generally not enforced. BEAM Plus is maintained by the Green Building Council of Hong Kong. BEAM follows the concept of BREEAM closely but is implemented like LEED.	No
Indonesia	No code. GREENSHIP is rating system.	No	Voluntary and run by private sector	Developed by private sector entirely. administered by Green Building Council of Indonesia.	No
Japan	No code. CASEBEE is nationally accepted rating system.	No	Voluntary and run by private sector.	Developed and administered by Japan Green Building Council.	No

1.3 Passive House

Interpretation of the passive house building concept is a guideline of building performance with tight level of energy efficiency in a high level comfortable but still economically affordable. It does not have to be a house, it could be any type of building.

Technically, the essences of passive building are solely achieve the high quality indoor air quality naturally, empower the solar energy for heating goal or minimize for cooling purpose, have continuous insulation without thermal bridging, significantly reduce infiltration of outside air and losing conditioned air.

At the time being, the standard of total energy source for Passive House per year could not more than 120 kWh/m^2 annually. And for either cooling or heating energy consumed is not exceed 15 kWh/m^2 per year each. [3]

1.4 Net Zero Energy Building

According to NREL[10], a net zero energy building is building that consume from renewable energy resources and reproduce at the same amount. The concept is to achieve the top level of energy efficiency aggressively. The energy being used as minimum as possible supplied from fossil (nonrenewable) energy resources or at least 50% of the energy consumed yearly must be renewable. These typical building targeted 5 kWh/m^2/annum in cooling or heating aim.

The vision of net zero energy building in the near future has targeted in year 2030 based on Home Energy Rating System [7] conciliation to International Energy Conservation Code. In figure 12 is the scale for residential energy performance, the lower value, the better energy efficient. The rating is relative to the type, size and configuration of the house.

[10] The laboratory for renewable energy and energy efficiency research and development owned by US government

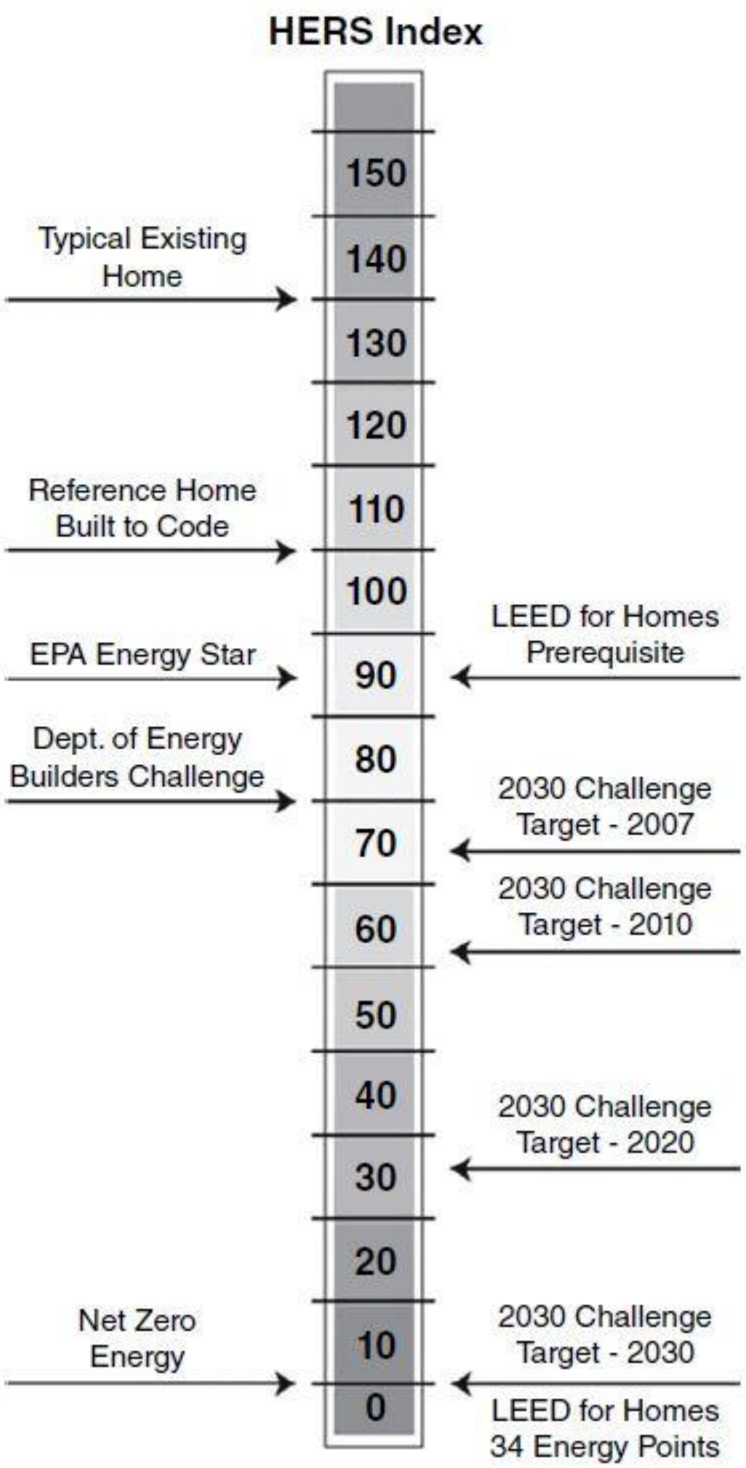

Figure 12 Home Energy Rating System Index (kWh/m^2per year) [3]

1.5 Energy Efficiency Strategies

Plain description of energy efficiency is maximize the output from any given input. This term is used in building to describe how the circulation process effort could be conserved and sustain.

Today, in developing countries like Indonesia, the important of energy efficiency still in low level. By jurisdictions, there is no systematic sanctions regulate to anyone who does not apply saving energy program, yet the awareness of citizens are highly expected to reach the efficiency goal.

The energy efficiency requisites for family house buildings inclined to concern over minimal physical envelopes such as door, roof, ceiling, floor, natural ventilation, windows and wall, the other is mechanical fixtures e.g. domestic hot water, cooling and heating. These physical and mechanical shaping two of characteristics systems; active and passive.

Table 12 The Characteristics of Active and Passive Systems [3]

Characteristic	Active System	Passive System
Elements	Single function, e.g. oil furnace	Multiple functions. e.g. ceiling
Integration	Not well integrated with building, e.g. heater unit	Well integrated, e.g. natural vent (windows)
Resource	Paid, e.g. utility grid	Free, e.g. sun

For house energy efficiency requisitions are listed in some international standards and codes for example: ASHRAE Standard 90.2, International Green Construction Code and International Energy Conservation Code. To accelerate energy efficiency achievement, these standards must be adopted into the national rules as well as the consequent to the user if disobeyed.

In hot countries or in summer season, there are some energy efficiency methods could be done to cool the temperature and decrease the heat from some commons electric appliance inside building.

Table 13 Cooling Methods for Energy Efficiencies

Conditions	Methods
Hot & humid	Precisely placed and measured the roof vents and louvers to reduce heat in the attic and open the ventilation while the humidity is not too
Hot daytime & cool night	Make sure the building well insulated by only gain 0.6 °C/ hr, when the inside temperature increase, exterior air can be allow to enter the building. At night. Let the outside air cool the interior
Day breeze	From the breeze coming direction and its opposite, let the windows open to support other building vent

Table 14 Decreased Methods Heat for Energy Efficiencies

Appliances	Methods
Lighting	Use sunlight to brighten interior in daylight, for night consider to use fluorescent or LED lamps which has around 90% radiate less heat incandescent
Laundry	Use only the latest less energy consumption machines that emit less heat by taking attention to the specification product label
Kitchen	Avoid to use an electric or gas stove as possible, prefer to use microwave oven or consider cooking outside grill

1.6 Indoor Climate Quality in Building

In 1973, the global consciousness increased about the limitation of energy resources because of the oil embargo. Since then, many structural engineers and building designers make boundaries to the required outdoor air for heating and cooling. The side effect of this trend arouse sick building syndrome[11] to the occupants. This syndrome is related to the air quality inside the building.

In order to obtain high level air quality or at least good quality indoor climate with low and optimum energy supply inside building, the designer must predict accurately in planning stage. This is not an easy task to be done, because many factors should be elaborated as input data information and estimation of the future consumption and the occupants of the building.

1.6.1 Psychrometrics Properties

The psychrometry is the study of interactions collaborate between dry air[12], heat, moisture[13] with all the effects. All of these components have the impact to the climate inside the building as well as the performance of the structures. The interactions indicator can be put in one chart called psychrometric chart as displayed on Figure 13.

Interaction between the mass of water vapor and the mass of dry air create the ratio called *humidity ratio*, can be expressed as;

$$W = \frac{M_w}{M_{da}} \tag{3}$$

Meanwhile, ratio of the mass of water vapor to the sum of mass of dry air and water vapor named *specific humidity*, which formulated as;

$$\gamma = \frac{M_w}{M_{da} + M_w} \tag{4}$$

Ratio of the mass of water vapor and the total sample volume is the *absolute humidity*, and has mathematical equation;

[11] The occupants of a building experience acute health- or comfort-related effects that seem to be linked directly to the time spent in the building

[12] The atmospheric air without water vapor

[13] The mixture of dry air and water vapor

$$d_v = \frac{M_w}{V} \tag{5}$$

The ratio of total mass and total volume is the *density* of moist air mixture, with the empiric equation;

$$\rho = \frac{M_{da} + M_w}{V} \tag{6}$$

The ratio of the mole fraction of water vapor in the moist air sample and mole fraction in an air sample saturated at the same pressure and temperature called *relative humidity*, expresses as;

$$\phi = \frac{X_w}{X_{ws}} \tag{7}$$

The chart is very helpful to set the heating or cooling devices in order to make indoor climate in the building feel comfort. Naturally, while air temperature decreases, the capability to hold the moisture are decreases as well, but the density of warmer air increases and vice versa. This condition possible to reach humidity level lower until below 30% or conversely above 70% which is will slowly damage occupants' health and building structure. By using the chart, it can be calculated to determine the values of those various components to achieve normal margin of humidity as well as temperature and so forth.

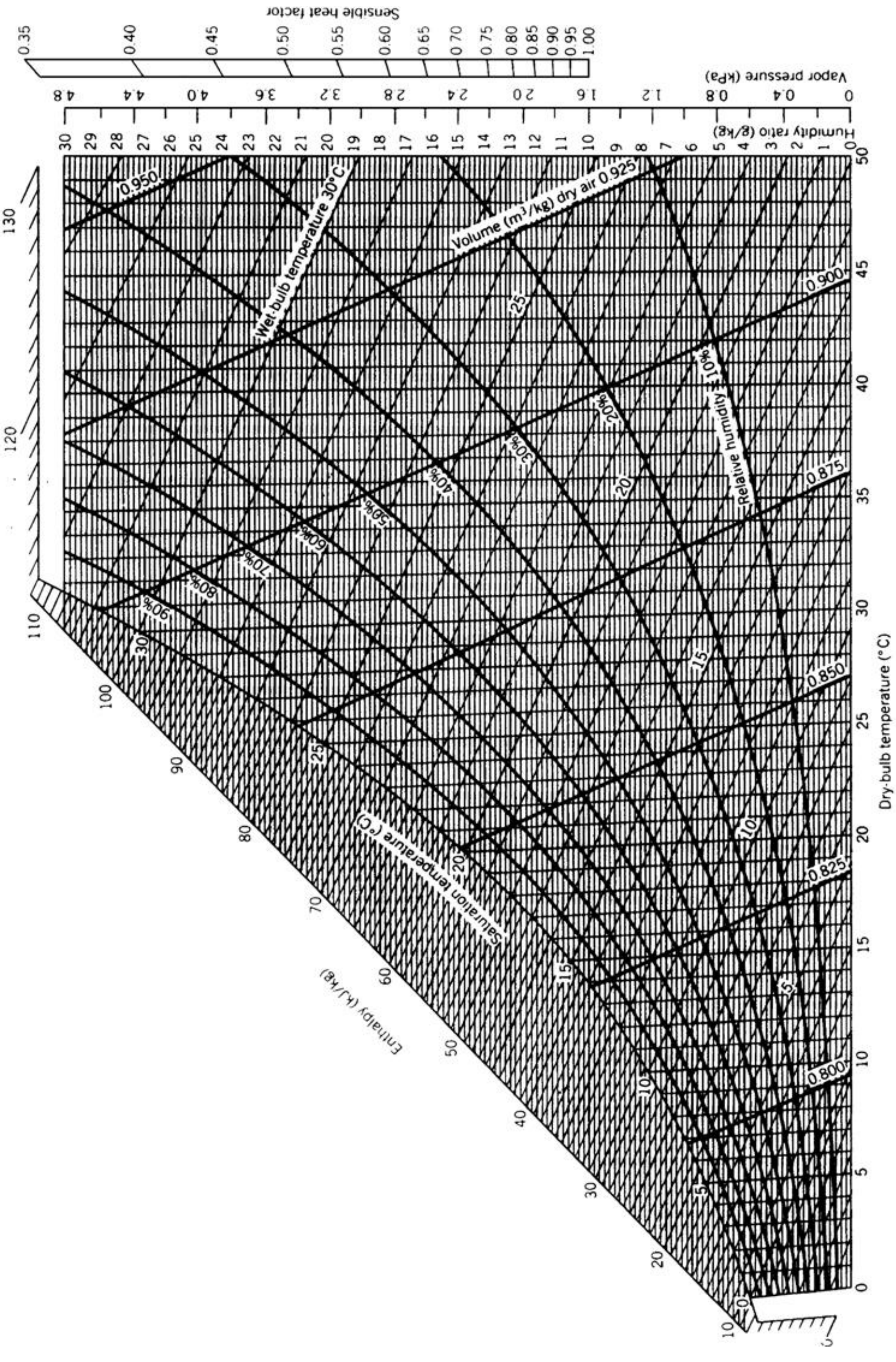

Figure 13 Psychrometry Chart [8]

The process variation methods that can be done from given conditions to reach interior climate comfort zone for human based on psychrometric chart shown in figure 15.

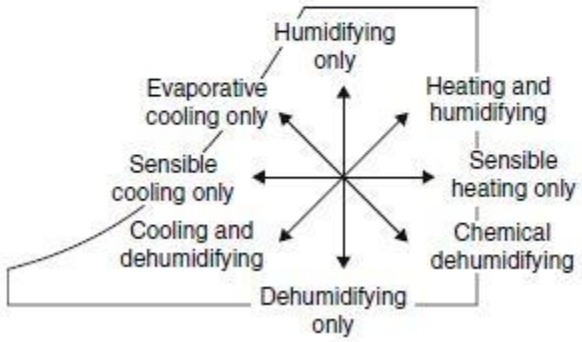

Figure 14 Various Interior Conditioning Processes [9]

In tropical hot-humid countries like Indonesia, the recommended ranges of ambient exterior air temperature and humidity inside building supported from natural vent hole, as seen on chart in figure 13.

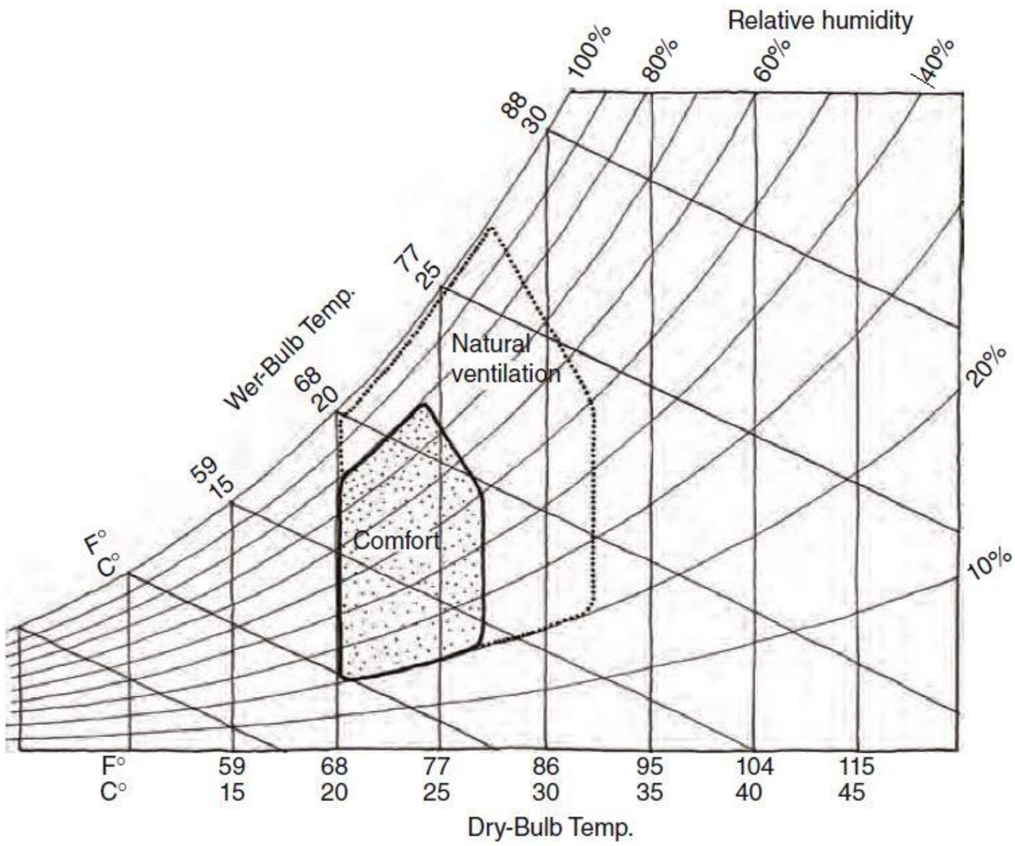

Figure 15 Recommended Comfort Zones in Hot Countries [9]

1.6.2 Air Quality Standard

The definition from ASHRAE Standard 62.1, 2013 stated "*indoor air quality is air in which there are no known contaminants at harmful concentration as determined by cognizant authorities and with which a substantial majority (80% or more) of the people exposed do not express dissatisfaction*."[10]

Air quality surround the building effect to the quality of interior climate. As the open air contains many elements, some of the elements could degrade the air quality inside building. Two parameters, the health criterion and comfort satisfaction come up the variables to attain admissible IAQ, they are;

1. Anticipate sufficiently fresh air supply and the circulation system
2. Filtering pollution by the selection of instrumentations and materials
3. Keep the building's elements and the instruments inside hygiene
4. Quarantine the inevitable pollution source

To estimate circulation system, it is important to concern about the air ventilation rate and the exhaust air. There is a formula to determine the ventilation rate;[3]

$$Q = 10\frac{G}{C_i - C_0} \quad (8)$$

where

Q = ventilation rate (L/s)

G = total pollution source (olf)[14]

C_i = perceived indoor air quality (decipol)[15]

C_0 = perceived outdoor air quality (decipol)

Alternately, for residential building it can be looked at the table for recommended ventilation rate as provided in Table 15

[14] Unit of pollution

[15] Unit of perceived air quality

Table 15 Recommended Ventilation and Exhaust Air Necessity [10]

Part A: Ventilation Air cfm (L/s)					
Floor Area ft² (m²)	1 Bedroom	2 Bedrooms	3 Bedrooms	4 Bedrooms	5 Bedrooms
<500 (<47)	30 (14)	38 (18)	45 (21)	53 (25)	60 (28)
501–1000 (47–93)	45 (21)	53 (24)	60 (28)	68 (31)	75 (35)
1001–1500 (93–139)	60 (28)	68 (31)	75 (35)	83 (38)	90 (42)
1501–2000 (140–186)	75 (35)	83 (38)	90 (42)	98 (45)	105 (49)
2001–2500 (186–232)	90 (42)	98 (45)	105 (49)	113 (52)	120 (56)
2501–3000 (232–279)	105 (50)	113 (52)	120 (56)	128 (59)	135 (63)
3001–3500 (279–325)	120 (56)	128 (59)	135 (63)	143 (66)	150 (70)
3501–4000 (325–372)	135 (63)	143 (66)	150 (70)	158 (73)	165 (77)
4001–4500 (372–418)	150 (70)	158 (73)	165 (77)	173 (80)	180 (84)
4501–5000 (418–465)	165 (77)	173 (80)	180 (84)	188 (87)	195 (91)
Part B: Exhaust Air					
If *continuous*—local ventilation exhaust air flow rates:					
Kitchen: 5 air changes per hour (based upon kitchen volume)					
Bathroom: 20 cfm [10 L/s]					
If *intermittent*—local ventilation exhaust air flow rates:					
Kitchen: 100 cfm (50 L/s) (vented range hood required if exhaust fan flow rate is less than 5 kitchen air changes per hour)					
Bathroom: 50 cfm (25 L/s)					

Controlling good IAQ level by way of low cost may achieve with manage some important sections in the building such as:

- *Skylights and Windows:* positioning the skylights and windows on the right location is important. For cooling purpose it is important to know the direction of wind come from and across the windows. And for heating purpose the sunlight direction source is important through the skylights.
- *Under-slab ventilation:* between the floor and the foundation below ground should have space for air circulating in order to keep the floor not too hot or too chill.
- *Stack ventilation:* to move air out and onto the building by chanelling it especially for hot condition. Since the hot air usually rises, the stack mostly happen in ceiling, therefore the best channel location is on the roof.

Outdoor air quality surrounding the building is another thing to be dealt as well. By making the boundaries from the pollutant could be the solution of approaching good air quality. In daily practical, for example in general is the hospital or medical clinic it used to be creating hygiene zone and the non-hygiene zone.

Environmental Protection Agency in U.S has the national outdoor air quality standards as seen on Table 16.

Table 16 Ambient Outdoor Air Quality Standards [11]

	Long-Term Concentration Averaging			Short-Term Concentration Averaging		
Contaminant	μg/m³	ppm		μg/m³	ppm	
Sulfur dioxide	80	0.03	1 year	365	0.14	24 hours
Total particulate	75[a]	—	1 year	260	—	24 hours
Carbon monoxide				40,000	35	1 hour
Carbon monoxide				10,000	9	8 hours
Oxidants (Ozone)				235[b]	0.12[b]	1 hour
Nitrogen dioxide	100	0.055	1 year			
Lead	1.5	—	3 months[c]			

1.6.3 Air Pollutant

Types of air pollutant inside the building divided into two kinds; (1) the kind of effects (toxic substances, irritants, and odors) and (2) the kind of contaminants (micro organics, microscopic particulates, and gaseous).[3]

- *Toxic substance:* vinyl floor and asbestos cement are very hazardous, must be well isolated. The others could came up from stove, tobacco smoke, kerosene, etc.
- *Soil gases:* Radon[16], could cause lung cancer if inhaled by human. Others are pesticides and methane gas.
- *Odours:* sensitive to people, felt strong at beginning then fading slowly
- *Biological contaminant:* viruses, bacteria, insect, fungi, etc could create allergic diseases.
- *Irritants:* insensitive for people but possible come up to suffered from time to time, symptoms are couching, sneezing, sore throat, dry nose, and chest tightness

[16] Radioactive gas that decays rapidly, colorless, odorless, tasteless

Table 17 General Air Pollutants [12]

Pollutant	Sources	Effects	Control Strategies
Excess moisture[a]	Cooking (heating open liquids), washing, exhaling	Increases growth of fungi, bacteria, and dust mites	Exhaust ventilation at source; dehumidification
Carbon dioxide (CO_2)	Human respiration	Minor discomfort at high concentrations; "stuffiness"	CO_2 is a good indicator of the ventilation rate in tightly enclosed spaces or where occupancy is high
Carbon monoxide (CO)	Incomplete combustion: furnaces, stoves, fireplaces; motor vehicle exhaust	Headaches, dizziness, sleepiness, muscle weakness, potentially lethal	Sealed combustion burners, adequate combustion air, safe exhaust flues
Nitrogen oxides	High-temperature combustion	Irritation, possible immune suppression	Safe exhaust flues, sealed combustion burners
Sulfur oxides	Combustion fuels containing sulfur (oil, coal)	Potential irritant, burning eyes, reduces lung function	Alternative fuels, safe exhaust flues, sealed combustion burners
Polynuclear aromatic hydrocarbons	Smoking, combustion of wood or coal, barbecuing, burnt food	Irritants and carcinogens	Prohibit smoking, lower temperature in cooking, use clean fuels, burn wood in enclosed firebox with adequate oxygen supply
Ozone	Laser printers, photocopiers, small motors, electronic air cleaners	Inflammation of bronchia, wheezing and shortness of breath, dizziness, asthma attacks	Remove sources or exhaust at source, maintain electronic air cleaners
Volatile organic compounds (VOCs) Formaldehyde	Particle board, interior laminated panels, glues, fabric treatments, paints	Burning eyes and nose, skin rash, shortness of breath, headaches, nausea, dizziness, fatigue	Use alternative materials, seal particle board if used, ventilate
Others	Paints, solvents, carpets, soft plastics, adhesives, caulkings, softwoods, paper products, cleaning and maintenance products	Intoxication, burning eyes and nose, shortness of breath, headaches, nausea, dizziness, loss of judgment, panic	Use alternative materials, age materials before installing, ventilate
Lead	Pre-1970s paint, pre-1985 pipes and solder, dust and soil near roads (residue from leaded gas)	Neurotoxic, especially if ingested by young children; learning disabilities, nausea, trembling, numbness of extremities	Identify and remove or seal old paint, replace pipes and solder, avoid foods grown by roadside
Pesticide residues[b]	Treated basements and foundations, treated ceiling and wall cavities, treated cabinets and closets, treated soil outside foundation	Neurotoxic or long-term risk of liver, kidney, and other diseases, including cancers	Identification and removal by expert if history known, sealing in pesticide if possible
Asbestos fiber	Pre-1975 steam pipe and duct insulation, furnace and furnace parts, pre-1980 reinforced vinyl floor tile, and fiber cement shingles and siding	Long-term cancer risk from inhaling fibers	Leave material undisturbed, get expert identification and removal if required, seal with special sealant and cover with sheet metal if not crumbling
Mineral and glass fiber	Thermal insulation, pipe insulation, fire-resistant acoustic tile and fabrics	Potential irritant, burning eyes, itching skin, long-term risk of lung damage and cancer	Handle only with respirator and gloves, seal and enclose, do not disturb in place
Fungus particles, dust mites	Grow in basements, damp carpet, bedding, fabrics, walls and ceilings, closets	Very allergenic, burning eyes and nose, sneezing, skin rash, congestion, and shortness of breath	Keep surfaces dry and clean, cover bedding and upholstery with barrier cloth, ventilate, use borax treatments to retard fungus
Hazardous bacteria (e.g., Legionella)	Standing warm water, untreated hot tubs, air-conditioning drain pans, humidifier reservoirs	Severe respiratory illness, potentially lethal	Prevent standing water, clean and treat tubs and reservoirs
Radon gas	Natural radioactivity in soils	Increased lifetime lung cancer risk	Seal foundation and floor drains, ventilate subsoil
Methane and other soil gases	Decomposing garbage in landfills, leaking sewage lines, toxic waste	Possibly explosive or toxic, nuisance odors	Know site history before building, remove soil if necessary, seal foundation and floor drains, ventilate subsoil

1.6.4 Comfort Quality

Human comfort is the primary intent of the house building. The thermal comfort expresses pleasant feel with the ambient temperature and relative humidity based on the personal subjective assessment. Therefore, it could be have a different in term of level satisfaction between persons in the same interior environment condition.

In order to response his/her ambient climate (either too cold or to hot), people has the ability to adapt and tend to make effort as best as they could for making the body feel comfort. This nature behavior to react various conditions can be categorized in five groups based on Humpreys and Nicol, given in table 18.

Table 18 Adaptive Attitude to Thermal Comfort [13]

Response Category	Actions in Response to Cold	Actions in Response to Heat
Regulating the rate of internal heat generation	Increasing muscle tension and shivering	Reducing one's level of activity Drinking cold liquids (induces sweating) Drinking hot liquids (induces sweating) Eating less Adopting the siesta routine (matching activity to the thermal environment)
Regulating the rate of body heat loss	Vasoconstriction (reduces blood flow to the surface tissues) Curling or cuddling up (reduces exposed surface area) Adding some clothing	Vasodilation (increases blood flow to the surface tissues) Adopting an open posture (increases exposed surface area) Taking off some clothing
Regulating the thermal environment	Turning up the thermostat Lighting a fire Complaining to management (so that someone else will raise the temperature) Insulating a loft or wall cavities Improving windows or doors, weather-stripping	Turning on the air conditioner Switching on a fan Opening a window Shading a window from the sun
Selecting a different thermal environment	Finding a warmer spot (such as going to bed) Visiting a friend (with a warmer place) Visiting a heated public building Building a new home Emigrating: a long-term solution	Finding a cooler spot Visiting a friend (with a cooler place) Visiting a cooled public building (or going swimming) Building a new home Emigrating: a long-term solution
Modifying the body's physiological comfort conditions	Acclimatizing, letting the body and mind become more resistant to cold stress	Acclimatizing, letting the body and mind adjust so that heat is less stressful

The comfort could be brought around by three categories factors;

1. Environmental: air temperature, air motion, radiant temperature, humidity
2. Individual: clothing and metabolism
3. Psychological: light, sound, color, aroma, movement, texture

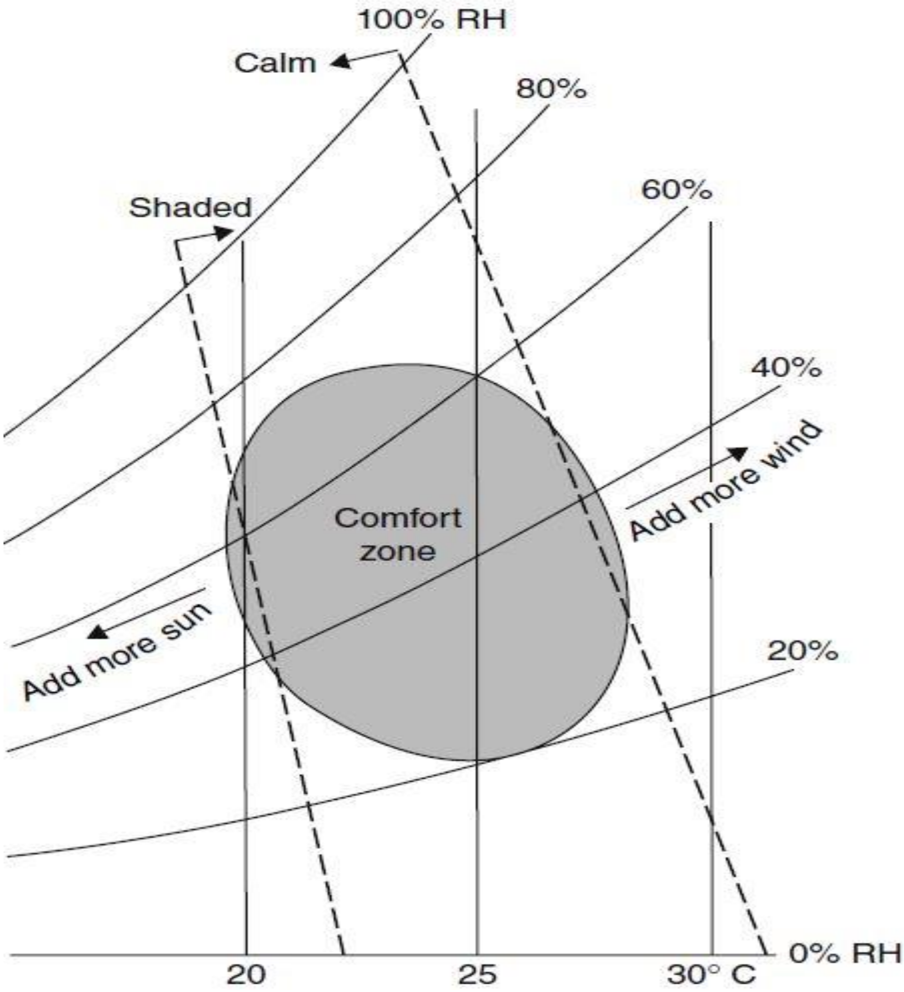

Figure 16 Thermal comfort area defined by environmentally [13]

Human produce heat and has units named metabolic (met). One met defined as the energy produced per unit of surface area from a seated person at rest, the value equals to 58.2 W/m^2. Average normal person (with 1.8 m^2 surface area) will produce around 106 W heat when seated at rest.

The formula to determine metabolic rating is given by:

$$M = \frac{21\ (0.23RQ+0.77)Q_{O_2}}{A_D} \tag{9}$$

where:

M = metabolic rate, W/m^2

RQ = molar ratio of CO_2 exhaled to O_2 inhaled, dimensionless

Q_{O_2} = volumetric rate of oxygen consumption at conditions of 0°C, 101.3kPa, mL

ASHRAE Standard 55 (Thermal Environmental Conditions for Human Occupancy) issues a table regarding the rating of human metabolism with typical activities as displayed on Table 19.

Table 19 Metabolic Rating [14]

Activity	met units[b]	Btu/h ft²	W/m²
Resting			
Sleeping	0.7	13	40
Reclining	0.8	15	45
Seated, quiet	1.0	18	60
Standing, relaxed	1.2	22	70
Walking (on the level)			
2 mph (0.9 m/s)	2.0	37	115
3 mph (1.2 m/s)	2.6	48	150
4 mph (1.8 m/s)	3.8	70	220
Office activities			
Reading, seated	1.0	18	60
Writing	1.0	18	60
Typing	1.1	20	65
Filing, seated	1.2	22	70
Filing, standing	1.4	26	80
Walking about	1.7	31	100
Lifting, packing	2.1	39	120
Driving/flying			
Car	1.0–2.0	18–37	60–115
Aircraft, routine	1.2	22	70
Aircraft, instrument landing	1.8	33	105
Aircraft, combat	2.4	44	140
Heavy vehicle	3.2	59	185
Miscellaneous occupational activities			
Cooking	1.6–2.0	29–37	95–115
Housecleaning	2.0–3.4	37–63	115–200
Seated, heavy limb movement	2.2	41	130
Handling 110-lb (50-kg) bags	4.0	74	235
Pick and shovel work	4.0–4.8	74–88	235–280
Machine work			
Sawing (table saw)	1.8	33	105
Light (electrical industry)	2.0–2.4	37–44	115–140
Heavy	4.0	74	235
Miscellaneous leisure activities			
Dancing, social	2.4–4.4	44–81	140–255
Calisthenics/exercise	3.0–4.0	55–74	175–235
Tennis, singles	3.6–4.0	66–74	210–270
Basketball	5.0–7.6	90–140	290–440
Wrestling, competitive	7.0–8.7	130–160	410–505

ASHRAE define the parameters of comfort zone of 80% resident plausibility for air speed maximum 0.2 m/s, tolerable operative temperature and the relative humidity margin, with wearing common clothing (around 0.5-1.0 clo) as well as major metabolism rating (1.0-1.3 met).

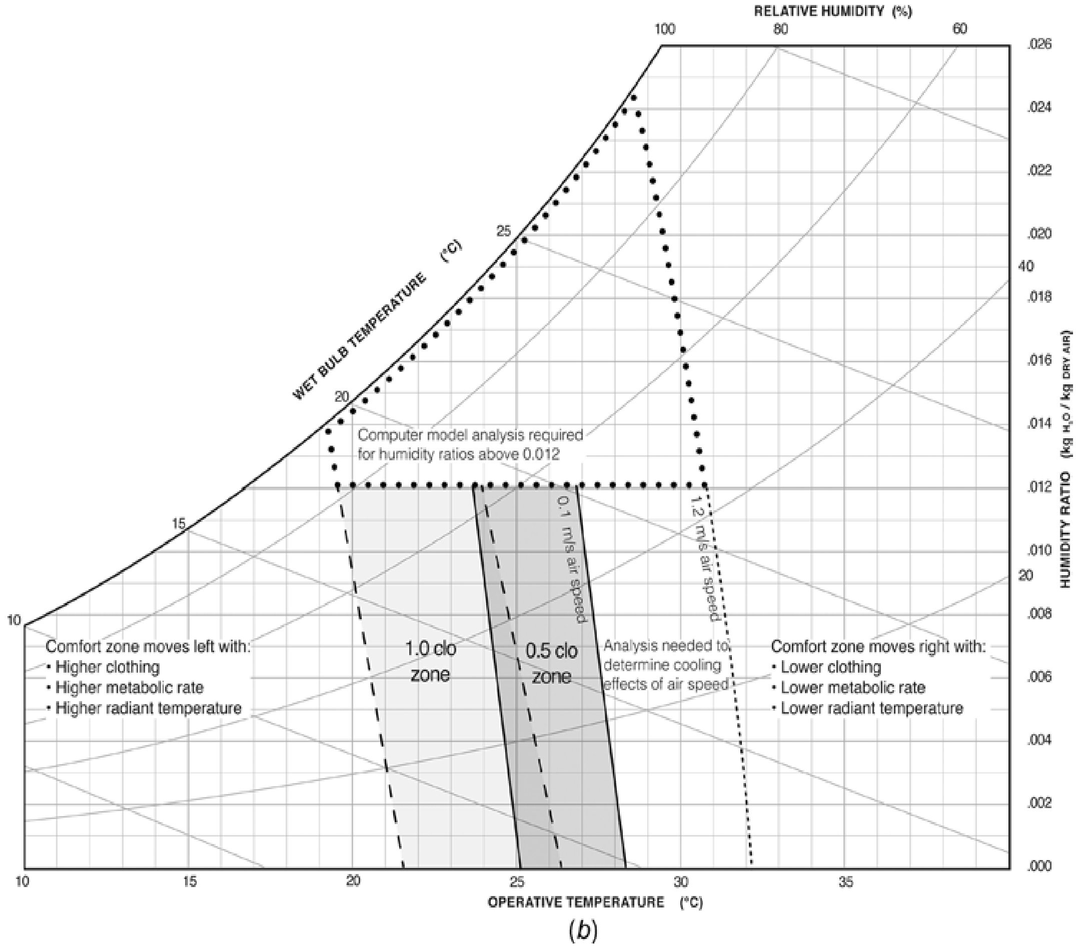

Figure 17 Thermal comfort area defined by ASHRAE [3]

.Level of thermal comfort can be assessed by several criteria:

1. *Predicted Mean Vote Index:* to measure medium value of large group of human sensastion, it could be reached from physical exertion and thermal resistance of clothing, include the air temperature, air velocity, humidity and the mean radiant temperature. The formula given by;

$$PMV = \left(0.303\, e^{-0.036M} + 0.028\right) \cdot L \tag{10}$$

where:

M = metabolic rate
L = thermal load

Thermal sensation level based on ASHRAE;

Table 20 Thermal sensation

Sensation	Value
Hot	+3
Warm	+2
Slightly warm	+1
Neutral	0
Slightly cool	-1
Cool	-2
Cold	-3

2. *Predicted Percentage of Dissatisfied Index:* to predict the quantitiy of thermal microclimate dissatisfaction's number of people, relate to health and mental condition include psychological side. The formula is;

$$\text{PPD} = 100\text{-}95\ e^{-0.03353\ PMV^4\ +0.2179 PMV^2} \qquad (11)$$

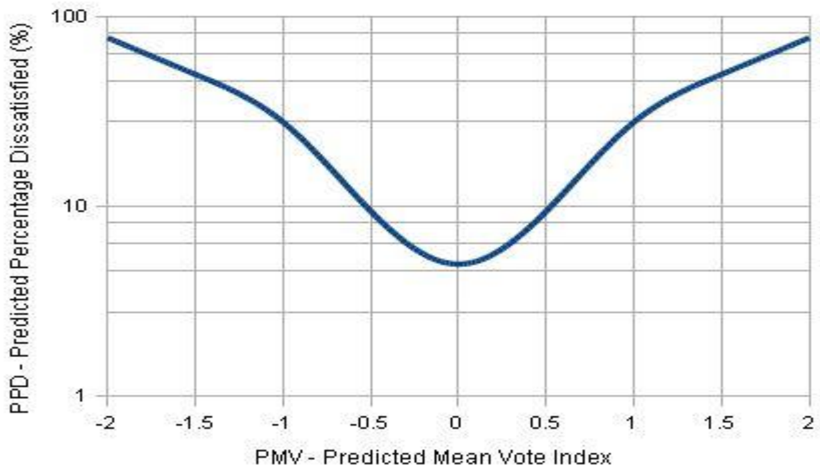

Figure 18 PPD index and PMV index relation [3]

Table 21 Comfort Categories Based on DIN ISO 7730 [15]

	Thermal condition of the occupant in total			Local discomfort PD [1] [%]		
Category	PPD [%]	PMV	DR [2] [%]	vertical temperature difference	warm or cold floor	asymmetric radiation
A	< 6	- 0.2 < PMV < + 0.2	< 10	< 3	< 10	< 5
B	< 10	- 0.5 < PMV < + 0.5	< 20	< 5	< 10	< 5
C	< 15	- 0.7 < PMV < + 0.7	< 30	< 10	< 15	< 10

[1] PD = percentage of dissatisfied concerning a single aspect
[2] DR = percentage of dissatisfied due to draughts

3. *Relative humidity:* to indicate the ratio between the amount of water vapour in the air and the air pressure at the same temperature. If it is too low (below 30%, will bring drying on the skin part), and if too high (over 70%, cause tightness feeling).

4. *Operative temperature:* average of ambient temperature and mean radiant temperature. The empiris equation given by:

$$\Theta_0 = \frac{h_c\,\Theta_a + h_r\,\Theta_r}{h_c + h_r} \quad (12)$$

where:

h_c = convection heat transfer coefficient

h_r = radiative heat transfer coefficient

Θ_a = air temperature

Θ_r = mean radiant temperature

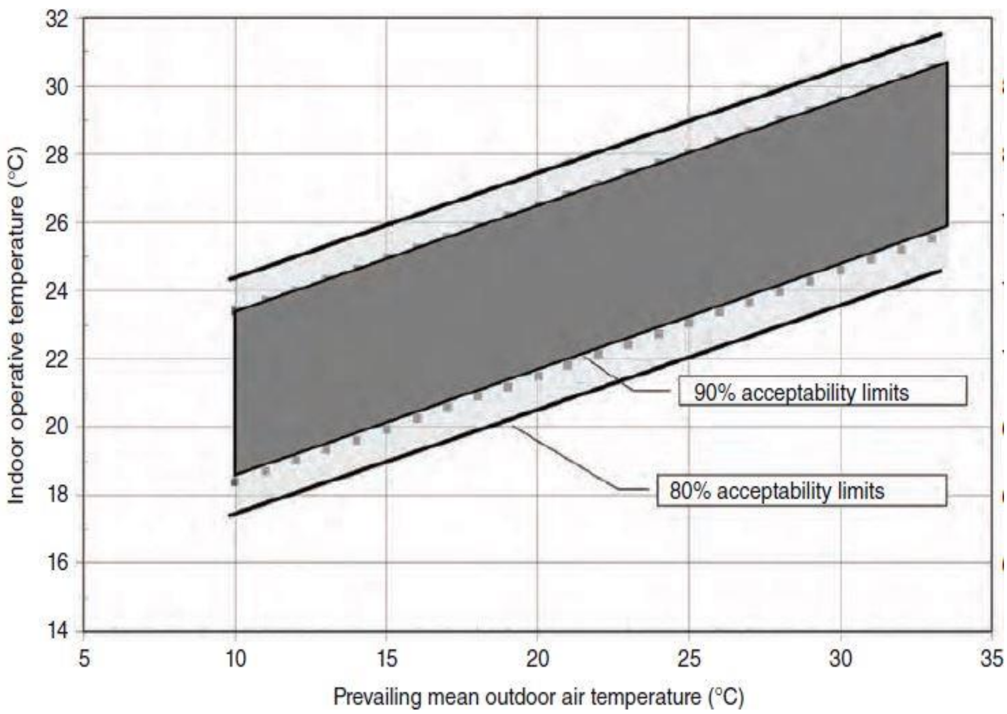

Figure 19 Admissible Operative Temperature [14]

5. *Mean radiant temperature:* amount of radiant heat temperature transfer from human body equal with the radiant transfer to actual nonuniform enclosure, the formula to calculate MRT;

6. *Air motion:* rate of the air velocity to the exposed body regard to location and time

Table 22 Air motion and comfort relation [16]

Air speed (m/s)	Temperature Comfort Sensation (°C)	Impact
0.25	No change	N/A
0.25-0.51	1.1-1.7 lower	cozy
0.51-1.02	2.2-2.8 lower	aware of air movement
1.02-1.52	2.8-3.9 lower	wind annoying
>1.52	>2.8-3.9 lower	health must secured

7. *Clothing* is the insulation tool for human body to be protected from direct radiation, conduction, or convection. Clothing is sized in clo units, one clo defined as 0.155 m^2K/W. A measure of one person's dress can be sum up by counting the clo value of each item. Table 13 provides clo values of clothing suits by ASHRAE Standard 55.

Table 23 Insulation Rating for Clothing Ensembles [14]

Ensemble Description[a]	clo[b]
Walking shorts, short-sleeve shirt	0.36
Trousers, short-sleeve shirt	0.57
Trousers, long-sleeve shirt	0.61
Same as above, plus suit jacket	0.96
Same as above, plus vest and T-shirt	1.14
Trousers, long-sleeve shirt, long-sleeve sweater, T-shirt	1.01
Same as above, plus suit jacket and long underwear bottoms	1.30
Sweatpants, sweatshirt	0.74
Long-sleeve pajama top, long pajama trousers, short 3/4-sleeve robe, slippers (no socks)	0.96
Knee-length skirt, short-sleeve shirt, pantyhose, sandals	0.54
Knee-length skirt, long-sleeve shirt, full slip, pantyhose	0.67
Knee-length skirt, long-sleeve shirt, half slip, pantyhose, long-sleeve sweater	1.10
Same as above; replace sweater with suit jacket	1.04
Ankle-length skirt, long-sleeve shirt, suit jacket, pantyhose	1.10
Long-sleeve coveralls, T-shirt	0.72
Overalls, long-sleeve shirt, T-shirt	0.89
Insulated coveralls, long-sleeve thermal underwear, long underwear bottoms	1.37

1.7 Mechanical Mode in IAQ

Most often this way is the active method by using electrical energy as the main supporter to run the equipment for heating and cooling include controlling humidity until reach the comfort sensation by the occupants. It is reduce the dependencies to the surrounding climate. Unlike the nonresidential building, house building usually not fully installed with these kinds of element in the whole part of the building.

The air tightness of the residential buildings (in this case is single family house buildings) are not as tight as in offices or other public buildings. Because it is not efficient to turn on the devices whole days in whole weeks, therefore the nature influences still take big part for comforting the occupants in certain time. In nonresidential buildings, these are only active when the buildings are occupied in particular time, other than that it must be shut down.

In order achieving (at least) good level of indoor climate quality without waste much energy and cost, the choosing the proper equipment are very crucial. Prior to the selection and installation, it is also important to survey the quantitative and qualitative parts of the building and occupants' needs of the condition which desired.

To help the engineers or designers making proper measurement and installment in residential buildings, some international standards already issued, one of them is ANSI/ASHRAE Standard 62.2 about *Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings.* Many of these mechanical products specifications in the market could be filter out and purchase the best matched for the building.

1.7.1 Exhaust Ventilations

Many typical of unwanted smell air like odor and so on circulate inside the building. Mainly in particular areas such as kitchen, bathrooms, and even in the bedrooms. Especially in the bathrooms, most case found are the exaggerated humid level, hence, exhaust fans most often are located in the bathrooms. Also, the kitchen is the place where contaminated with the by fume or smoke from the cooking process and the leftovers foods, Therefore, electric chimney as the part of integrated kitchen appliances or could be stand-alone exhaust fans installed in this area.

According to ASHRAE Standard 62.2, minimum capacity of exhaust fans is 50 L/s for kitchen and 25 L/s in the bathroom. It should be positioned close to the polluted source to avoid the pollutant spread out inside the building before it sucked by the fans.

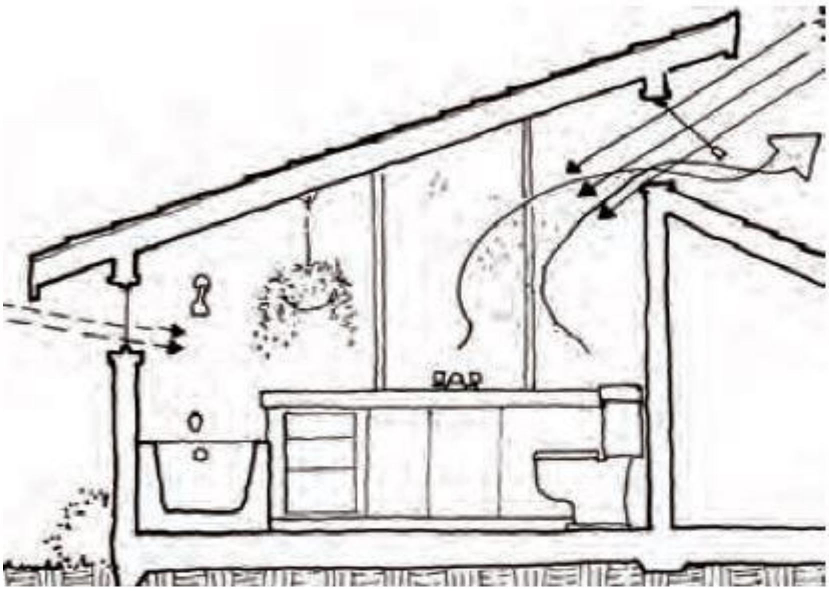

Figure 20 Exhaust Ventilation in Bathroom [3]

1.7.2 Humidifier & Dehumidifier

Hot temperature air has high humidity, escalate the friction between clothes and skin, intensify the skin sweatiness, and more difficult to evaporate. Low humidity create dry sensation and chill temperature, with the risk of skin irritation. Every 1°C temperature change impact the comfort feeling as 30% relative humidity change.

Humidifier[17] most often needs in winter season and dehumidifier[18] in summer season and in the tropical countries which are have hot temperature almost whole year. Nowadays, both of humidifier and dehumidifier are integrated in the cooling/heating systems as embedded devices, but there are also still available as stand-alone devices.

[17] A device which adds moisture to the air

[18] A device which removes moisture from the air

Over humidification has consequences condensation on the surfaces in the building especially windows, if the moisture spread out through all the structural components could be damage, mould, outside painting exfoliate, and wet insulation.

There are two typical humidifier common used in residential building, they are power humidifier[19] and bypass humidifier[20]. A bypass humidifier usually positioned on the furnace supply part in heating system, it uses the pressure differentiation between return air and supply air moving air.

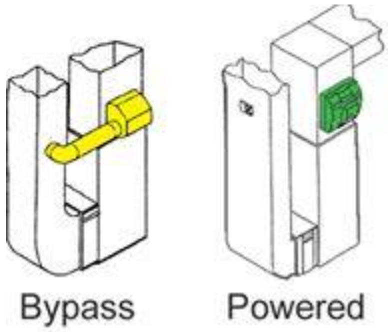

Figure 21 Bypass and Power Humidifier Attached on Duct

Dehumidifier could be classified into three groups based on the way they remove moisture from air;

1. absorption dehumidifiers: remove the moisture by using sorbent[21] material,
2. spray dehumidifiers: spraying the lower temperature air washer to ambient air
3. refrigeration dehumidifiers: extract the moisture from the air by passing over cooling coil

[19] Consists of an evaporator panel embedded to a small motor, a rotating device and a fan, no duct connection

[20] Consists of an evaporator panel embedded to a small motor and a rotating device

[21] Substance contains a cast number microscopic pores

Both humidifier and dehumidifier operation are controlled by a humidistat.

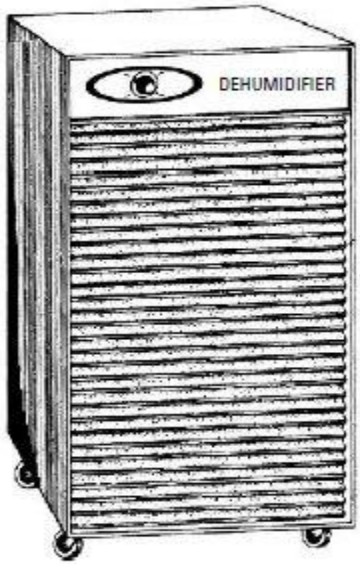

Figure 22 Electric Dehumidifier

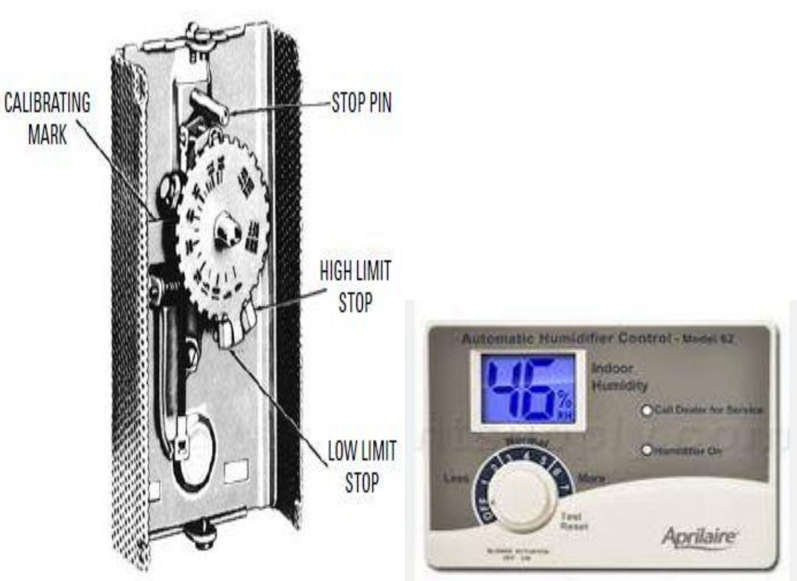

Figure 23 Humidistat Control

1.7.3 Air Filters and Cleaners

Small particle air pollution smudge the fabrics and furniture cause a respiration health damage. ASHRAE Standard 52.2 (Method of Testing General Ventilation Air Cleaning Devices for Removal Efficiency by Particle Size) has the filtration parameters evaluation of the air cleaning devices performance, they are: (1) ability to remove particles from air, (2) resistance to airflow, (3) capacity to hold dust and weight efficiency.

There are three air cleaner devices;[17]

1. Electronic Air Cleaner: approximately can remove 70% – 90% air pollutant. It could be mounted in cooling/heating systems (embedded on air handler, furnace, air conditioning, and at return grilles) or stand-alone unit.

2. Air washer: could be use to monitor bacterial growth and humidity, must be well maintained to avoid moisture threat.

3. Conventional air filters: common used in furnace to remove and trap air pollutant contaminants from air.

Table 24 Typical of Air Filter [18]

	Percent Efficiency Range			
Media and Type	**Atmospheric Dust**	**Small Particles**	**Dust-Holding Capacity**	**Airflow Resistance in. water (Pa)[a]**
Dry panel, throwaway	15–30	NA	Excellent	0.1–0.5 (25–125)
Viscous panel, throwaway	20–35	NA	Good	0.1–0.5 (25–125)
Dry panel, cleanable	15–20	NA	Superior	0.08–0.5 (20–125)
Viscous panel, cleanable	15–25	NA	Superior	0.08–0.5 (20–125)
Mat panel, renewable	10–90	0–60	Good to superior	0.15–1.0 (37–250)
Roll mat, renewable	10–90	0–55	Good to superior	0.15–0.65 (37–162)
Roll oil bath	15–25	NA	Superior	0.3–0.5 (75–125)
Close pleat mat panel	NA	85–95	Varies	0.4–1.0 (100–250)
High-efficiency particulate	NA	95–99.9	Varies	1.0–3.0 (250–745)
Membrane	NA	to 100	NA	NA
Electrostatic with mat	80–98	NA	Varies	0.15–1.25 (37–310)

1.7.4 Heat Exchanger

The heat exchanger[22] could preserve fresh air supply and control the air changes per hour (ACH), very effective in high tightness buildings type. Regard to the application, it has different size, shape and design. The common devices which use heat exchangers principal among others are cooling tower, boilers, regenerators, condensers, and radiators, it always equipped with fan.[19]

There are things must be alert in using heat exchangers;

- For cold temperature area, it needs the built-in defroster
- Keep away from exhaust air which contains pollutants and much moisture, to avoid fire
- Place the air fresh inlet far away from the exhaust air stream

The value of heat transferred while heat is exchanged between two fluids stream down along heat exchanger can be calculated as;

$$Q = U\ A\ \Delta t_m \tag{13}$$

where:

U = overall coefficient of heat transfer between fluid, W/m²K

A = heat transfer area of the heat exchanger, m²

Δt_m = log mean temperature difference, K

When the temperature difference is large (Δt_m), heat exchanger should able to manage the movement and forces in small surface area (A), but if the temperature difference is small, surface area should be big.

The types of heat exchangers that most often used are plate unit and counter flow shell-and-tube. The plate heat exchanger made from pairs of metal plate composed to accommodate different two flow streams. A counter flow shell-and-tube constructed with tube bundle and welded inside a tubular shell.

[22] A device to transfer energy between two fluids without mixing them.

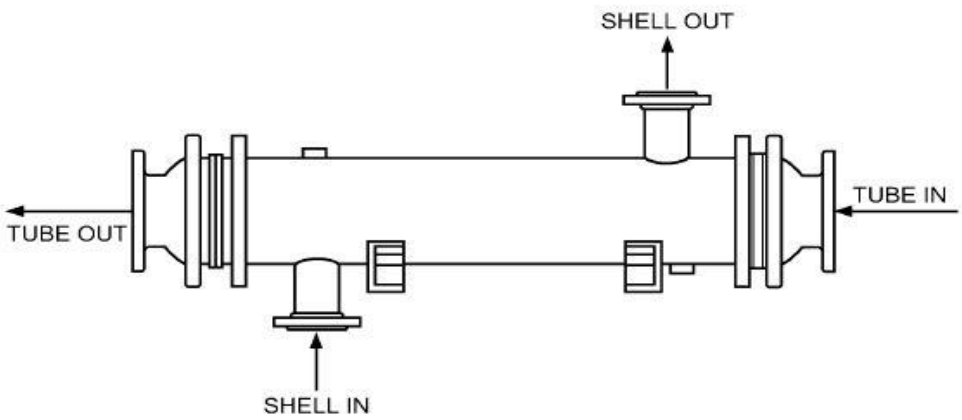

Figure 24 Shell and tube counter flow heat exchanger

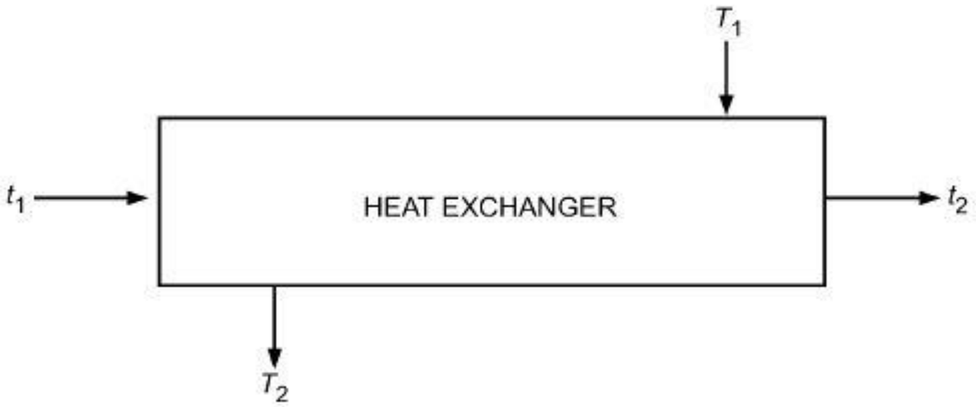

Figure 25 Temperature distribution of counter flow heat exchanger

$$Q = m\ c_p(t_1 - t_2) \tag{14}$$

where:

Q = quantity of energy

m = mass, kg

c_p= specific heat, J/kg °C

t_1 = temperature in, °C

t_2 = temperature out, °C

2 HVAC SYSTEMS

The HVAC term is common used to express the methods to control climatic condition inside the building. It is stand for Heating, Ventilation, and Air Conditioning. The simple description of heating is to escalate the temperature of anything, related to climate is air. Ventilation is the way to make air circulated. Air conditioning usually simply describe as to reduce the temperature of air.

Actually the air conditioning part means more complex, because it contains to make the condition of air to be in good condition, which is include the quality, humidity and the movement of air beside the temperature. Around the world, there are some places that need both heating and cooling systems, and some areas only need either heating or cooling system.

The determination of the HVAC system and its feasibility including all resolutions and executions should be taken simultaneously since the phases of predesign, design, construction, until tenancy of the project.

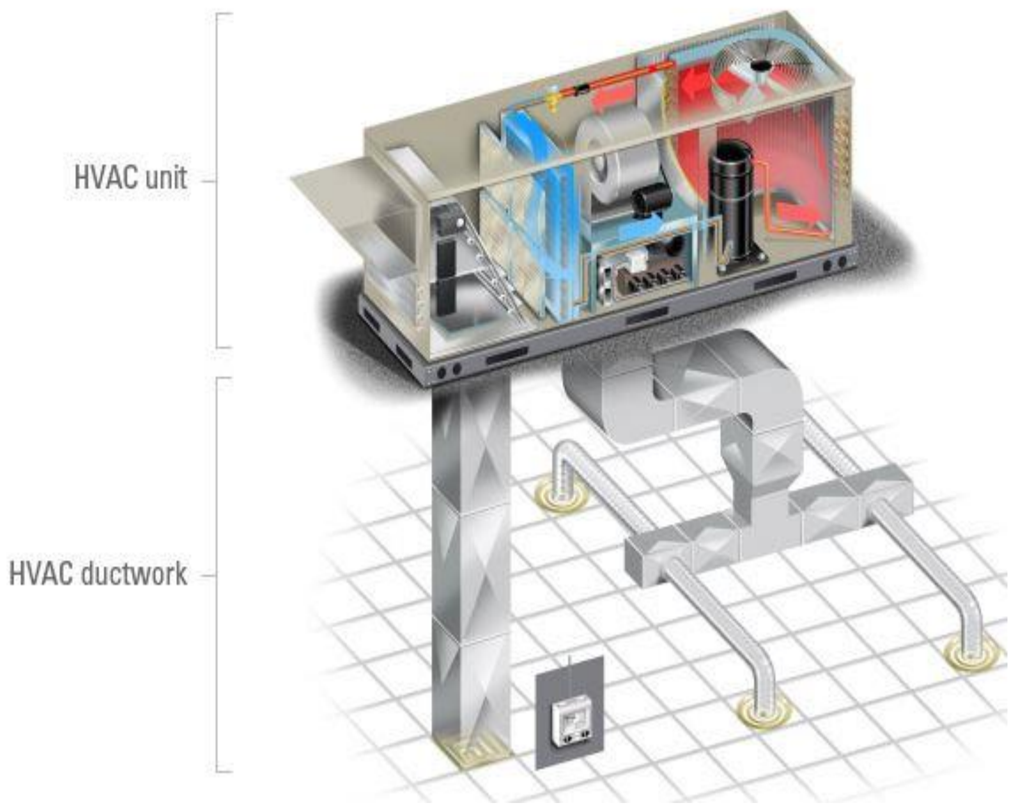

Figure 26 HVAC systems

2.1 Heating Systems

Main heat sources for the building heating systems commonly come from the fossil fuels e.g. oil, coal, and gas. For particular conditions, solar radiation and electricity are used to heat some zones inside building and also water service. Basically, heat lost flowing by radiation, evaporation and convection. Therefore, to obtain heat could be through those three ways.

Based on the functional component, the heating system could be specified in to three groups:

a) Source elements : producing the heat impact
b) Distrubution elements : circulating the heat impact to the conditioned zones
c) Control elements: monitoring and operating the whole functionality devices

The heat source type is important to be selected prior to design the system. Some concept ways to present heat into the building, such as;

- *Heat transfer* : by moving the heat to the spot that more needed, the application can be found on air-to-air heat exchanger and heat pump.
- *On site combustion* : by burning the fuel source on the spot area that need heat, the source could be firewood, oil, gas, coal, etc.
- *Energy capture*: by tapping the energy form and convert it to heat, solar energy is the common source for this approach
- *Electric resistance* : electrical current passing through the electrical resistance device and producing heat.

2.1.1 Heat Pump as Heating Source Equipment

Electric *heat pump* is the modern equipment generally used in high performance buildings. The principle being used is the reversible cycle, which means could be used as both heating and cooling purpose. In residential building, the capacity of heat commonly used is 10 kW and produce hot water up to 105 °C.

Heat pumps contain of two heat exchangers and a compressor. Indoor and outdoor heat exchangers produce sufficient heat transfer coefficient by using convection forced in the air. Usual problem appear in heat pump while in heating cycle is the frost accumulated at the external coil over the freezing temperature point. It can be solved by defrosting with defrost control equipped with sensor or timer.

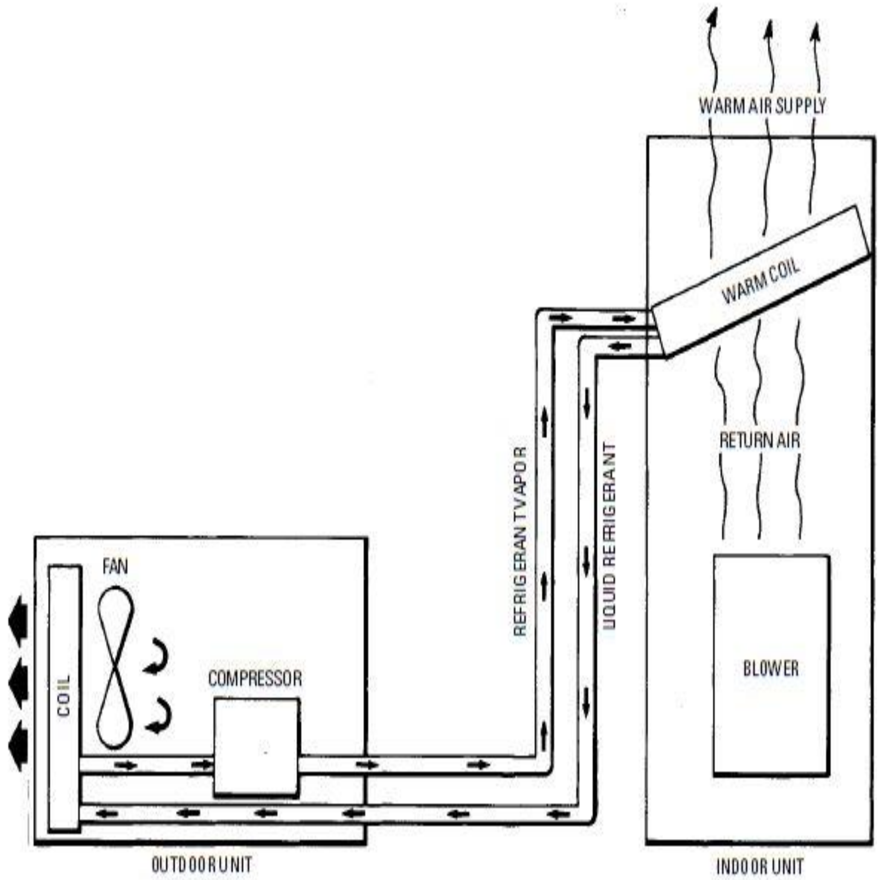

Figure 27 Heating Cycle in Heat Pump [17]

In generally, the performance of heat pump in heating can be compared to the ideal Carnot Coefficient of Performance (COP)[23]. The margin of low and high temperature reservoirs have reversely proportional. The fresh low pressure fluid leaves evaporator in point 2 ahead to the compressor to increase the temperature and pressure. As shown in figure 29, at point 3 the compressed fluid passing by the condenser to release heat to the ambience (warming the building). High pressure cool fluid exit the condenser at point 4 and through the expansion valve in order to decrease the pressure for entering back into the evaporator (point 1).

[23] Ratio of heat delivered and energy input

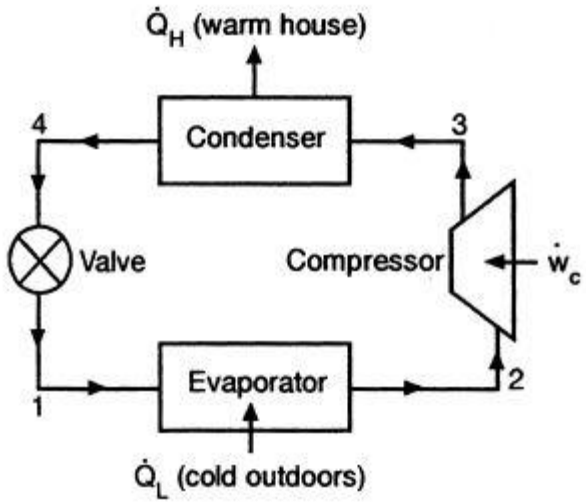

Figure 28 Thermodynamic cycle of heat pump in heating mode

The flows between point 1 and point 2 taken from the First Law of Thermodynamics;

$$e_2 + \frac{u_2{}^2}{2g} + \frac{gz_2}{g} + p_2v_2 = e_1 + \frac{u_1{}^2}{2g} + \frac{gz_1}{g} + p_1v_1 + \frac{\bar{Q} - \dot{w}}{\dot{m}} \qquad (18)$$

where:

$\dot{m}$ = mass flow of fluid, kg/s

$\bar{Q}$ = heat absorbed by fluid, kW

$\dot{w}$ = rate of work done on ambience, kW

v = specific volume of fluid, m^3/kg

p = pressure, N/m^2

As $e + pv = h$ called specific entalphy[24], equation 18 may simplified into;

$$\frac{1}{2g}(u_2{}^2 - u_1{}^2) + \frac{1}{g}(gz_2 - gz_1) + \Delta h_{2-1} = \frac{\bar{Q} - \dot{w}}{\dot{m}} \qquad (19)$$

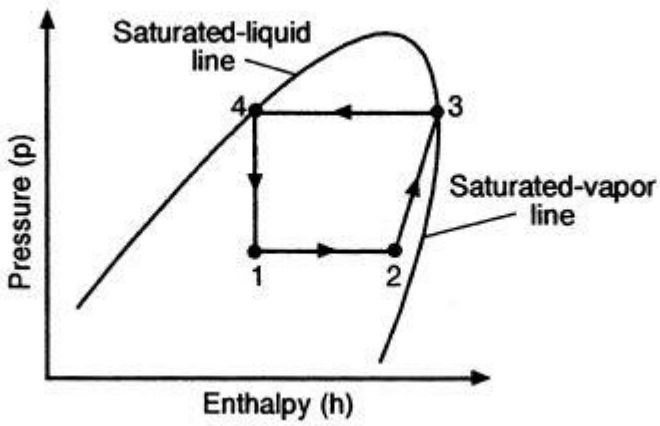

Figure 29 *p-h* diagram of heat pump in heating mode

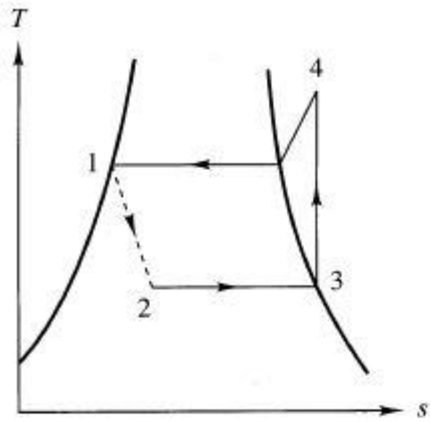

Figure 30 *T-s* diagram of heat pump

From figure 33 the temperature – entropy diagram, shown the process between point 1 and point 2 the fluid flashes into vapor and liquid through expansion valve, at point 2 to point 3 both liquid and vapor changed become all vapor in evaporator, then from point

---

[24] Total energy in a system due to pressure and temperature per unit of mass in the system

3 to point 4 the vapor compressed, from point 4 to point 1 vapor superheat removed and converted into liquid in the condenser.

The ideal heat pump cycle is expressed as:

$$\text{COP} = \frac{T_H}{T_H - T_L} \tag{20}$$

Hence, the real COP of heat pump is:

$$\text{COP} = \frac{1}{1 - \frac{T_L}{T_H}} \tag{21}$$

where:

T_H = high temperature

T_L = low temperature

The capacity of heat pumps vary from 10 kW to 15 MW. The smaller capacity commonly used in residential buildings and the large capacity generally in public or commercial buildings. This heating capacity and the electric input rate ratio usually measured from COP value with the conversion factor in 3.413 British Thermal Unit (Btu) per watt hour, commonly known as Energy Efficiency Ratio (EER). For each different season it has Seasonal Energy Efficiency Ratio (SEER) which is used in US similar as European Seasonal Energy Efficiency Ratio (ESEER) in Europe.

Based on the source of the heat pumps, there are several types, such as: air, water, gas fired, dual fuel (gas + air) and ground source. The air source (split system) type mostly used in residential building, it is located split at outdoor part and indoor part, connected with refrigerant tubing. The indoor part contains blower, filter and evaporator coil, meanwhile at the outdoor part has fan, compressor, and condenser coil.

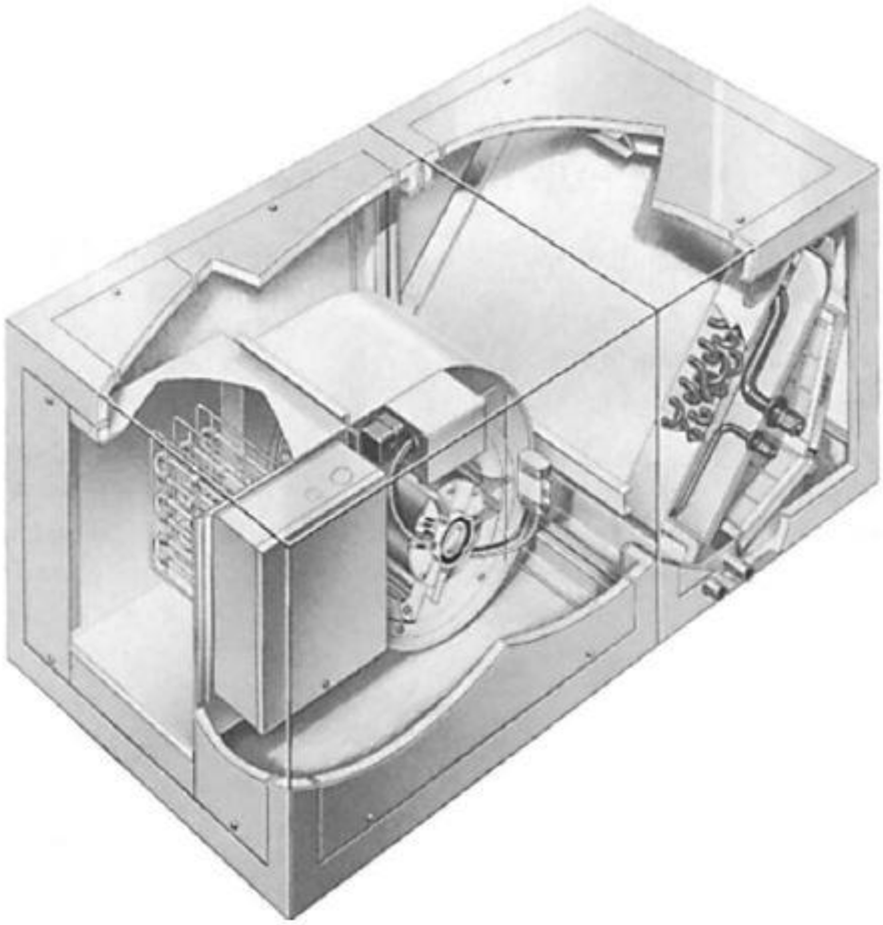

Figure 31 Indoor Heat Pump Unit [17]

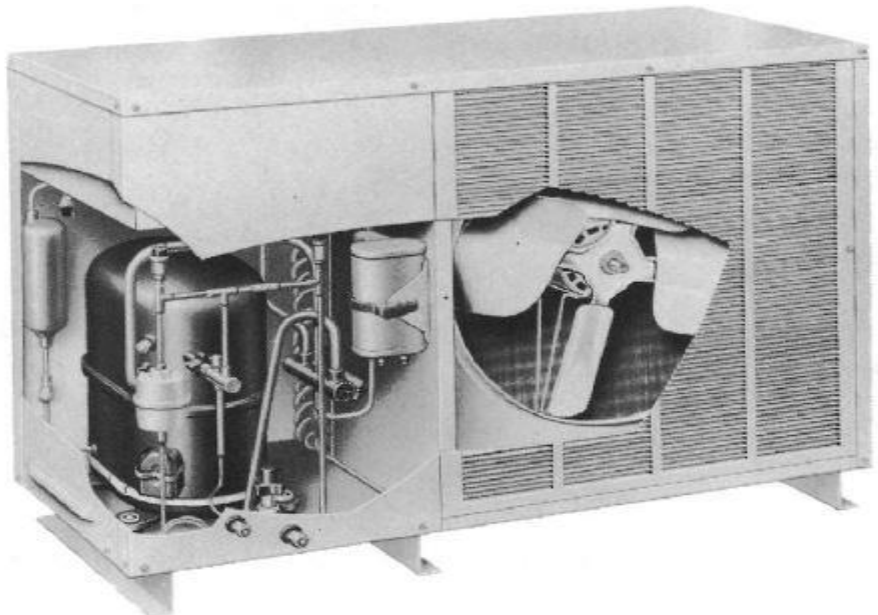

Figure 32 Outdoor Heat Pump Unit [17]

Another subtype of air source heat pump is the packaged system unit. All the components are inside one box and it located outdoor. It could be used with or without ductwork, for the single room heating or cooling purpose does not required ductwork.

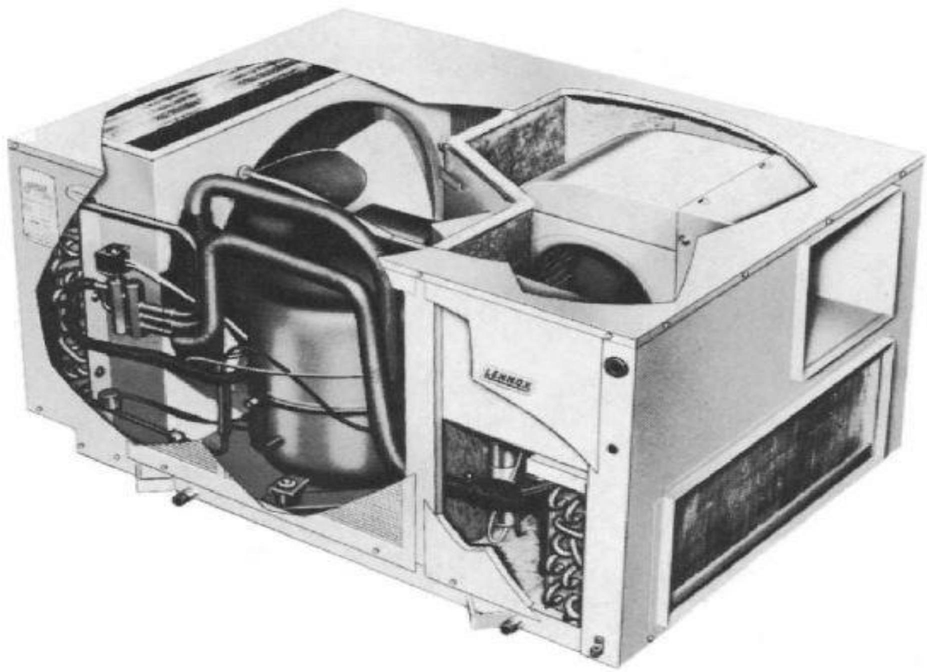

Figure 33 Packaged System Heat Pump Unit [17]

The water source type use the water as the source for heating and also as the heat sink. It has closed loop and open loop coupling systems. In open loop coupling system extract the water from the surrounding groundwater source by making the wells.

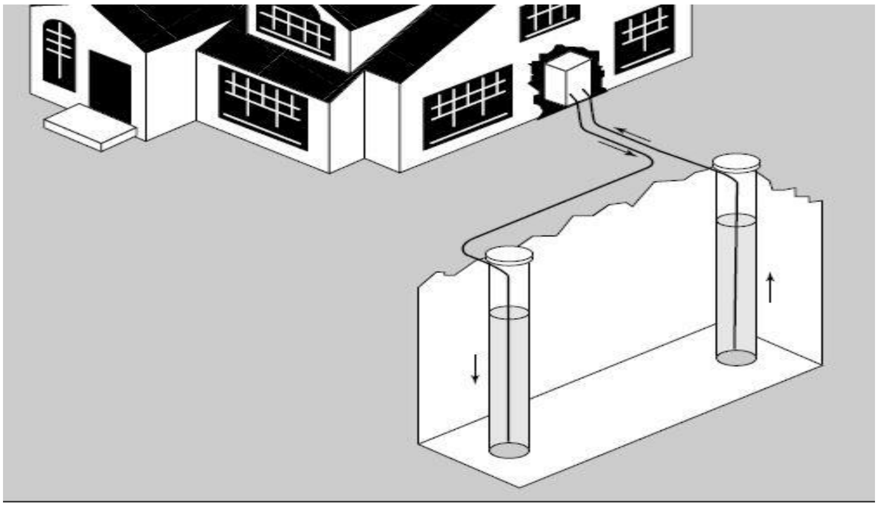

Figure 34 Open Loop Coupling System of Water Source Heat Pump [19]

For the closed loop coupling system, the water circulated in the pipes from the sources using compressor for pumping by separate coils in to refrigerant then to the heat exchanger (which heat transfer occurs) and come back to the water source.

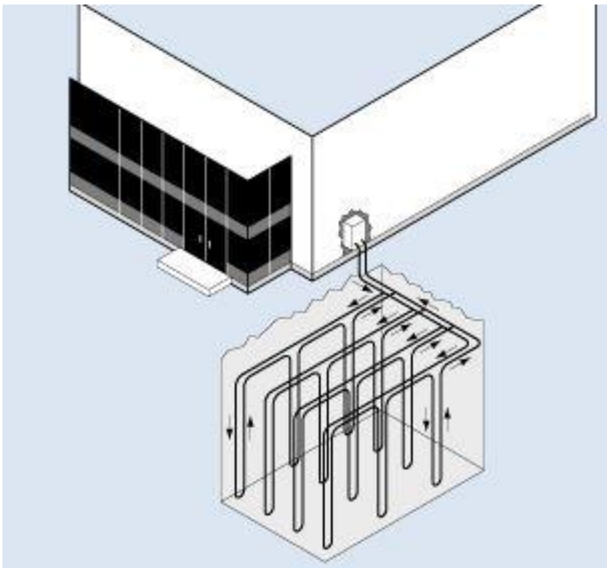

Figure 35 Closed Loop Coupling System of Water Source Heat Pump [19]

There are some good and weakness of the air and water heat pumps as shown in table 26; [19]

Table 25 Advantages & Disadvantages of Air and Water Source Heat Pump

Type	Advantages	Disadvantages
Air source	Indoor distribution permits air conditioning and humidity control Outdoor air source readily available Simple installation Least expensive Established commercial technology	Defrost required Low capacity at cold outdoor temperature Lower efficiency because of large evaporator $\Delta T \approx 30°F$ Indoor air distribution temperature must be high for comfort reasons Reliability at low temperature is only fair, due to frosting effects Must keep evaporator clear of leaves, dirt, etc.
Water source	Multiple family and commercial installation as central system In commercial installations, good coupling to cooling towers No refrigerant reversal needed; reverse water flow instead	Needs water source at useful temperature Efficiency penalty due to space heat exchanger ΔT

The ground source heat pump, commonly called as geothermal heat pump as well. It harness the constant temperature of the earth ground as the heat source and using closed loop ground coupling system. Loop's system design could be horizontal, vertical and spiral. Horizontal design is the most often used in residential single family house. The fluid flows pass through the outdoor coil and absorbs the heat and pumps out in to the interior building via the pipe located underground.

The geothermal heat pump is the most clean and energy efficient for heating/cooling residential building according to the U.S Environmental Protection Agency (EPA). It does not need defrost cycle[25] and has lower maintenance than other type of heat pump, but it requires large are to keep the piping loop and the initial high installation cost.[17]

[25] Heat pump is reversed at particular intervals and returned to the cooling cycle

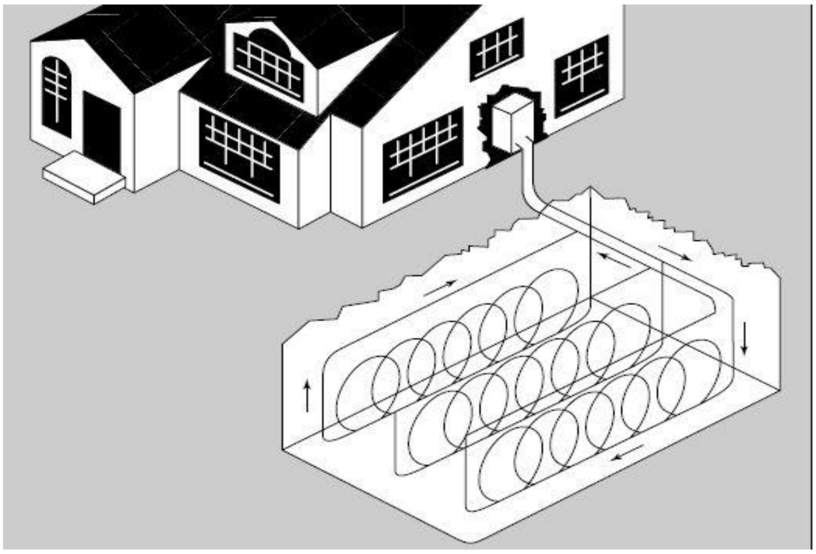

Figure 36 Ground (Geothermal) Source Heat Pump System [19]

Another types of heat pumps is gas fired heat pumps which has propane or natural gas engine as the source, the heat waste from the engine still be used for adding heat to the heat output or heating the domestic hot water.

Dual-fuel heat pump system that collaborate a gas furnace and air as the source of heat, the gas furnace consumes less energy than electric resistor heating and it backups heat pump if the exterior temperature extremely cold. The operation similar with the air-source heat pump.

The last type is dual-source heat pump that merge air-source heat pump and geo-thermal heat pump in one unit. It uses both ground and air for evaporating, with dual com-pressors for supplementary heat. The area of ground loop needed are far much smaller than the stand alone geothermal heat pump.

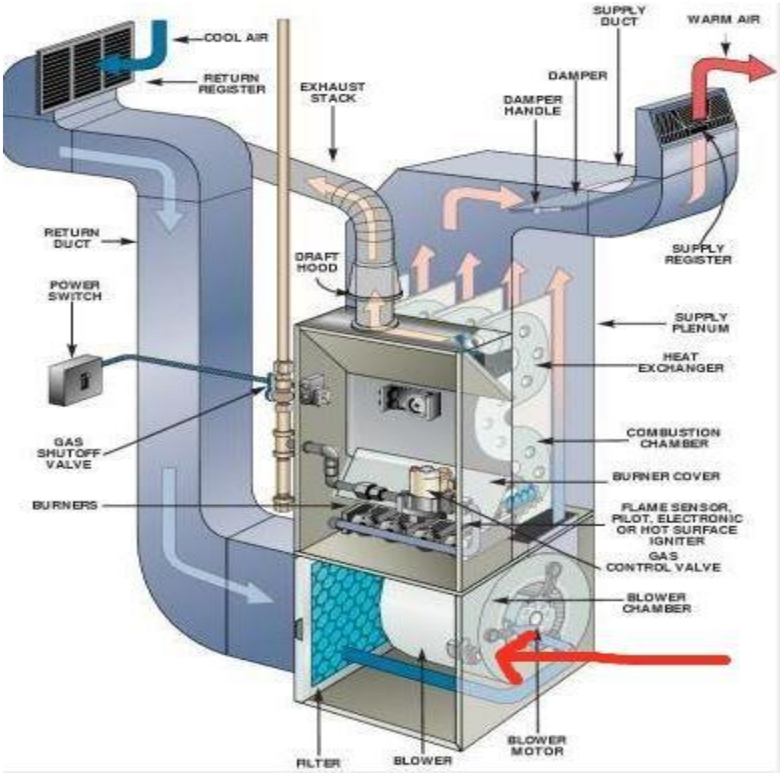

Figure 37 Dual-Fuel Heat Pump System [3]

Solar heating commonly used for elevating the domestic water temperature in mostly residential house within these days. It collects the solar energy using plate panel, and can effectively heat the water up to 50 - 60 °C. The water must be stored in the water tank to keep water warm, heat counter flows from panel to the tank in the loop system.

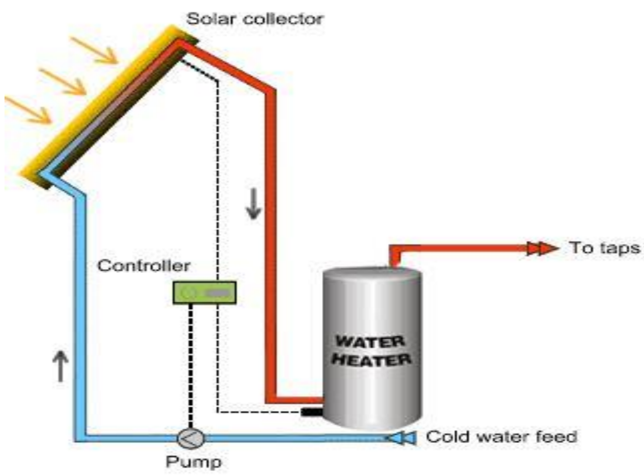

Figure 38 Solar Heating for Domestic Water System

2.2 Cooling Systems

For conditioning air an interior of a building, there are three fundamentally definitions based on how it works: (1) absorption refrigeration (2) evaporative cooling, and (3) vapor compression cycle. All the three definitions will help the designer or engineer to decide which equipment should be chosen.[3]

Absorption refrigeration commonly used to produce large amount of cool water. The circulation has a mechanical-electrical cycle with the chemical refrigerant flow controlled by heat, natural gas and solar hot water. Generally the equipment tend to be quite but it less efficient or lower COP.

The evaporative cooling straight to chill the water or to chill air using evaporative cooler as the equipment to produce coolness, has high energy efficient, and does not use any mechanical vapor compressor or refrigerant. The equipment mostly influenced by the surround climate, it simultaneously involved the mass and heat as with the water contact along open air.

Vapor compression cycle has the mechanical-electrical loop with a refrigerant circulated upon the temperature point can remove heat from the interior of the building to outside. This system needs condenser unit to reject heat from outside, and most of HVAC system using this way.

2.2.1 Cooling Source Equipment

Vapor compression refrigeration is the common device that used for cooling purpose, it has the refrigerant as the crucial material to cool. The gaseous refrigerant is compressed into the high pressure vapor and heat is extracted then condenses until becomes high pressure liquid refrigerant, after that it absorbs heat while passing through the expansion valve as well as the depressurized process till back to gaseous state. This cycle scheme illustrated in figure 39.

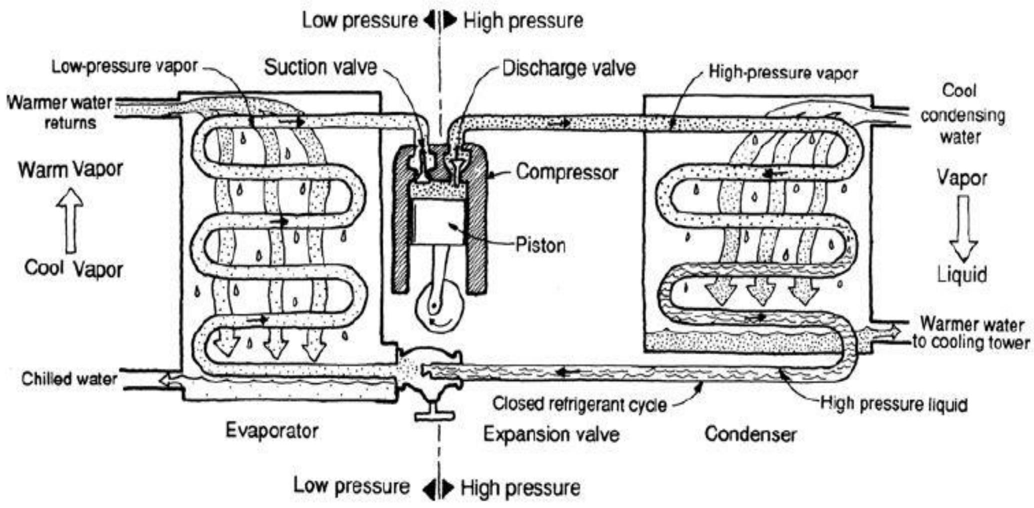

Figure 39 Vapor compression refrigeration cycle [17]

The use of heat pump for cooling purpose also use the refrigeration cycle principal, basically it removes heat from interior of the building to exterior. The refrigerant counter flows makes heat extraction at the interior part then has direction to outside building during condensation of the refrigerant.

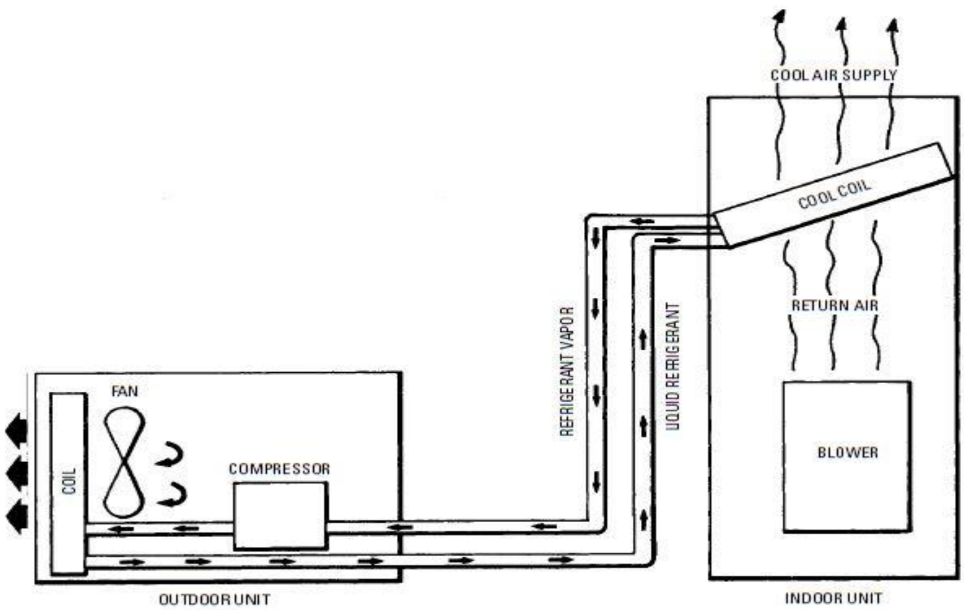

Figure 40 Cooling Cycle in Heat Pump [17]

Generally in residential building air to air heat pump unit is being used (air as the cool source), this unit removes the heat through refrigerant loop among indoor unit and outdoor unit, as shown in figure 41.

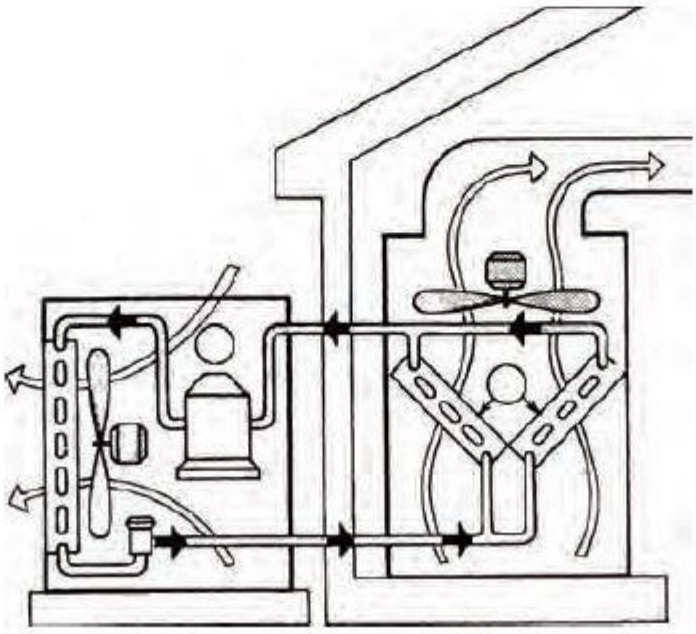

Figure 41 Air to Air Heat Pump Cooling System [3]

Major components of the mechanical cooling equipment contains five elements, such as: (1) compressor, (2) condenser, (3) receiver, (4) evaporator, and (5) refrigerant.

Compressor has the function mainly to compress refrigerant vapor becomes smaller volume at higher pressure so the refrigerant could stream down in the system. Some types of compressor are piston compressor, rotary compressor, centrifugal compressor, sealed compressor and scroll compressor. In residential buildings, it is common to use the piston compressor type (a piston inside cylinder is moving for compressing low pressure refrigerant).

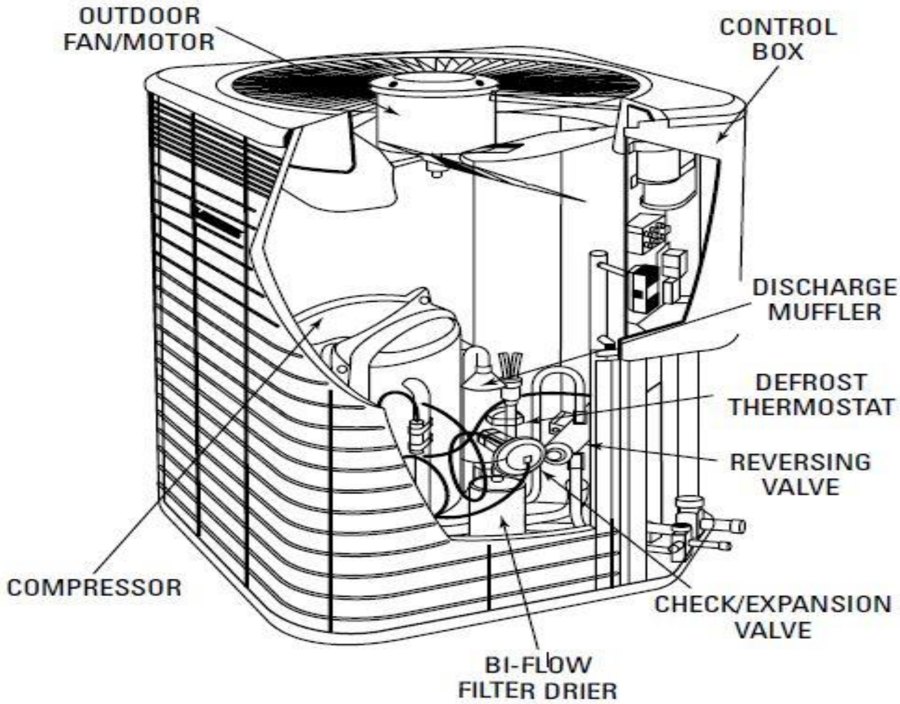

Figure 42 Piston Compressor Unit [17]

Condenser has the role for liquefying the gas through cooling, the refrigerant vapor from compressor enters the coil inside condenser afterward drain out to the receiver which placed at lower level. Based on cooling method there are three types condenser: water cooled, air-cooled, combined air and water cooled condenser.

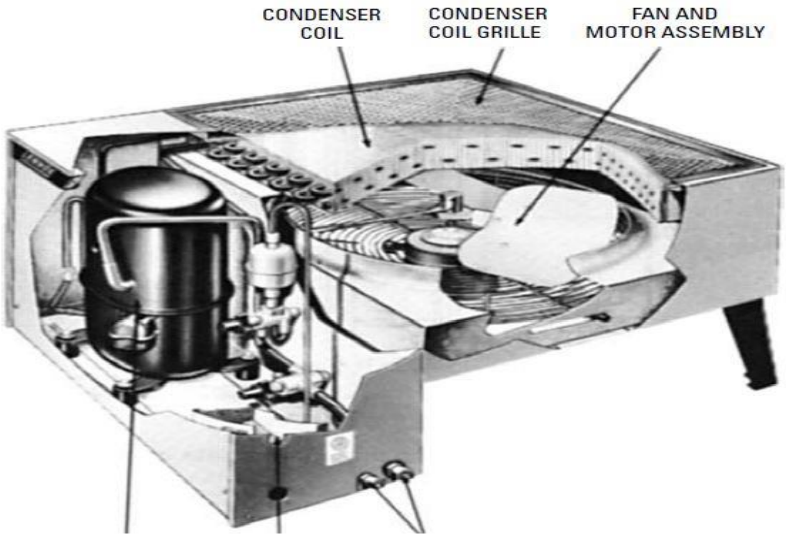

Figure 43 Condenser Unit [17]

Evaporator plays as the absorption and transfer of heat device from atmosphere air to refrigerant, then the refrigerant being evaporated while passing by the evaporator. In the market evaporator known as blower coil, expansion coil or cooling coil.

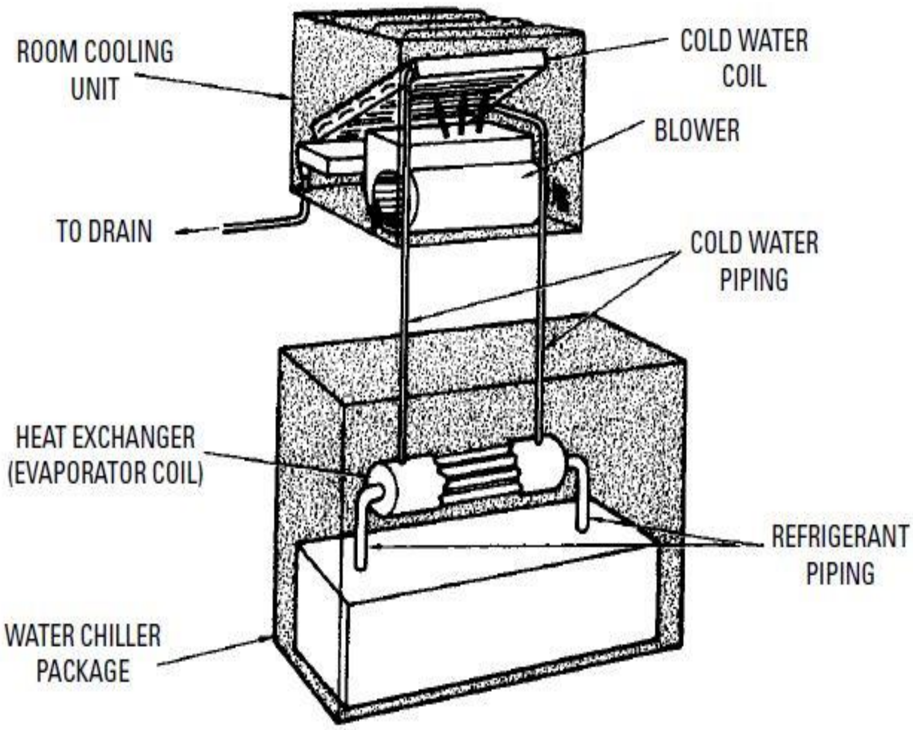

Figure 44 Evaporator Unit [19]

Refrigerant is the material which has contains physical, chemical, and thermodynamic properties that can efficiently safe absorbing the heat as it vaporizes or expands. Some properties of being a good refrigerant are: (1) non-toxic, (2) non-flammable, (3) not affected by moisture, (4) mixes safe with oil, (5) non-explosive, (6) low boiling point, and (7) high latent heat. [17]

2.3 Possibility Utilization of Renewable Energy Sources for HVAC

To keep achieve the green residential building label along with the level of inner comfortable condition for the occupants inside, resolution could be made by using ecofriendly energy resources which are sustainable and have low emission or even could be zero pollution.

Indonesia has several diversification potentially renewable energy resources that could be utilized for HVAC systems, such as: solar energy, geothermal energy, hydro, ocean wave and wind energy. As a tropical country, these nature resources are the blessing for Indonesia to realize green building label especially in cooling purpose as a part of mechanical HVAC systems.

The potential capacity and installed capacity of renewable energy resources in Indonesia shown in table 26.

Table 26 Potential and Installed Energy Resources in Indonesia (2013)[20]

NO	NEW & RENEWABLE ENERGY	RESOURCES	INSTALLED CAPACITY (IC)	RATIO OF IC/RESOURCES (%)
1	2	3	4	5 = 4/3
1	Hydro	75,000 MW	6,848.46 MW	9.13%
2	Geothermal	29,164 MW	1,341 MW	4.6 %
3	Biomass	49,810 MW	1,644.1 MW	3.3%
4	Solar	4.80 kWh/m²/day	27.23 MW	-
5	Wind	3 – 6 m/s	1.4 MW	-
6	Ocean	49 GW ***)	0.01 MW ****)	0%
7	Uranium	3,000 MW *)	30 MW **)	0%

Several attempts are being made to intensify the utilization of renewable energy resources in Indonesia, some of them are:

- Policy & regulation : making clear law and order about using energy amount
- Create the market : by supplying more renewable sources and limiting fossil source
- Incentives & facilities : by decrease taxes and custom duties for the non fossil energy consumed equipment
- Educate human resources : through the education institution mainly in public academic institutions improve the quality and quantity of it
- Financial support : by funding the program from ministry office to the renewable energy access in remote area
- Enchance research in the field of renewable energy : by multiply research cooperation with energy institution abroad

- Subsidy : national distribution energy company has subsidize the bio-fuel since 2009
- Feed in tariff : national electric company purchase electric generated from the renewable sources from the private sector with the fixed price

2.3.1 Requirements on HVAC Systems

For designing HVAC system in plan phase, it is important to determine and fulfill all the standard requirements and its necessity prior to installment of the equipment. In most common HVAC systems, following aspect involved;[19]

a. Space configuration
b. System specification
c. Sound criteria
d. Design parameter of exterior humidity and temperature
e. Interior air temperature and humidity based on standard comfort in ASHRAE Standard 55
f. Design sensitivity and latent loads in every conditioned zone as obtained from building load analysis result
g. Ventilation standard for good indoor air quality as regulated in ASHRAE Standard 62

2.4 Artificial Lighting Systems

Mostly electric energy consumption in building is used for the lighting systems. Based on IESNA, there are several systems of units used in lighting industries, such as:

- luminous intensity : with SI unit is candela (candle power, cp), indicates the force of the light which people could see
- luminous flux : SI unit is lumen (lm), indicates measurement of light power that feel by human eye
- illuminance : SI unit is lux which is equally to lumens per square meter area
- brightness : SI unit is candela (cd) per square meter area

Recommended values of illuminance visiblity are provided by IESNA Standard, it depends on visual task necessity. Since brightness is the product of reflectance and illuminance, it formulated as:

$$L = \frac{E \cdot RF}{\pi} \tag{22}$$

where:
L = brightness, cd/m^2
E = illuminance, lux
RF = reflection factor

Required brightness (luminance) according to IESNA Standard 90.1 categorized into five tasks type as shown in table 27.

Table 27 Brightness Category

Category of Visual Task	Required Luminance (cd/m^2)
Causal	10–20
Ordinary	20–100
Moderate	100–200
Difficult	200–400
Severe	Above 400

2.4.1 Energy Efficient Artificial Lighting System

To improve the efficiency of energy consumption of the lighting systems, some strategies can be done, for instances;

1. Decreasing the quantity of luminaries by delamping (remove the unecessary light fixtures at the location which produce bigger than required illumination.
2. Reducing the length of lighting use by install lighting control which is could be done automatically after setting up based on the occupancy sensing censor technology.
3. Limitating the wattage rating of the lighting source luminaries, can be done by choosing low watt lamp technology i.e. LED lamp.

The formula to calculate total electical energy used by lighting could be shown as:[19]

$$\text{Kwh} = \sum_{j=1}^{J} \text{N}_{Lumj} \,.\, \text{WR}_{Lumj} \,.\, \text{N}_{hj} \qquad (23)$$

where;
N_{Lumj} = number of lighting luminaries of type j
WR_{Lumj} = wattage rating of each luminaries of type j
N_{hj} = number of hours per year when the luminaries of type j operating
J = number of luminaire types of the building

2.4.2 Artificial Lighting Design Quality

The aim of artificial lighting is creating pleasant luminous sphere effectively. Visibility comfort mainly set by the lack of glare[26]. There are two kinds of glare, they are direct glare (caused by light sources in vision range) and reflected glare (caused by reflection of a light source in a visible surface).

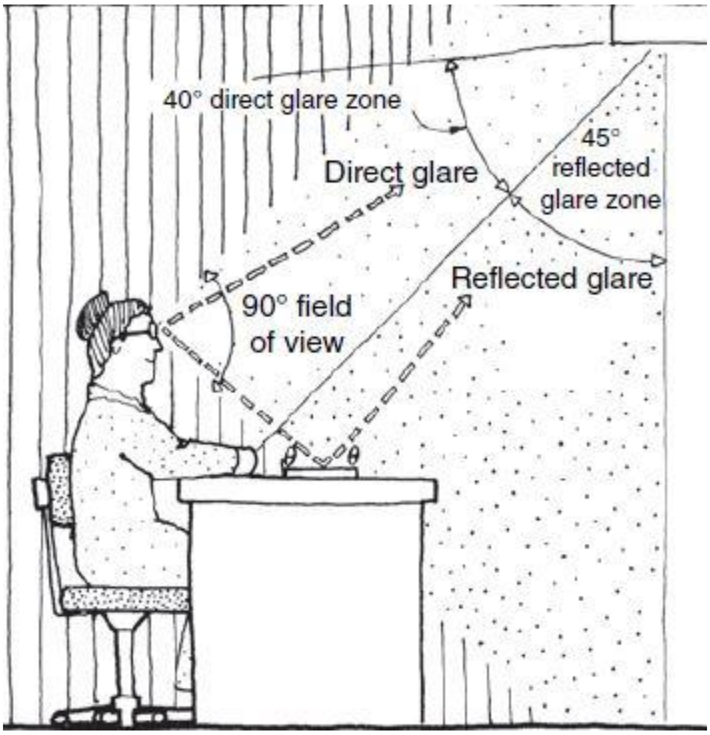

Figure 45 Glare Zones [3]

Some fundamental ways to reach the goal could be provide as below;

a. Lighting devices as can be as possible located unnoticable but still visible.
b. Illuminance rate ought to be enough for clear visible view.
c. Appropriate lighting quality should be maintain according the occupant necessity.
d. Whole lighting design should be has proper energy and its cost
e. The variation of lighting devices may be expected to make aspect effects and avoid monotony.

[26] Exaggerated luminance ratio in the field of vision

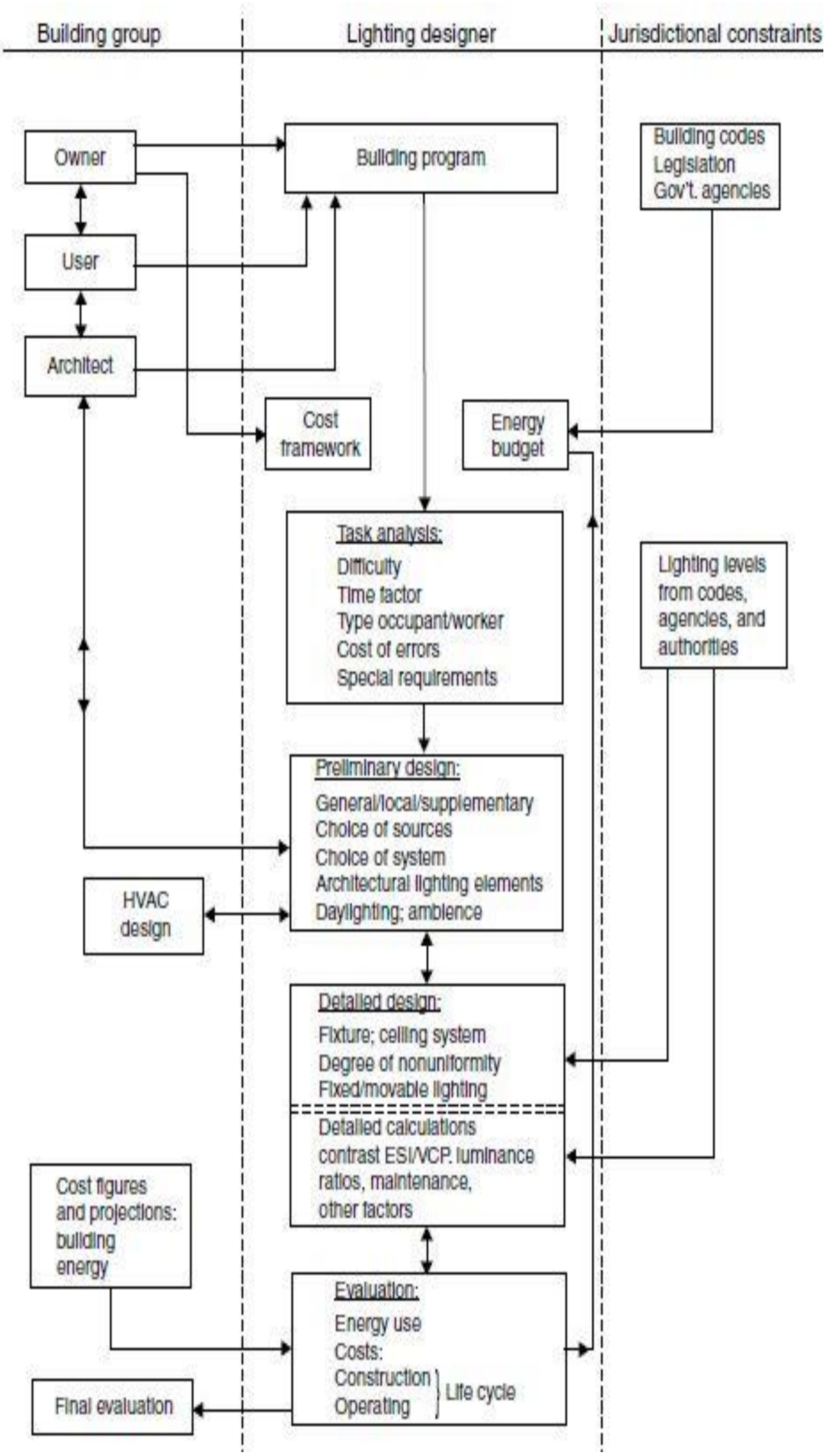

Figure 46 Artificial Lighting Design Step [3]

2.5 Control and Communication Systems

Basically the fundamental control in building energy management system is about collaboration and optimization between HVAC distribution systems, lighting, plumbing, with the controllers loop process. The control system in HVAC have objectives, such as:

a. Energy, temperature, pressure, humidity, light level, and all flows have to be precisely controlled
b. Gas, conditioned air, and water have to be flow at necessity location
c. Interior building has to be maintain the acceptable temperature level by occupant
d. The fresh air has to be enter the building and distributed effectively
e. All the generated pollutants, water, and air have to be rinse out of the building

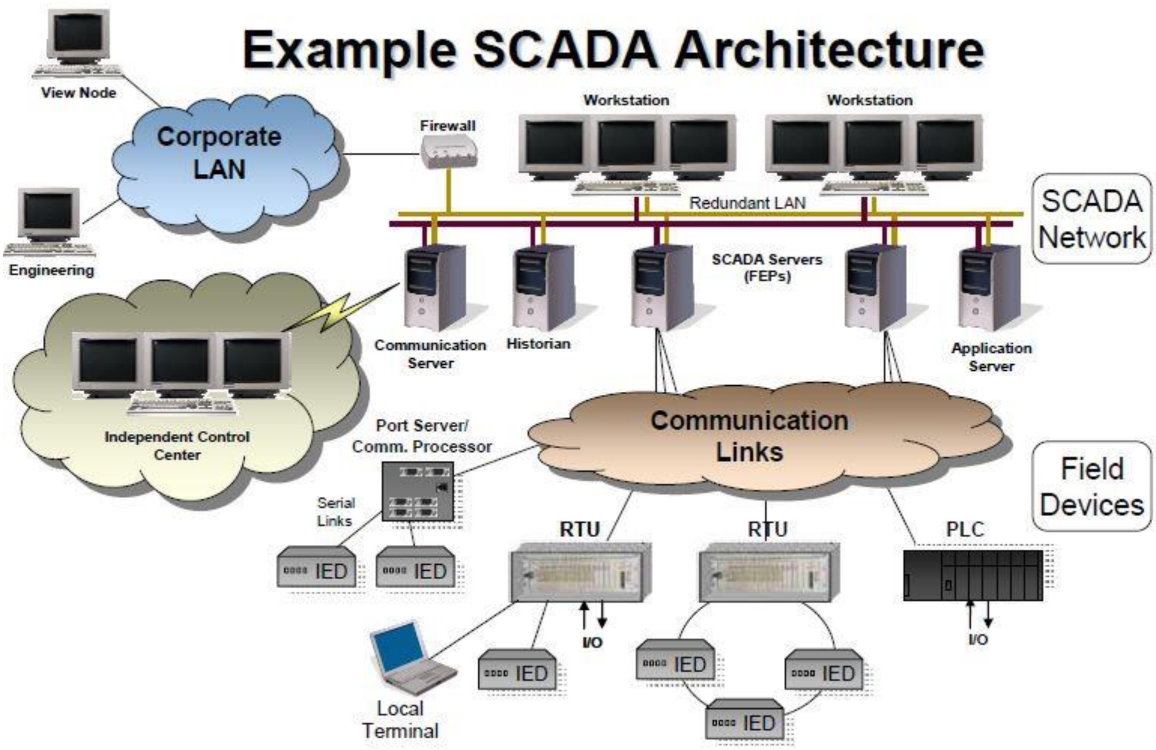

Figure 47 SCADA Scheme

SCADA stand for Supervisory Control and Data Acquisition, the function is to analyze and encounter real time data. It consists of software and hardware elements, which the hardware part getting the signal (data) then input it to the computer, then computer will process and give the information data through human machine interface.

HVAC system important to have suffice stabilization, there are three types for stabilizing the HVAC system;[19]

1. Unstable : need some setpoint assignment, method for process controlling and measurements
2. Self-stabilizing : always has the final correct result output after certain quantity of execution steps
3. Moderate stabilizing : small interference could make unstable respons but most of the time it is properly stable

In HVAC control systems, there are some own terms for definition of event, they are:

- Setpoint : expected value of the output result
- Actuator : an electric or pneumatic device which move a valve or damper, perform physical action in the control process and activates relay
- Controller : sending signal to actuator
- Sensor : produce indicator signal impulse and transmit information

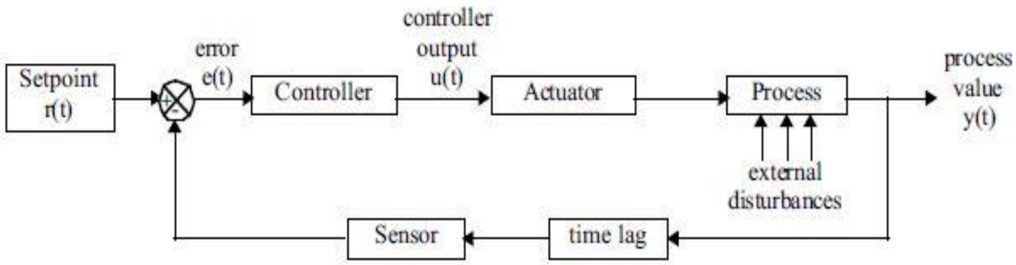

Figure 48 Control with Closed Loop Scheme [19]

II. PRACTICAL PART

3 THE SINGLE FAMILY HOUSE DESIGN

The house building is placed in Medan, the capital city of North Sumatera province, Sumatera Island, west part of Indonesia. The existing single family residential building is a simple one floor conventional house with electric grid utility system and normal water system. It was established since 1983, without any of central HVAC (cooling) system, security system, renewable energy utilization, or domestic hot water system installation. For cooling purpose, the occupants use table / stand fans.

The refurbishment processes are explained in this project, from general existing building conditions until the new minor shape design but major change in material construction with the upgraded of advance integrated technology equipment complete with the prediction of energy consumption by the residential building and occupants.

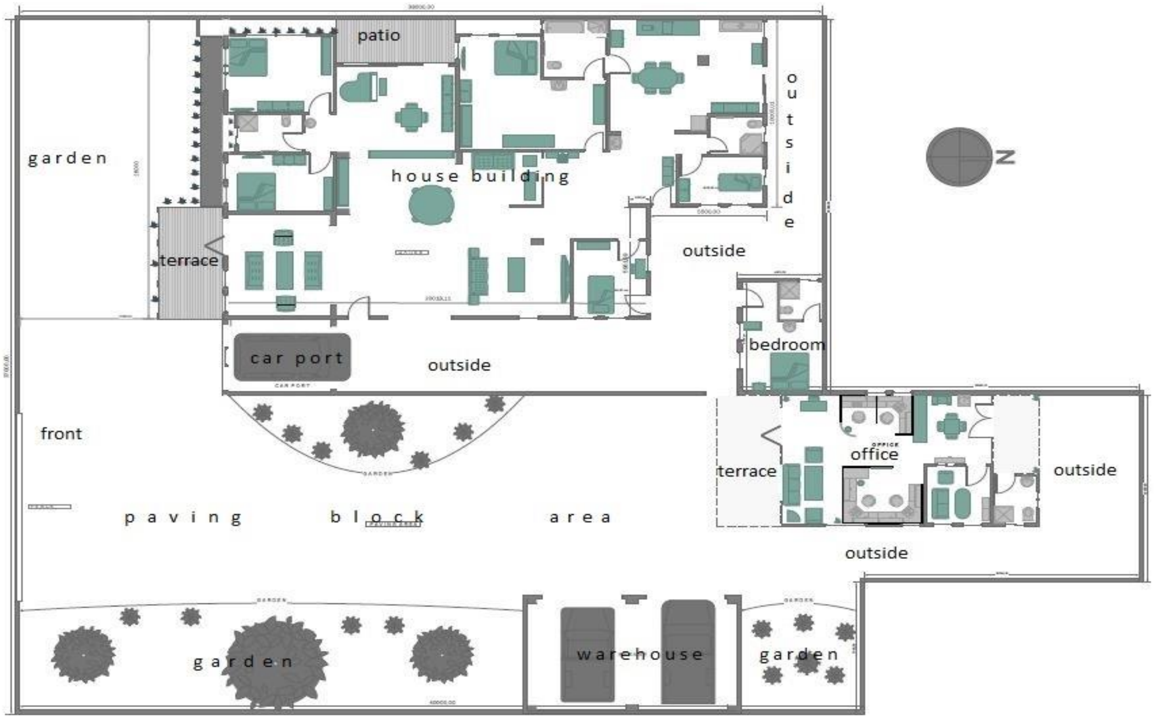

Figure 49 Spacious Area of Residential Building

The spacious area is 1570 m^2, besides the house building there is a small office building with size 140 m^2 (20m length & 7m width), a bedroom size 24m^2 (6m length & 4m width) and a warehouse / garage building with size 84 m^2 (12m length & 7m width) within the land area location. The size of the house building itself is around 300 m^2, the building shape is not exactly rectangle, for the rest of the area is garden and paving block. Front side of the house and the office building in the area is heading to South, meanwhile for the warehouse entrance door is heading to West.

3.1 Existing Residential Building Properties

Physics condition of existing residential building already has many leaks in major parts area and no extra insulation found. The building's materials being used were not qualified based on ASHRAE STANDARD 90.1.2007 for current residential building standard in hot climate zone. Table 28 provide the list of basic construction properties of the old house single-family building.

Table 28 Existing House Properties

Assembly	Basic Construction	Thermal compo-	U-value	Insulation
Outdoor Wall	Concrete masonry	-	2.63	N/A
Celling &	Standard wood	Gypsum board	0.2	5.3
(Slab) Floor	Unheated slab	Concrete slab	F-1.264	N/A
Doors	Swinging	Wood frames	3.4	N/A
	Uninsulated double	Metal frames	4.0	N/A
Windows	Clear & operable,	Wood frames	5.05	SHGC[27]=0.64
Unit Leakage Area	Average		2.8 cm^2/m^2	

F = per linear foot of building perimeter

[27] Solar Heat Gain Coefficient - represents the percentage of solar radiation on a window or skylight assembly which ends up in a building as heat, range value is between 0 and 1.

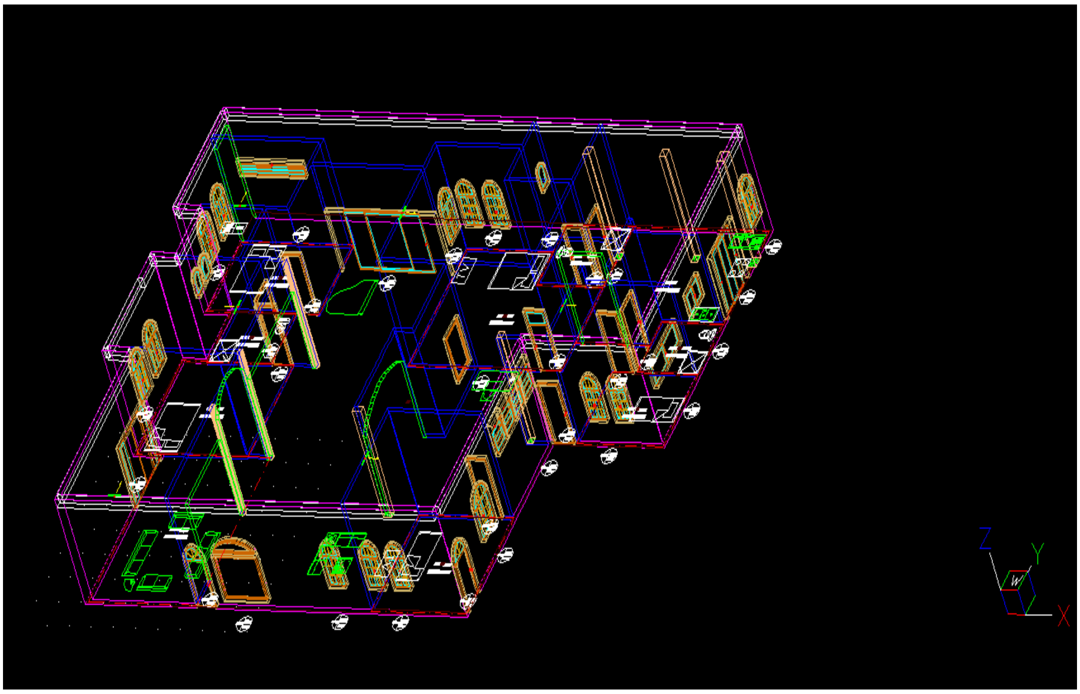

Figure 50 3D View of Existing House Building

3.1.1 Existing Residential Building Environment

The existing house building is located at 3.57° N latitude and 98.67° E longitude, local climate data analysis using the closest weather station data available in IWEC database list from the residential location which is located in George Town-Penang Island, Malaysia, positioned at 5.3° N latitude and 100.27 ° E longitude. The basic codes for calculation being used is ASHRAE Standard 55 and current ASHRAE Fundamental.

Table 29 Existing House Environment

Item	Cooling	Notes
Latitude	-	3.58° N
Longitude	-	98.67° E
Elevation		25 m
Indoor temperature	29°C	
Indoor relative humidity	65 %	
Outdoor temperature	34 °C	
Outdoor Relative Humidity	82%^{a}	

Wind Speed	2 m/s	
△T	5 °C	T(outdoor-indoor)
Outdoor wet bulb temperature	27 °C	MCWB[28] at 1%
Occupants		7

.[a] Using software Climate Consultant 6.0 beta[29], based on IWEC weather data input

3.1.1 Existing Building Envelopes

The envelopes of the building generally consists of roof, ceiling, doors, windows, walls and floor. Observation and measurement need to be done for collecting information of the elements. From all of these elements data, the total cooling load through building envelope can be obtained.

Table 30 Existing Building Envelopes Parametes

Component	Area (m^2)	Notes
Ceiling (Roof)	425	No insulation
Doors	23	3(0.9 x 2 m) , 1(2x2m), 1(1.8x2m),
Windows	26.925	14(0.8x1.5m), 5(0.75x1m), 3(0.5x0.75m),
Outdoor walls (without windows and doors)	230.075	Wall height = 3.5m
Slab Floor above grade	375	Unheated

[28] Mean Coincident Wet Bulb - the mean value of all those wet bulb temperatures which occur together with the dry bulb temperature within 5°C interval

[29] Graphic-based computer program to plot climate data

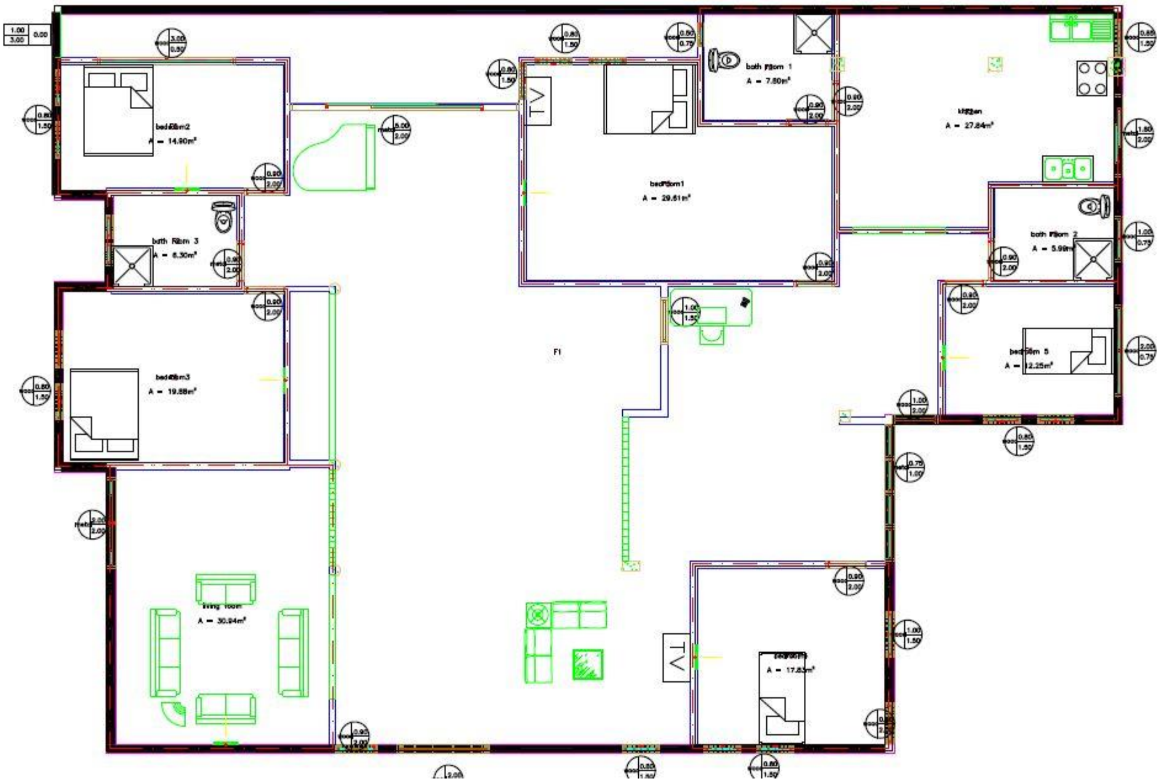

Figure 51 Floor Plan View of Existing Building

3.1.2 Sensible Heat Gain of Existing Residential Building

The sensible heat gain or known as cooling load required to determine specification of the cooling equipment to be installed inside the building. To find the cooling load of each element, there are some mathematical equations can be used. For roof, wall, and door the formula is:

$$q = U_x \text{ x A x CLTD} \tag{24}$$

where;
U_x = coefficient of heat transfer of element (For roof, wall, or door), *W/m2 K*
A = area, m^2
$CLTD$ = Cooling Load Temperature Differences, K

For the windows (using draperies), the equation is:

$$q = \text{A x GLF} \tag{25}$$

where;
GLF = Glass Load Factor

Table 31 Cooling Load of Roof, Wall, and Door of Existing Building

Section	*Area (m^2)*	*U-value (W/m2)*	*CLTD (K)*	*GLF*	*Cooling Load*
Roof	475	0.2	23		2185
South wall	42.95^a	2.63	6		678
North wall	42.95^a	2.63	4		452
East wall	74.9^a	2.63	10		1970
West wall	84^a	2.63	10		2209
South	4	4	6		96
North	3.6	4	4		58
	1.8	3.4	4		25
East Doors	3.6	3.4	10		122
West	-	N/A		N/A	
South Win-	5.55	5.05		85	472
North Win-	7.65	5.05		57	205
East Win-	9	5.05		142	1278
West Win-	-	N/A		N/A	
Total					**9750**

.^{a} Calculated from gross wall area less windows and doors areas

For heat gains from occupants, the formula is:

$$q_{people} = \text{number of occupant x cooling load per occupant} \qquad (26)$$

q = 7 x 67 = 469 W
In residential building, cooling load / person often assumed 67 W[3]

For heat gains from outdoor air, the equation is:

$$q_{infiltration} = A_{exposed} \text{ x infiltration factor} \qquad (27)$$

q = 15 x 2.2 = 33W

Table 32 Sensible Cooling Load Infiltration/Ventilation Factor [3]

Design Temperature °C:									Design Temperature °F:					
29.4	32.2	35.0	37.7	41.5	43.3	Units	Condition	Units	85	90	95	100	105	110
2.2	3.5	4.7	6.0	6.9	8.2	W/m²	Infiltration, per gross exposed wall area	Btu/h ft²	0.7	1.1	1.5	1.9	2.2	2.6
6.8	9.9	13.6	16.7	19.8	23.6	W per L/s	Mechanical ventilation	Btu/h per cfm	11.0	16.0	22.0	27.0	32.0	38.0

Sensible heat gains from appliances is using standard assumption of cooling load produced from appliances in residence which is 470W [3]

Total sensible heat gains (cooling load) = (9750 + 469 + 33 + 470) W = 10722 W

Latent heat gains have many variations, it depends on type of occupancy, the basic method assumes it is nearly connected with the tightness of building construction. The recommended range value is 10% to 30% of total cooling load.

Which means the minimum latent heat gains is 10% x 10722 W = 1072.2 W and the maximum is 30% x 10262 W = 3216.6 W.

Therefore, the total range of cooling load of the building is between 11794.2 W and 13938.6 W.

The percentage of latent heat from total sensible cooling load illustrated in figure 52.

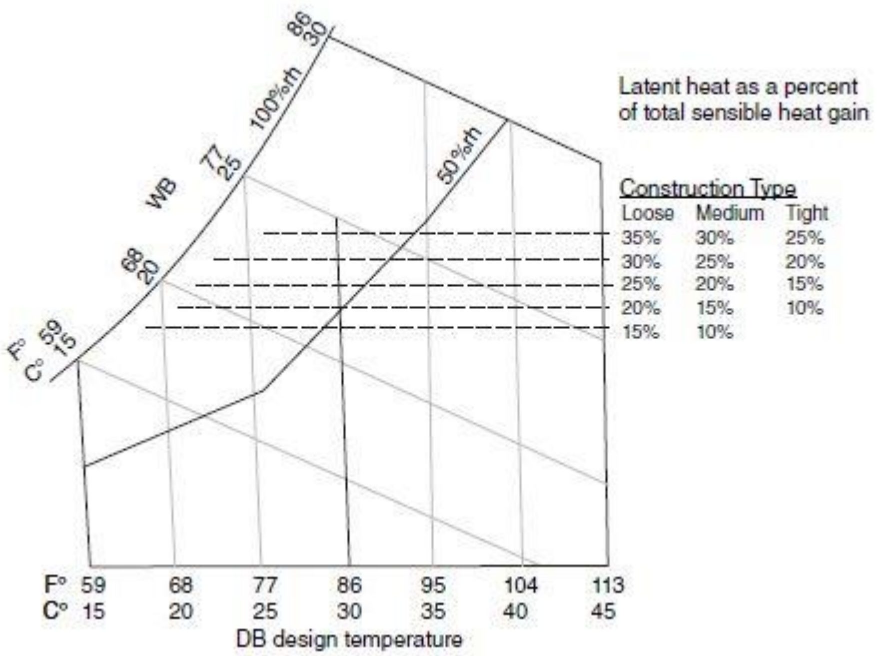

Figure 52 Percentage of Latent Heat From Total Sensible Heat Gains [3]

3.2 Refurbishment Residential Building Properties

The refurbishment building basically has the same shape design but major changes in the material construction and re-decorating as well. The materials construction that being used are based on ASHRAE STANDARD 90.1.2007 recommended for new building in hot countries climate zone 1.

Almost all the material elements are decrease in U-value and increase the insulation (R) value, then the cooling load of the building envelopes will reduce and the main goal is to achieve cooler temperature and lower humidity level inside the house than older one wherever possible without any installation of HVAC system (only rely on natural cooling). So later on the HVAC mechanical cooling demand could be minimize in term of energy uses.

The way of the building get cooled itself without mechanical cooling equipment is called passive cooling. In equatorial area such as Indonesia, it is common for residential buildings not having the air conditioning turn on at the daylight (6 am – 6 pm), because mostly the occupants have activities outside the house (i.e. school, work, shopping, sport, etc.)

Table 33 Refurbishment House Properties

Assembly	Basic Construction	Thermal component	U-value W/(m^2·K)	Insulation (m^2·K)/W
Outdoor Wall	Brick masonry	Metal Stud, ply-	0.16	6.4
Indoor Wall	Laminated Veneer	Wood	0.12	8.6
Insulation	Fiberglass batt		0.01	11
Celling	Standard wood	Gypsum board	0.25	4.0
Roof	Asphalt	Wood fiber	0.21	4.7
(Slab) Floor	Unheated slab	Concrete slab	4.2	0.24
Indoor floor	Spruce Wood	Wood	12.5	0.08
Doors	Single Swinging	Wood frames	2.2	0.46
	Triple glass layer	Metal frames	2.8	0.36
Windows	Clear & operable,	Wood frames	1.45	0.69
Leakage	Good		2.8 cm^2/m^2	

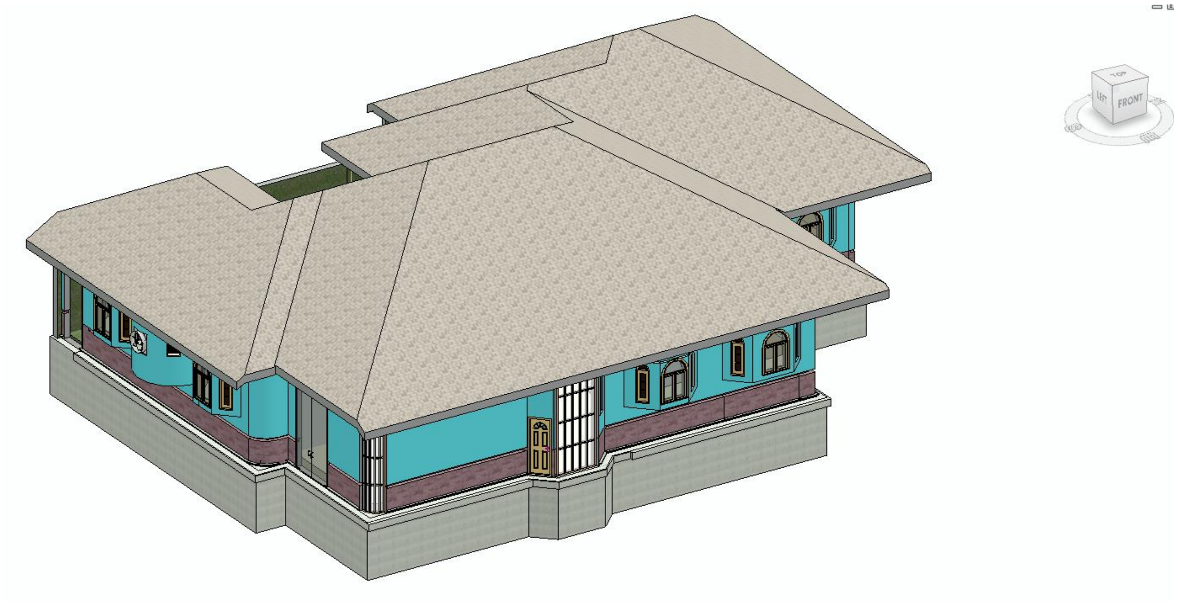

Figure 53 3D View of Refurbishment Building

3.2.1 Refurbishment Residential Building Envelopes

The building envelopes part have the changes in quantity of doors and windows, the number of doors changing from 6 become 7, but the total size area has the significant increasing from 23 m^2 to 40.2 m^2. Number of windows increase as well from 25 to 28, but total size area for windows decrease from 26.925 m^2 to 17.5m^2, this is happened because in the refurbishment building design put more focus on the distribution of ventilation placement for getting the more variation and frequently airflow circulation from and to outdoor.

Table 34 Refurbishment Building Envelopes Parameters

Component	Area (m^2)	Notes
Ceiling (Roof)	543	Fully insulated
Doors	40.2	2(0.8 x 2.1 m) , 1(2.3x1.7m), 1(1.4x2.1m),
Windows	17.5	16(0.5x1.2m), 7(0.9x1m), 4(0.4x0.4m),
Outdoor walls	374	Wall height = 3.5m
Slab Floor above grade	356	Unheated

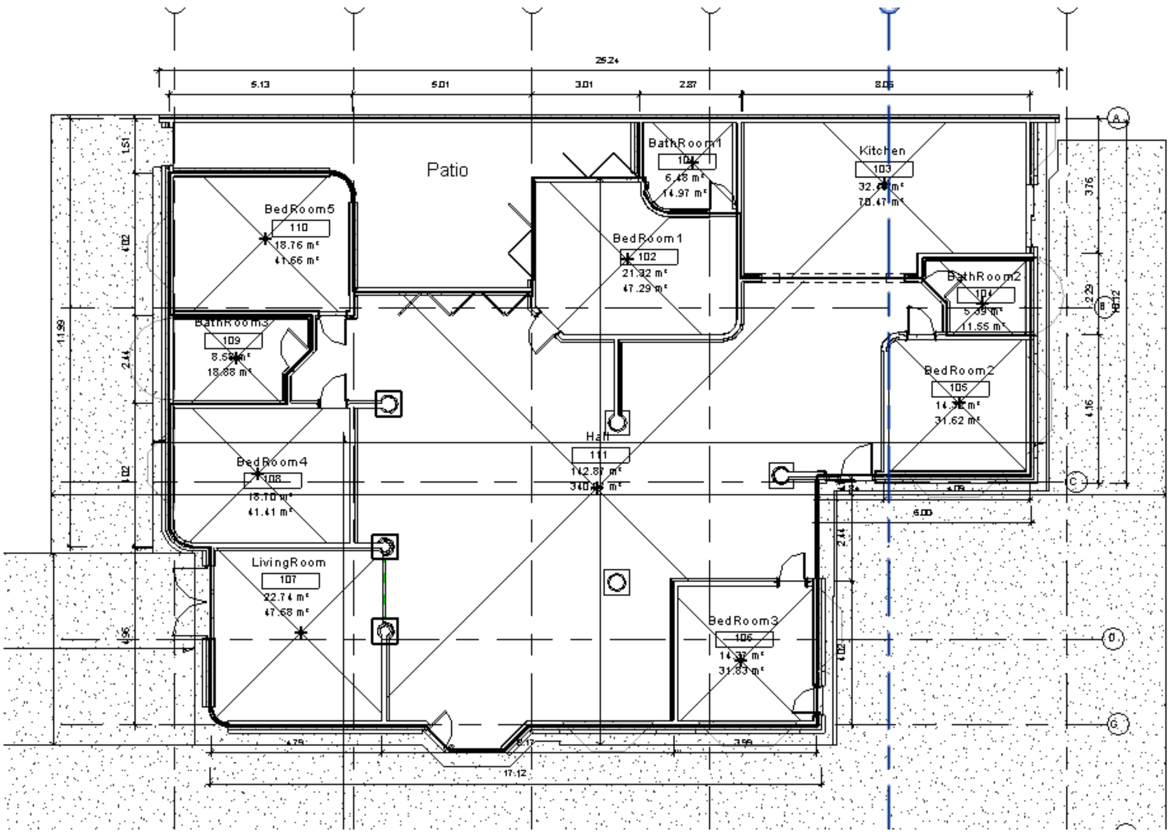

Figure 54 Floor Plan View of Refurbishment House

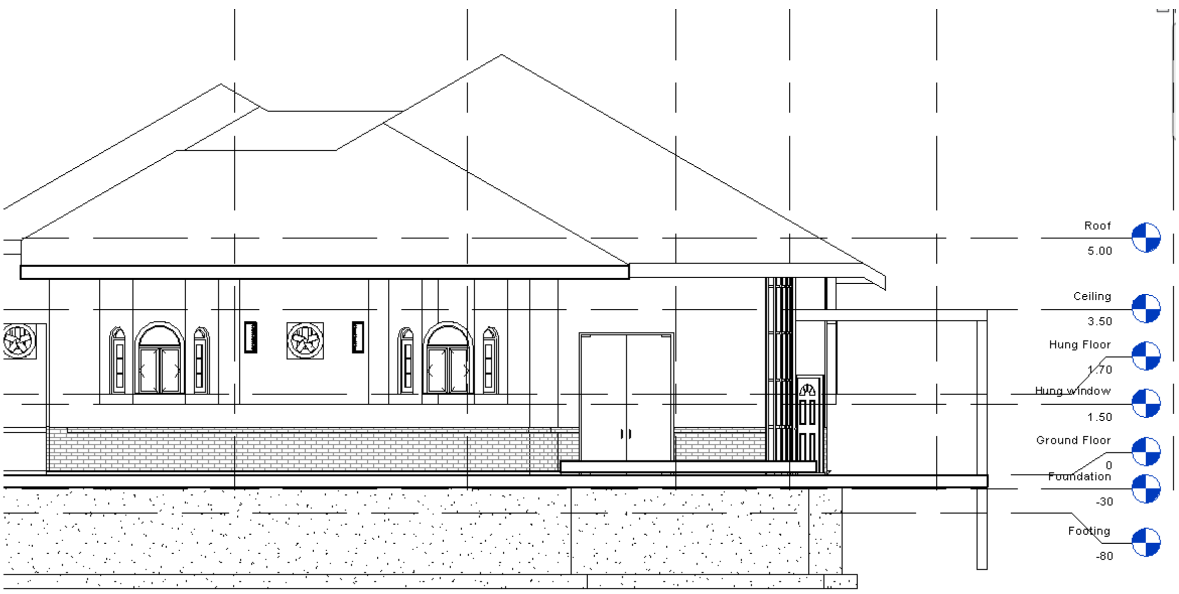

Figure 55 House with front elevation view in 3D

3.2.1 Sensible Heat Gain of Residential Building

The sensible heat gain (cooling load) inside of the house could be observed based on interior sections. Based on ASHRAE Fundamental Handbook, at indoor air temperature of 25°C, rates of sensible heat gain from each occupant can be assumed 70 W, meanwhile the latent heat gain per person is 59 W.

Table 35 Cooling Load per Section Interior House

Space	Area (m^2)	Volume (m^3)	Infiltration Airflow (L/s)	Number of Occu-pant	Cooling Load (W)
Bathroom 1	6.2	14.9	1.2	1	145
Bathroom 2	4.8	11.6	1.3	1	153
Bathroom 3	7.8	18.9	0.6	1	178
Bedroom 1	21.1	47.3	1.4	1	554
Bedroom 2	14.1	31.6	1.8	1	320
Bedroom 3	14.2	31.8	3.4	1	420
Bedroom 4	18.5	41.4	0.9	2	343
Bedroom 5	18.6	41.7	2.7	2	486
Kitchen	31.6	70.5	3.3	7	958
Living Room	22.8	47.7	2.1	7	1393
Hall	139.3	340.1	10.4	7	4240
Total	299	697.5			9190

3.3 HVAC Systems of Residential Building

The central active mechanical cooling will only installed inside some room parts of the house, such as all bedrooms, living room, and family room (hall). The rest of room such as bathrooms, kitchen will be hanged on either naturally ventilation or just using exhaust cooling (i.e. exhaust fan).

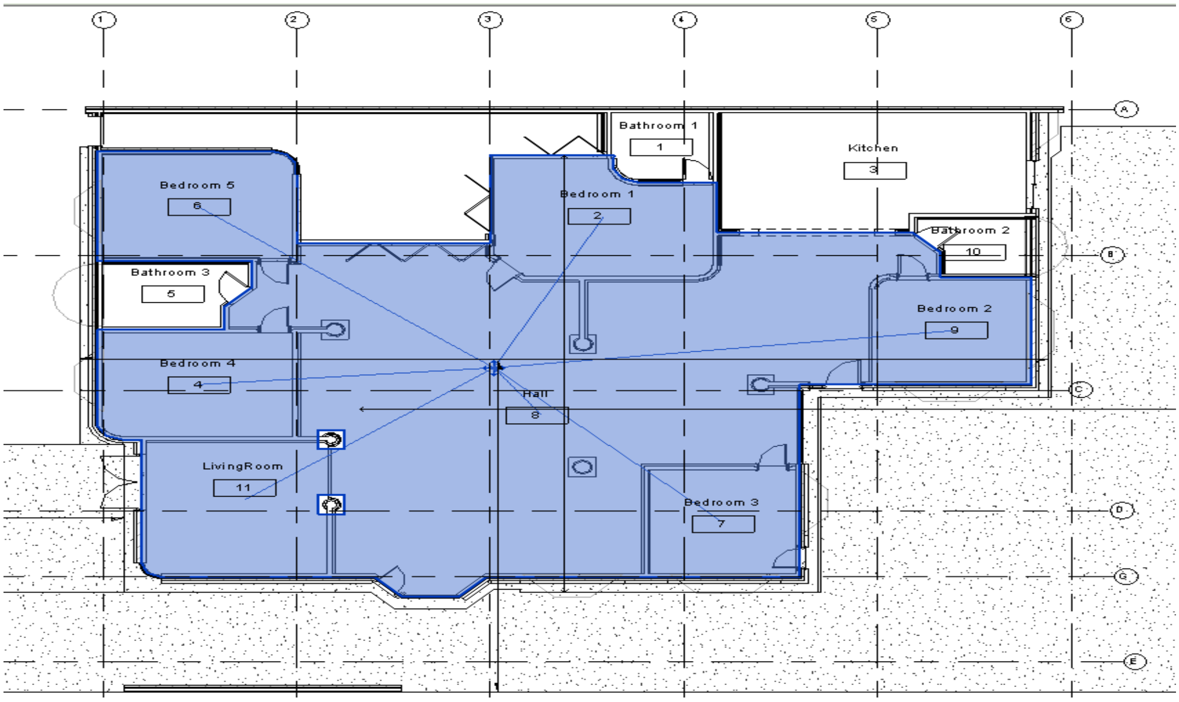

Figure 56 HVAC zone inside house

The HVAC systems use 2 ductwork for supply air and return air, which are for the supply air uses rectangle duct and for the return air uses round duct. Both ducting connected to the Air Handling Unit (AHU) that function to manage airflow to the conditioned space. Some of the return air will be go back to heat pump and the other will deliver to Variable Air Volume (VAV) Box as the fresh air. The ratio of these air are 0.4, means 2 of 5 of return air will be recirculated as supply air after being filtered in AHU. Meanwhile the rest will be continued into heat pump then to the water tank for heating the water.

The cooling source used in this HVAC system is air source reversible heat pump. As a cooler this pump assumed work only 12 hours a day in average. Since the heat pump is reversible it is also capable produce heat, and this waste heat is optimized for heating the domestic water in the house. For the electric source, the heat pump directly connected into the electric panel as well as into the main control cabinet (panel) in order being part of the building integrated system.

Heat pump specification is 9kW of cooling power, COP = 4, and 4kW apparent load. The AHU specification 124.00 Pa external static pressure, cooling capacity 3629kJ, and 516 W apparent load. VAV box unit pressure drop 47 Pa, and 500W apparent load.

Figure 57 3D View of Ductwork of HVAC System inside House

Table 36 Supply Cool Air Ductwork Branches

Space	Velocity (m/s)	Cooling Airflow (L/s)	Reynolds Number	Equivalent Diameter (mm)	Length (m)	Friction (Pa/m)	Pressure Loss (Pa)
Bedroom	2.3	35.8	18999.81	137	3.83	0.70	2.7
Bedroom	2.1	20.7	13732.41	109	11.25	0.77	8.7
Bedroom	2.2	27.2	16039.57	122	4.72	0.74	3.5
Bedroom	2.2	22.2	14727.51	109	7.70	0.88	6.8
Bedroom	2.5	31.5	16717.71	137	10.37	0.96	10.0
Living Room	2.6	90.2	30686.56	202	7.55	0.74	5.6
Hall	2.9	91.5	33260.94	193	4.49	0.72	3.2
	2.3	91.5	30350.61	219	0.13	0.39	0.0
	2.9	91.5	33260.94	193	0.25	0.72	0.2
Main	4.6	502.1	98694.50	361	2.5	0.75	21.8
Total	-	502.1	-	-	-	-	62.5

Table 37 Supply Air from AHU to VAV

Section	Velocity (m/s)	Cooling Airflow (L/s)	Reynolds Number	Equivalent Diameter (mm)	Length (m)	Friction (Pa/m)	Pressure Loss (Pa)
Duct 1	2.1	200.8	48469.51	350	0.46	0.16	2.3
Duct 2	3.4	200.8	62140.40	273	0.06	0.55	7.0
Duct 3	4.1	200.8	67857.31	250	0.65	0.85	7.9
Total	-	200.8	-	-	-	-	17.2

Table 38 Return Air Ductwork Branches

Space	Velocity (m/s)	Cooling Airflow (L/s)	Reynolds Number	Diameter (mm)	Length (m)	Friction (Pa/m)	Pressure Loss (Pa)
Bedroom 1	2.4	35.8	22072.40	137	2.75	0.69	1.9
Bedroom 2	2.2	20.7	15996.93	109	10.26	0.77	8.1
Bedroom 3	2.3	27.2	18831.96	122	5.13	0.74	3.8
Bedroom 4	2.4	22.2	17156.13	109	9.81	0.88	8.6
Bedroom 5	2.7	31.5	21809.10	122	12.39	0.97	12.0
Living Room	3.2	90.2	40099.54	190	7.82	0.75	5.9
Hall	3.1	91.5	40045.18	193	5.23	0.71	1.9
	0.9	91.5	21409.20	361	0.54	0.03	0.0
	3.1	91.5	40045.18	193	2.66	0.71	1.9
Main	4.9	502.1	117481.50	361	6.46	0.75	4.9
Total	-	502.1	-	-	-	-	49.0

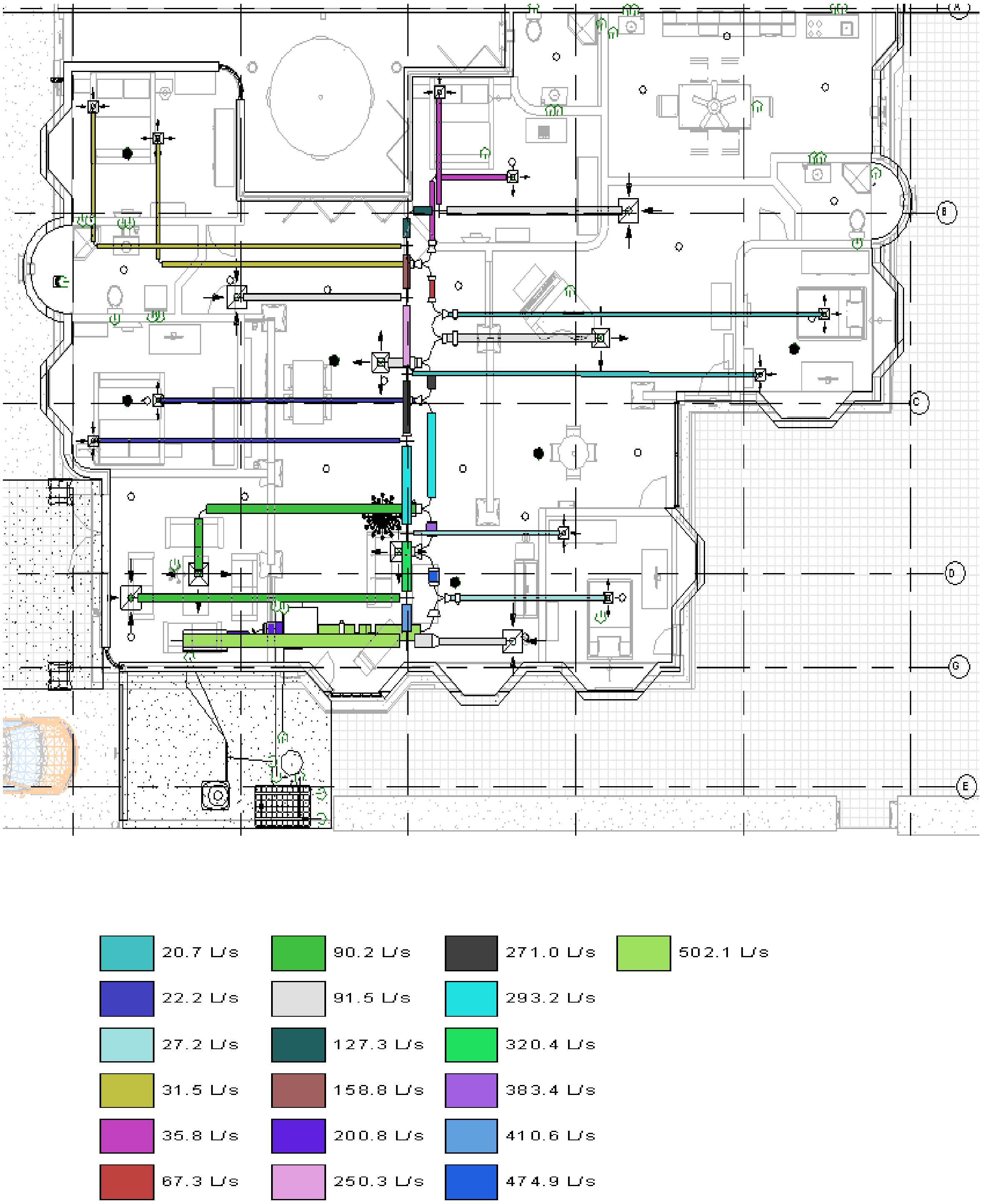

Figure 58 Ductwork of HVAC System Scheme

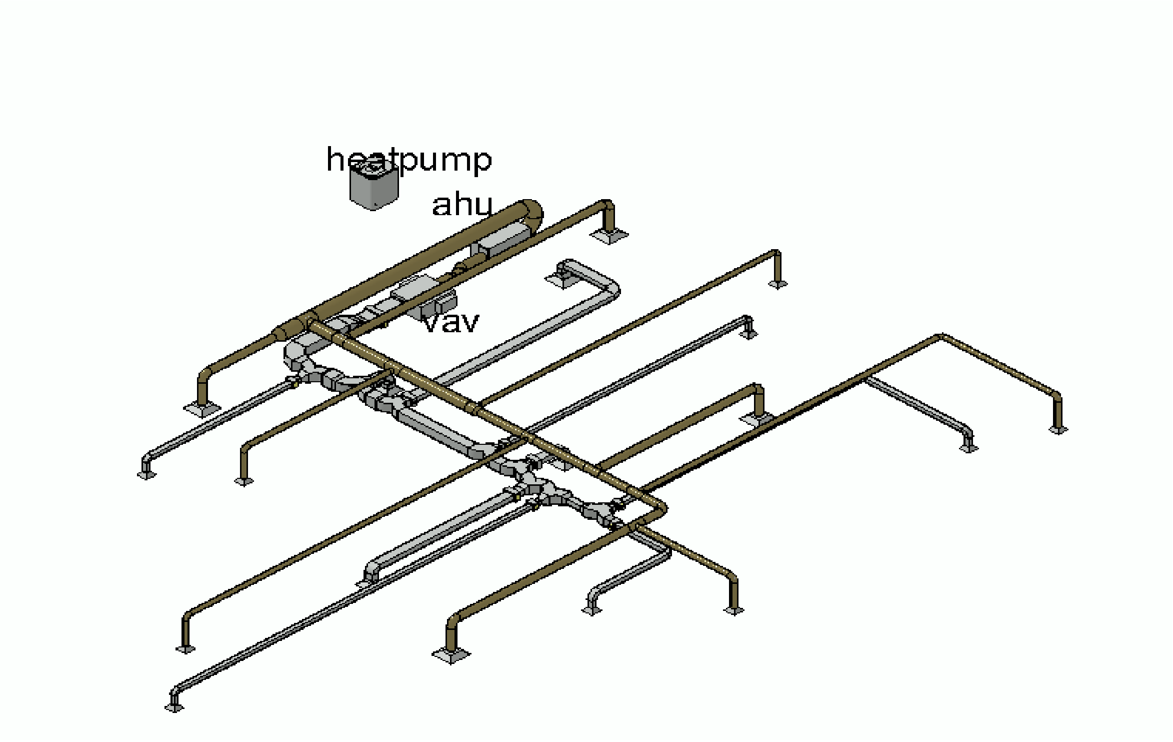

Figure 59 Ductwork of HVAC System 3D View

Supply air duct itself has automatic damper on each branch. It could regulate the airflow amount into the room based on thermostat controllers which are located in the every conditioned room. All these distributed controls are connected to the sensor and will ignite A/C based on signal received.

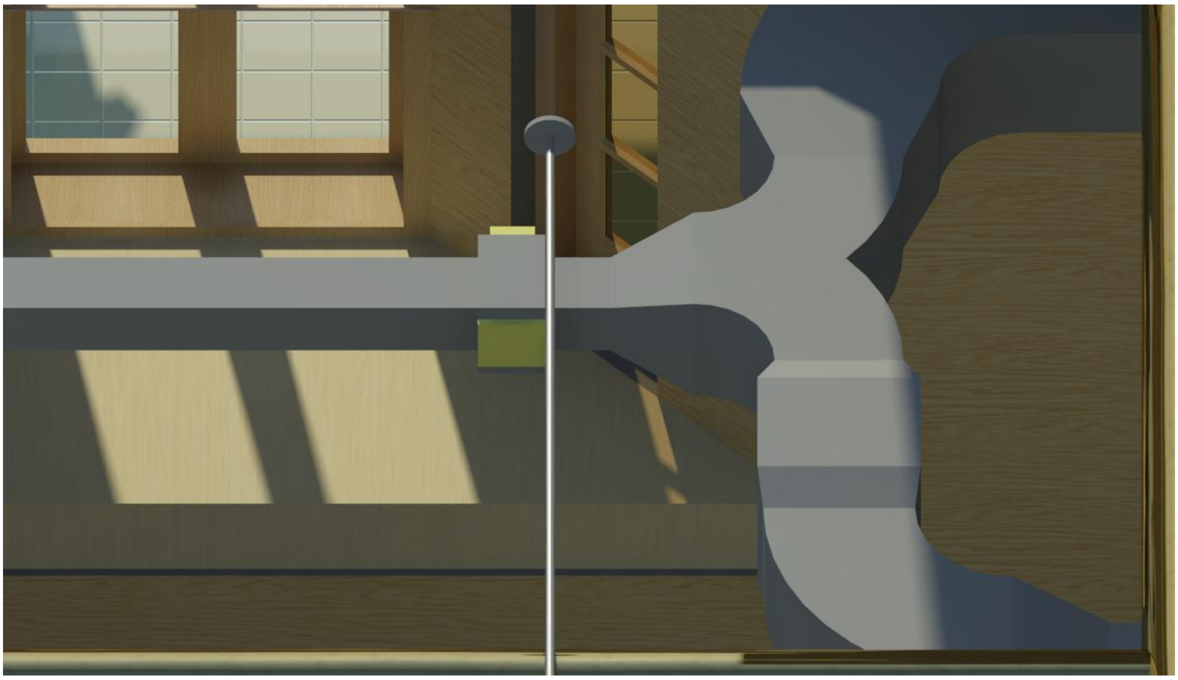

Figure 60 Automatic damper (yellow) in air supply duct

3.3.1 Plumbing, Water Heating & Sprinkler Systems

The water heating system is inseparable with plumbing system. In this design the sprinkler system is included as part of the fire fighter system (security system). Water system has two flows, they are cool water which is can be obtained either from national water company or ground water, and the second one is hot water that gain the heat from heat waste of the heat pump and solar heater panel.

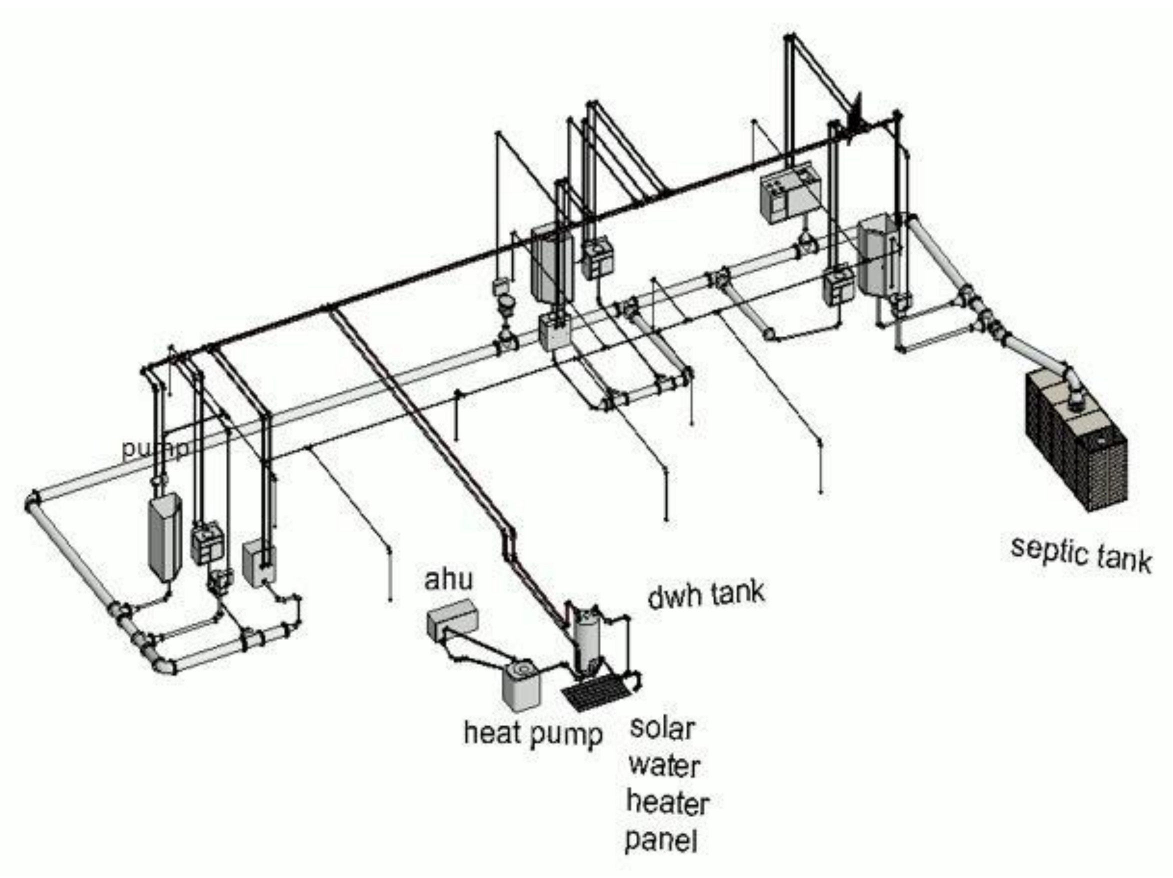

Figure 61 Plumbing and Sprinkle Systems

According to ASHRAE 2011 Handbook-HVAC Applications the minimum residential water heater capacity for house with 5 bedrooms and 3 bathrooms is 190 L, this house is using 380 L with the water's temperature target is maximum 40°C. The consumption of hot water in this house mainly for the showers, but the pipe also connected to the washing machine and all washbasins in the three bathrooms and kitchen. Table 33 shown the representative hot temperature based on ASHRAE.

Table 39 Representative Hot Water Temperature[21]

	Temperature	
Use	°F	°C
Lavatory		
Hand washing	105	40
Shaving	115	45
Showers and tubs	110	43
Therapeutic baths	95	35
Commercial and institutional laundry (based on fabric)	Up to 180	Up to 82
Residential dishwashing and laundry	140	60
Surgical scrubbing	110	43
Commercial spray-type dishwashing[a]		
Wash	150 minimum	65 minimum
Final rinse	180 to 195	82 to 90

The domestic water heating system harness passive heat from both heat sources, at day time the solar panel collect the sun energy and give the heat meanwhile during the night heat pump give the heat waste into the tank. Solar panel use the principal of thermo-siphon[30], so it does not need a pump to distribute the hot water into the tank.

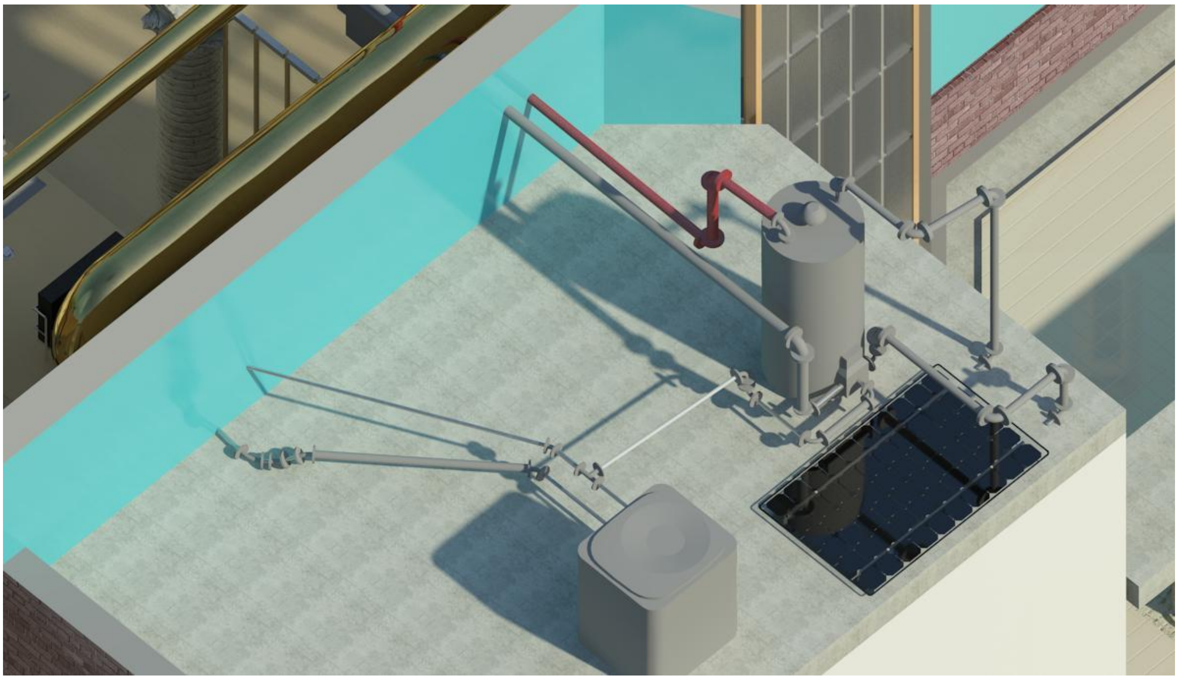

Figure 62 Heat pump, Water Tank and Water Solar Heater Placed above Garage

[30] Physical effect and refers to a method of passive heat exchange based on natural convection, which circulates a fluid without the necessity of a mechanical pump

Plumbing system built with main pipe connection placed 1 m underground with slope variation start from front bathroom until septic tank. The main pipe connect all the bathrooms and kitchen's ditch. Final waste disposal will end up in a septic tank with capacity 7633 L which is buried 3 m below the ground at the backyard.

Sprinkler system as the part of security system in the house only use cold water from the ground water. The system only work based on fire detector that placed at the celling. In case of wildfire, the detector send the signal to main control and then turn on the water pump immediately. The fire alarm is set up to active at 85°C.

The sprinklers' head placed in all rooms except bathrooms. The water pump is using electrical energy and must be in steady status (connected into electricity) for precaution. The main purpose of system to mitigate and have first aid in fire case before the firefighter come, because of the limitation of water source and the device. Specification of water pump being used in the system is 450W and 1760 RPM (type 3.6 LPS-0.9 m head).

3.3.2 Electrical Installation & Artificial Lighting Systems

Common residential house in Indonesia using utility grid with 220 V single phase 2 wire. For power supply source which provide from national electrical grid could be vary based on the price per kWh between 1300VA, 2200VA, 3500VA -5500VA, and more than 6600VA. In this model, the house is using 6600VA from utility grid and 1100VA from the photovoltaic panel, therefore the total available power is 7700W (35A).

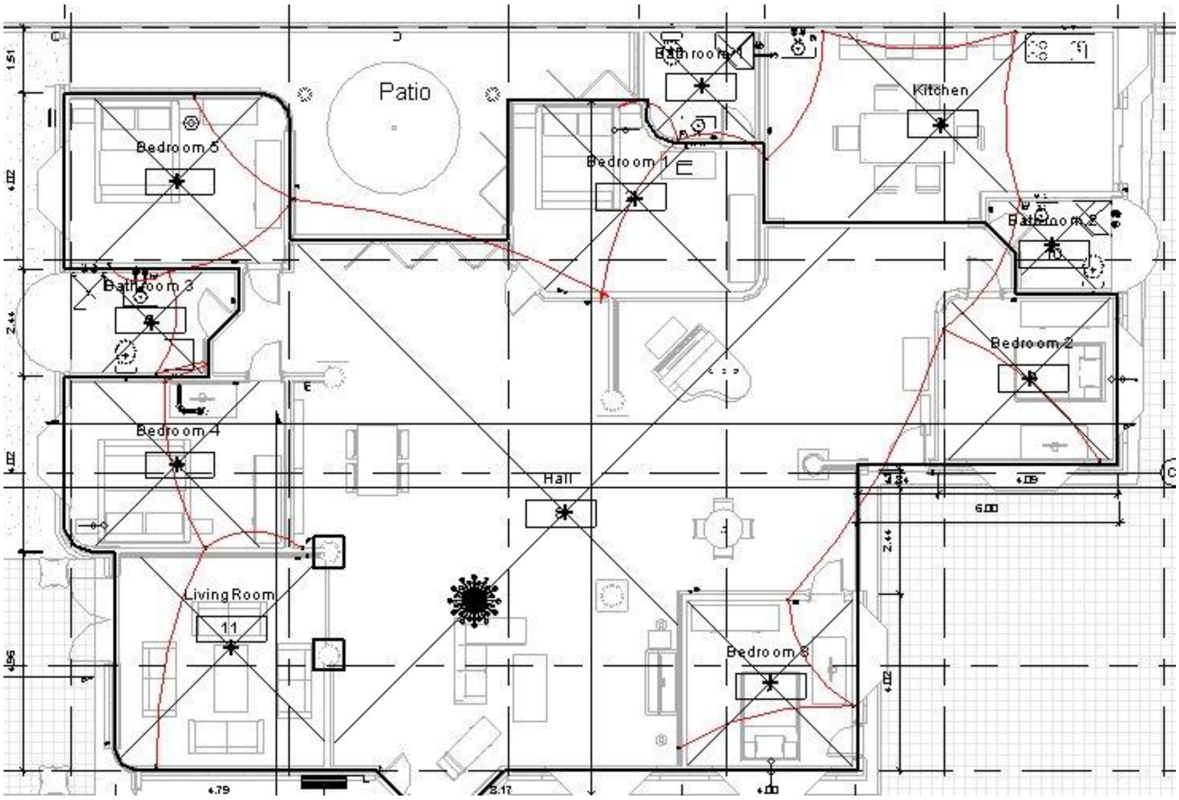

Figure 63 Receptacle Circuit Installation

All the receptacles installation directly connected with electrical panel board, this wiring system not passing through the control cabinet. The purpose is to separate between the scheduled load of the house consumption (i.e. air conditioner system, lighting, security, and water system) and any other appliances (i.e. TV, blender, PC, toaster, kitchen appliances, etc.).

Artificial lightings specifications for each bathroom contains two lamps, they are ceiling lamp (type LED, 20W apparent load, intensity 2398 lm) and wall lamp (type LED, 15W apparent load, intensity 25000 lm). In each bedroom contains 2 lamps, they are ceiling lamp (type LED, 15W apparent load, intensity 2398 lm) and table lamp (type fluorescent, 60W apparent load, intensity 14.25 lm).

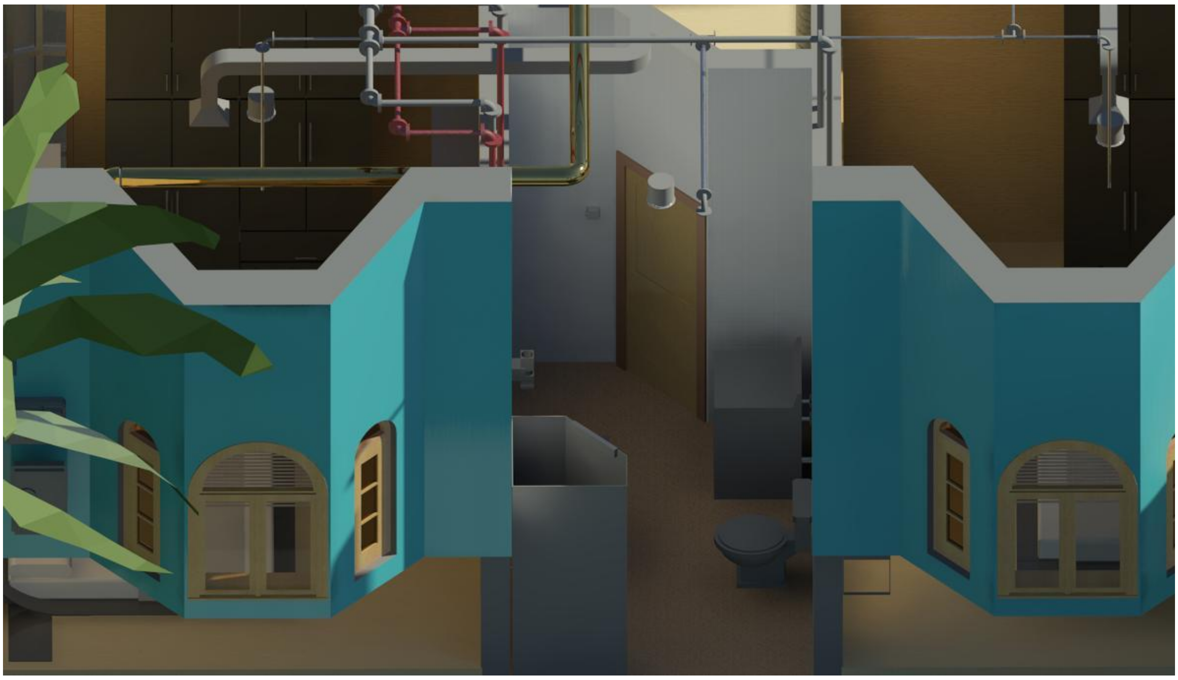

Figure 64 Bathroom with light sensor inside

Kitchen area has three ceiling lamps with same specifications as bathroom's ceiling lamp and one wall lamp as well. The living room has four ceiling lamps with same specifications as in bedroom's ceiling lamp specification and one chandelier lamp (type fluorescent, 75W apparent load, intensity 1800 lm). Hall area contains eleven ceiling lamps same as bathroom's ceiling lamp specifications two wall lamps (same spec with bathrooms' wall lamp), and one chandelier lamp (type LED, 100W apparent load, intensity 2400 lm). Patio area has three garden lamps (type LED, 10W apparent load, intensity 1500 lm). At the terrace, there is a coach lamp same specification as garden lamp.

Figure 65 Lighting Inside House at Night

Table 40 Electrical Load per Area

Area	Receptacle Load (W)	Lighting Load(W)	Other Loads (W)
Hall	3 x 7700	350	1506
Bathroom 1	7700	35	66
Bathroom 2	7700	35	51
Bathroom 3	2 x 7700	35	84
Bedroom 1	2 x 7700	75	200
Bedroom 2	2 x 7700	75	400
Bedroom 3	2 x 7700	75	153
Bedroom 4	2 x 7700	75	500
Bedroom 5	2 x 7700	75	100
Living Room	7700	135	50
Kitchen	3 x 7700	75	340
Patio	1 x 7700	30	N/A

Ultrasonic sensors (24 V DC load, with major and minor motion capability 92 m^2 range) are located at all area inside the house except all bedrooms, the sensors' function are replace switch lamp based on the human's presence. It integrated to the decentralization control in each area where it placed and connected to the main control cabinet as integrated system with other devices system that used regularly scheduled (i.e. HVAC system and water system).

All bedrooms has decentralization control as well, but the sensor not placed in these areas to give the occupants more privilege to manage their own comfortable by semi-automatically from the local control in the room.

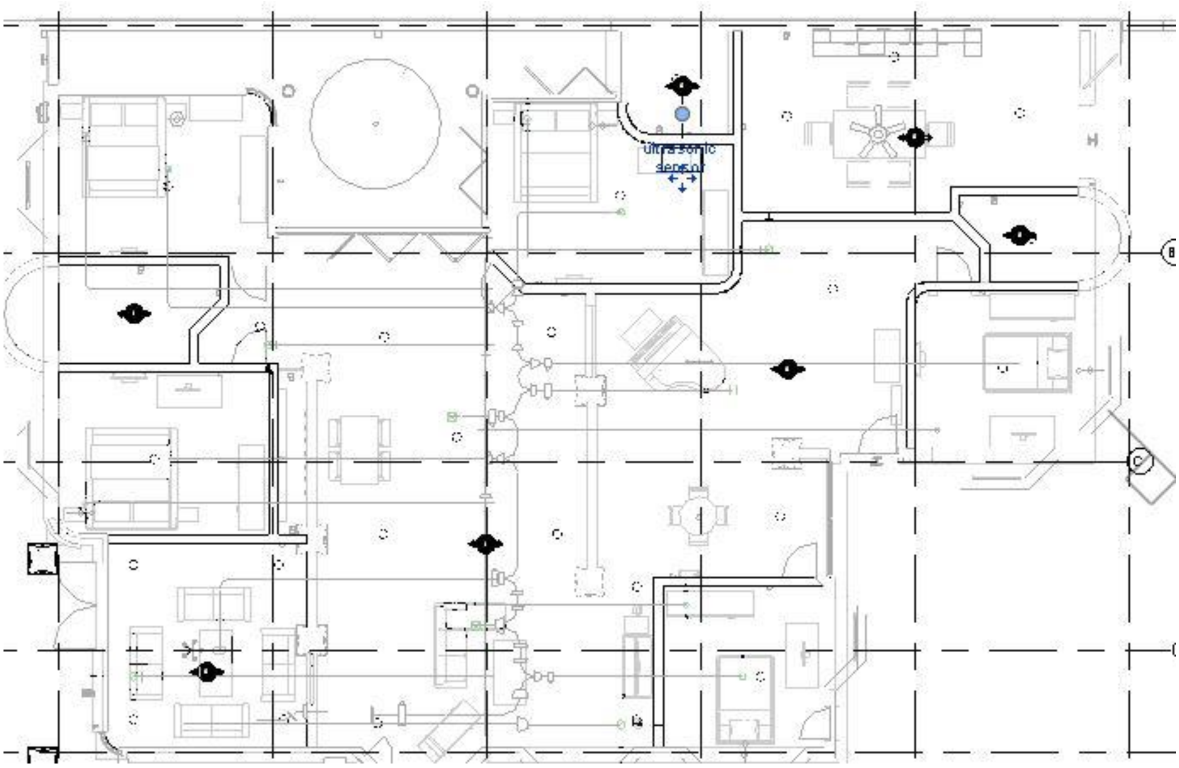

Figure 66 Ultrasonic Sensor Location inside House

Using the energy simulation analysis software from Revit MEP 2015 (Green Building Studio), the electric demand each month in a year found the highest peak in the middle of March and mid of June around 7.1 kW as shown in the figure 66.

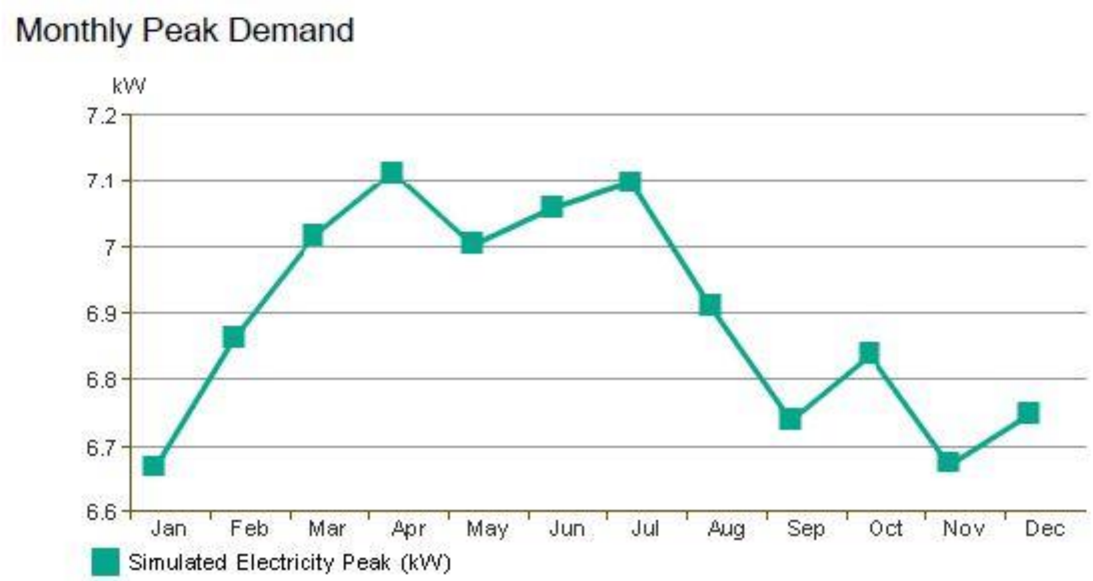

Figure 67 Simulation Electricity Monthly Peak Demand

The monthly electricity consumption simulation for year 2015 shown that the highest consumption are in May and July around 3300 kWh, meanwhile the lowest is in February. This data related to the weather condition in Indonesia in 2015, which May and July are the highest average temperature during the year, hence the active cooling is needed longer and more than the other months.

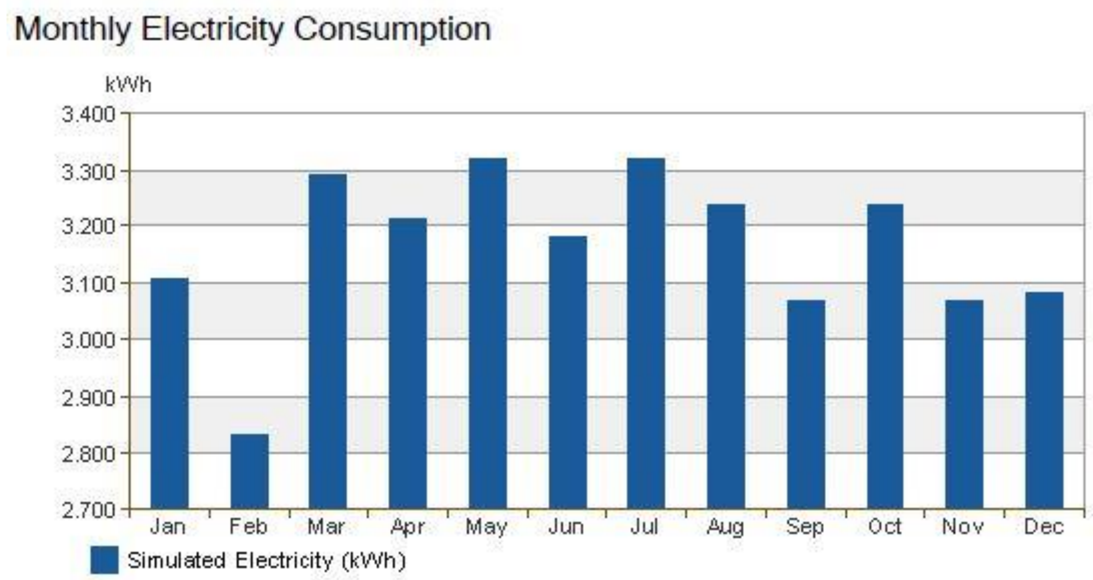

Figure 68 Simulation Electricity Monthly Consumption

In the house location, utilization of the sunlight effectively from 9 am to 3 pm. Hence, positioning of the photovoltaic panels located at the east and west rooftop with 30° angle.

Figure 69 Mount Roof PV Panel

Figure 70 Electric panel and Control cabinet located inside garage

The electrical panel connected to power meter from utility grid and DC to AC inverter as PV panel source, since the loads in the system are all AC. The output would supply control cabinet before reach the load. Battery 12 V 100 AH is used with backup capability.

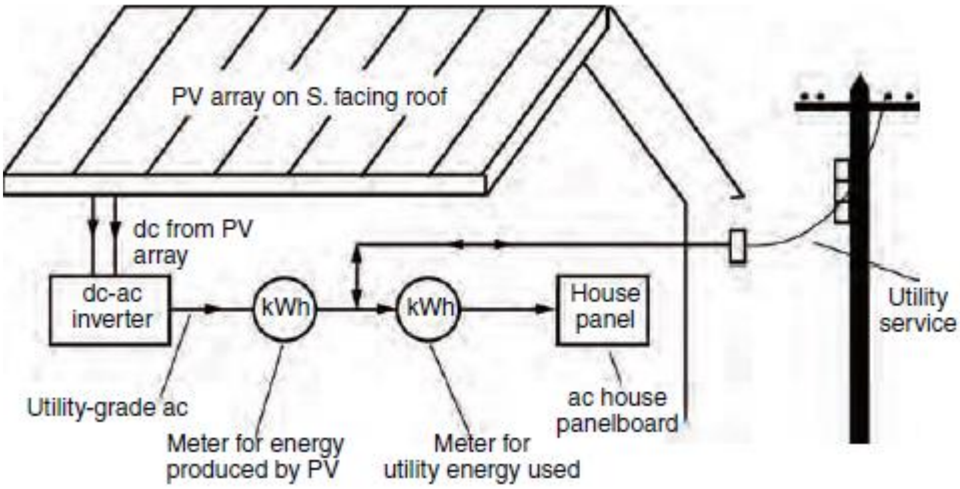

Figure 71 PV Grid-Connected Systems Scheme

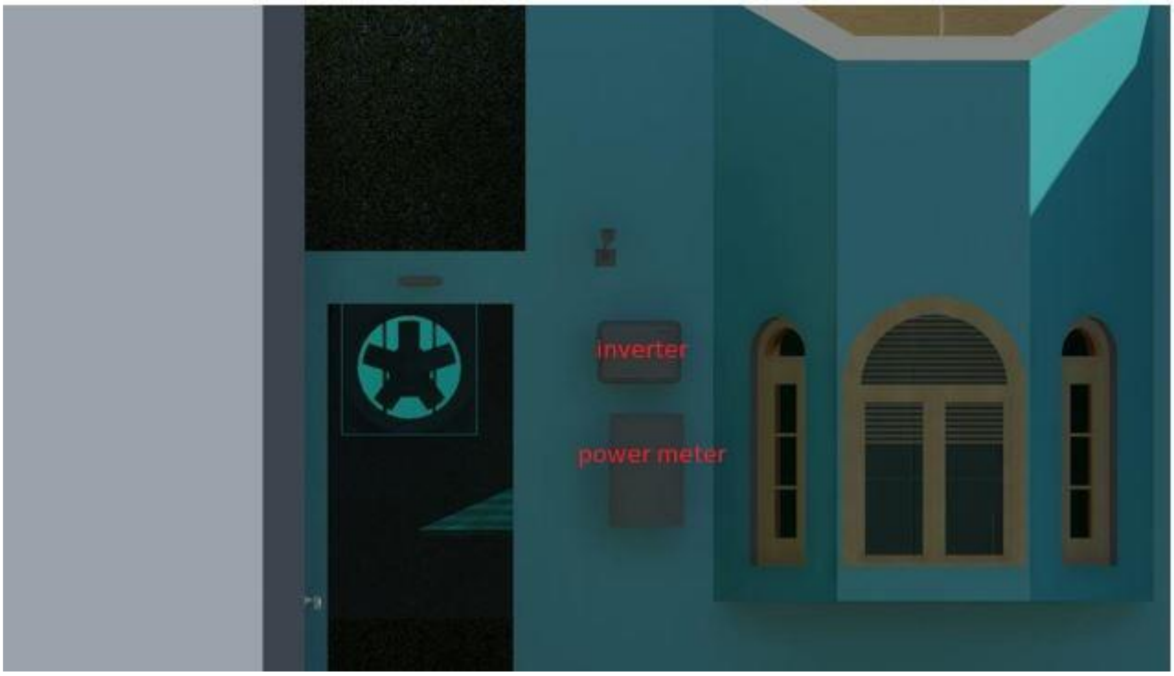

Figure 72 Power meter and DC to AC inverter

3.3.3 Security Systems

The house using alarm system at the main gate, sprinkle system as fire protection, CCTV (IPTV) and motion sensor to avoid unwanted intruder, but for advance execution it should be done manually. Advance execution means the owner must call the police or the fire fighter in case of worst thing happen because the emergency call in Indonesia does not have integration communication to the residential single family house. For now it is only possible for the public building or apartment.

There are six video cameras surveillance located outside the building, all the video records are keep in local disk storage (server), but it is optionally to connect into net server real time monitoring by subscribes into some cloud server hosting that available on the internet, so the subscriber can monitor their home situation while out of the house from gadget that connected to internet.

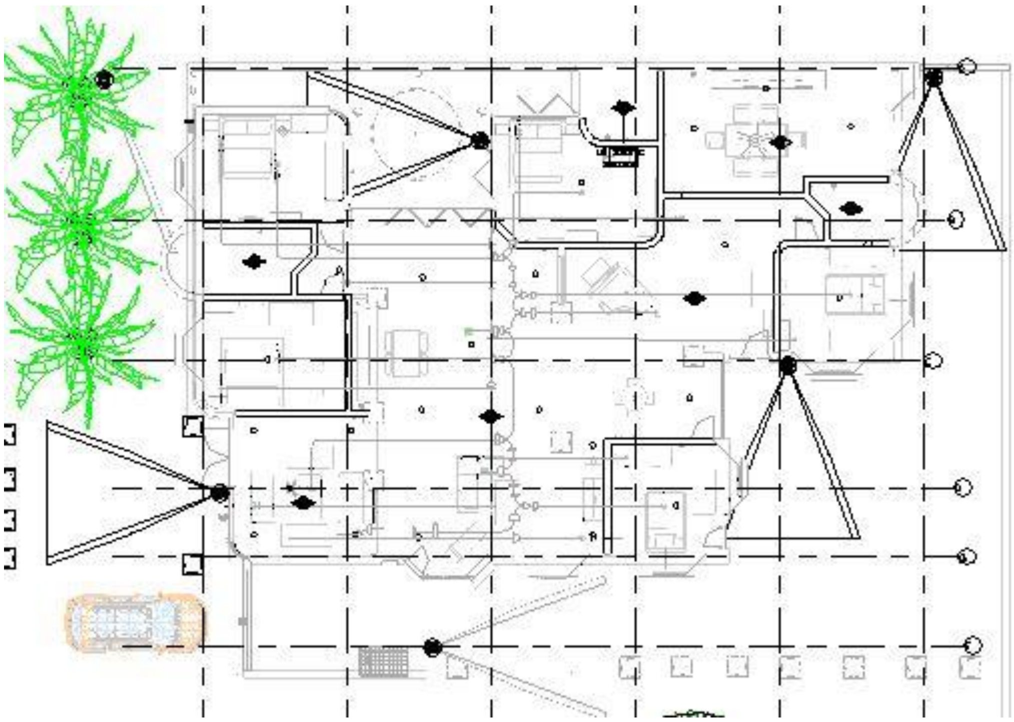

Figure 73 CCTV reachable area top view

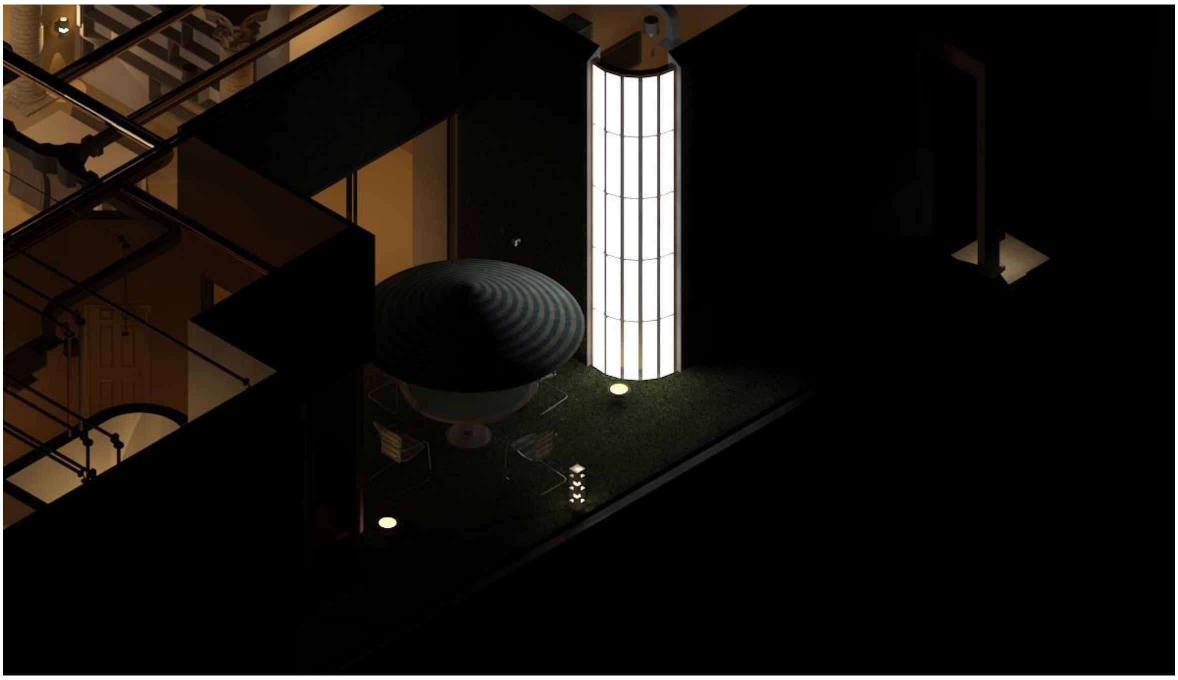

Figure 74 The view of patio when sensor activated at night

3.3.4 Communication & Control Systems

The communication for building automation system used by distribution mini control in each room which contains of lighting (except in all bedrooms), cooling (HVAC), hot water system, electrical power metering and IP-CCTV (security), fire alarm system.

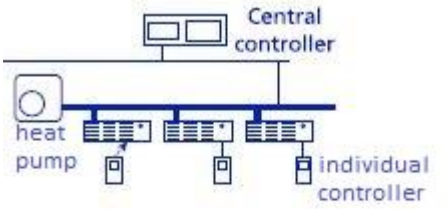

Figure 75 HVAC Control System Scheme

For the building management system (BMS) based on BACnet ASHRAE/ANSI standard communication protocol for building automation applied to this house.

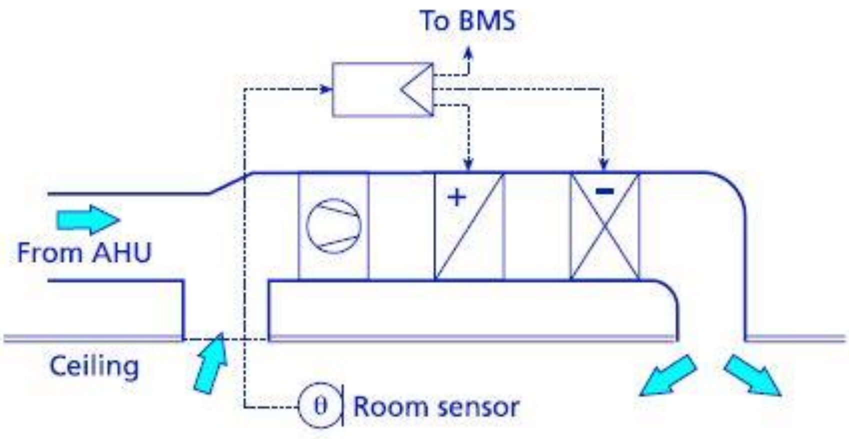

Figure 76 HVAC Control System Scheme

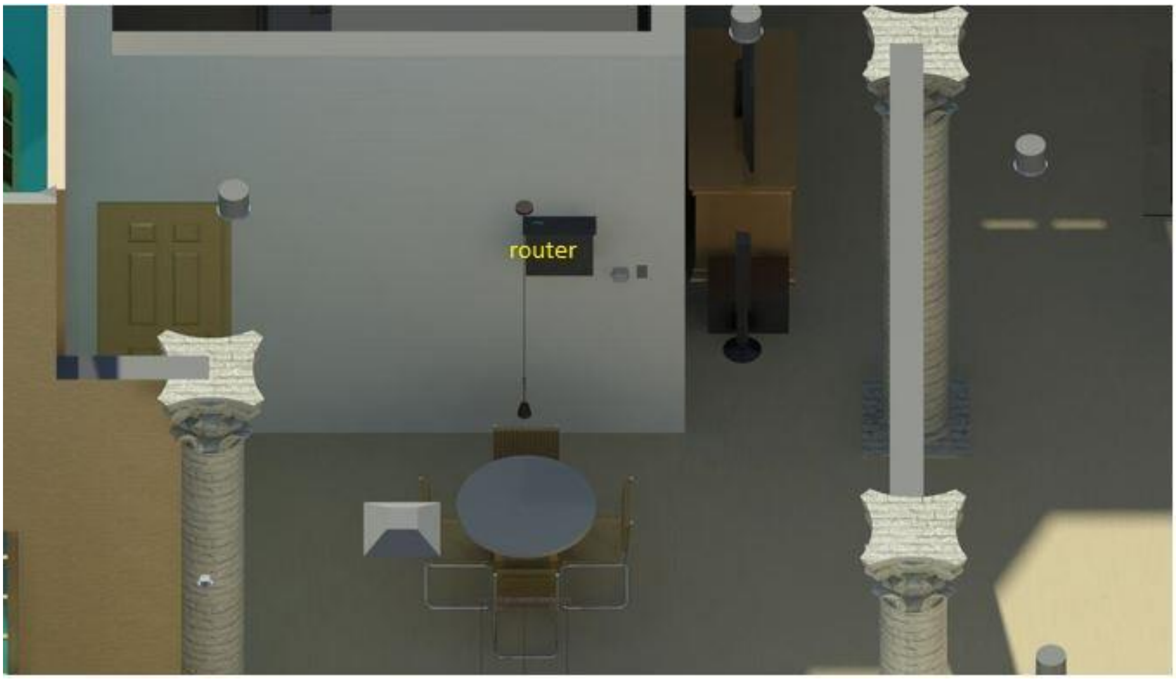

Figure 77 The Communication Devices (Router) Inside House

3.3.5 Photovoltaic Panel Utilization

The use of PV panels in this project are for electricity supply and heating the domestic water systems. Different panels are used of those purpose, as solar collector for water heating only one panel, meanwhile for electricity purpose uses two panels which are roof mounted at the east and west part of the house.

Indonesia has 4.8 kWh/m^2 /day solar energy, it is equals to 112000 GW. Specification of PV panel as electricity supply is Single Crystalline with efficiency 13.8% (102745.6 kWh/year), and the yearly estimation for the roof mounted PV panel shown below;

Table 41 PV System Energy Estimation per Annum using Green Building Studio Analysis

Renewable Energy Potential

Roof Mounted PV System (Low efficiency):	37,227 kWh / yr
Roof Mounted PV System (Medium efficiency):	74,453 kWh / yr
Roof Mounted PV System (High efficiency):	111,680 kWh / yr
Single 15' Wind Turbine Potential:	147 kWh / yr

*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems

To determine the PV panel location depends on the orientation of the house in global position with cast shadows appearance based on time in the morning, noon, and afternoon as respectively shown in figure 56, 57, and 58:

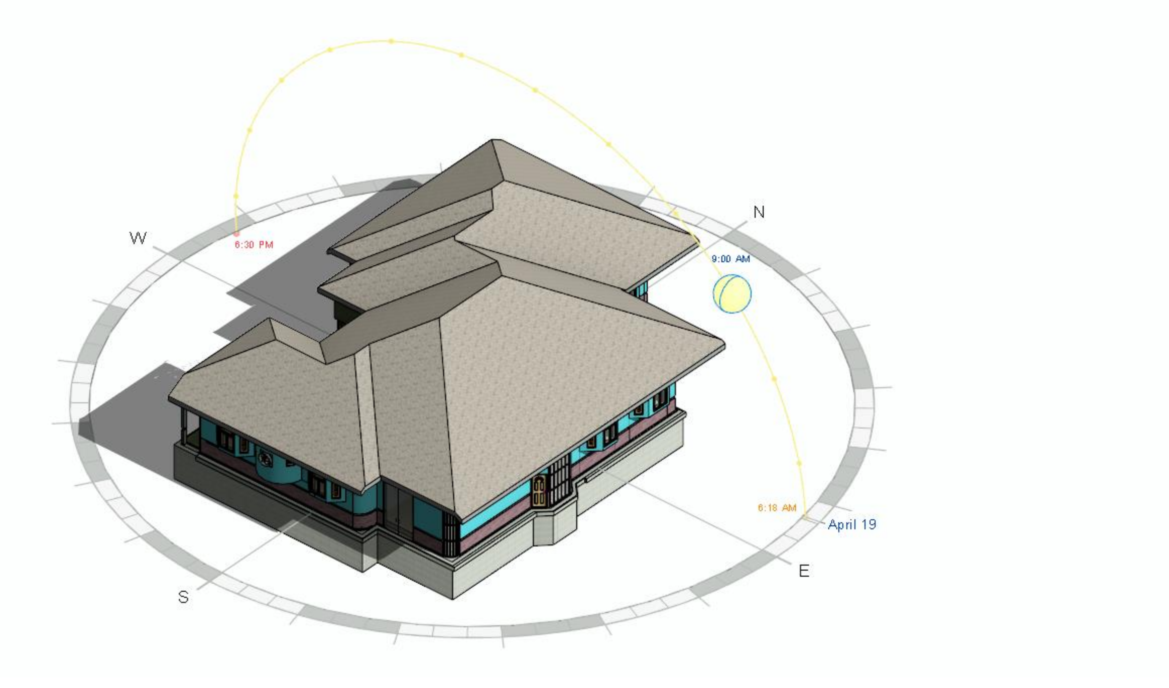

Figure 78 Sun Position at 9 am local time, April 19 2015

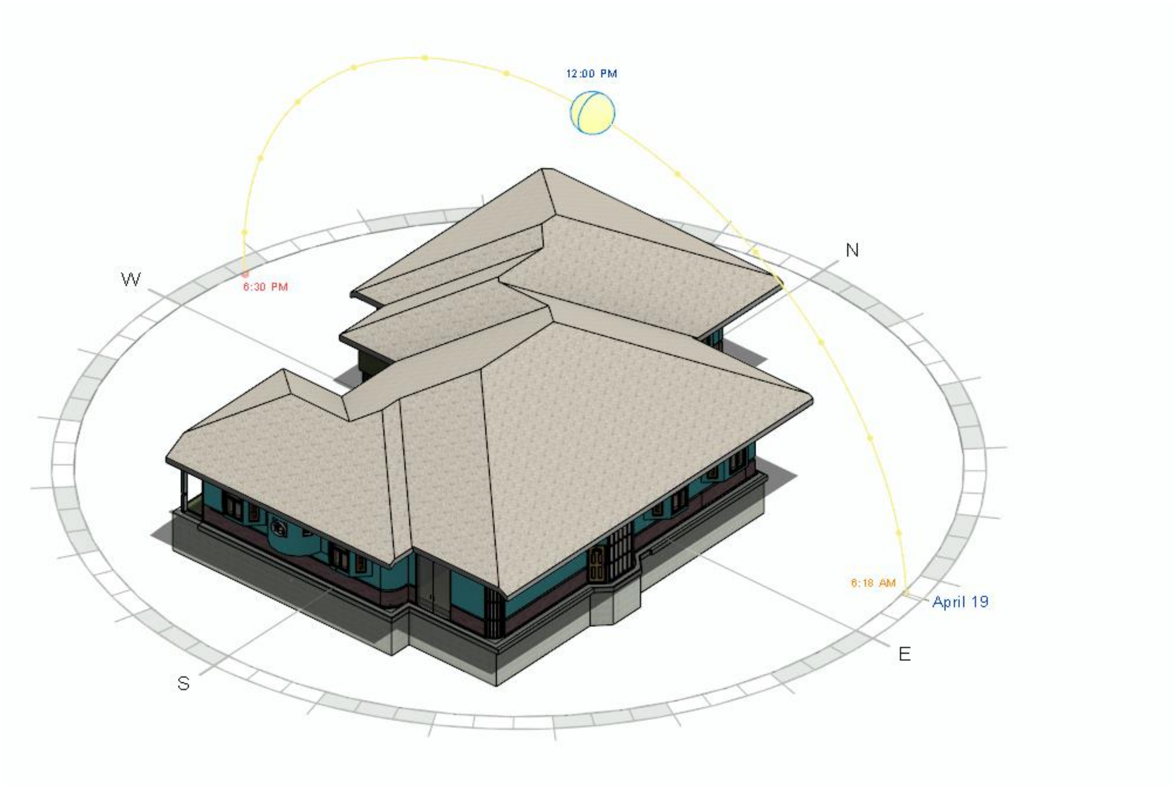

Figure 79 Sun Position at 12 pm local time, April 19 2015

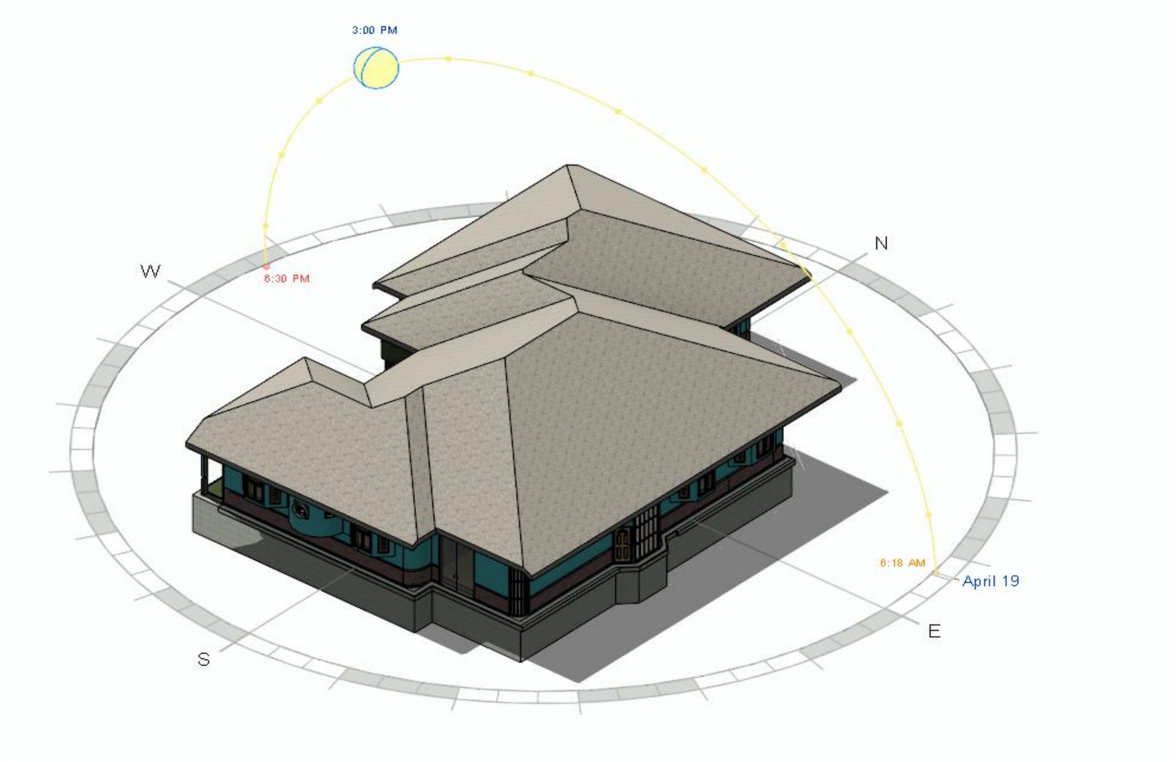

Figure 80 Sun Position at 3 pm local time, April 19 2015

3.3.6 Economic Evaluation

Based on electric tariff adjustment categories issued by PLN (Perusahaan Listrik Negara), national electric company per June 2015, this house belongs to R-3/TR (residential category, more than 6600 W), that is 1524 IDR/kWh or equals to €0.09/kWh. It still subsidize by the Indonesian government.

Table 42 Electric Tariff in Indonesian Rupiah before Adjustment June 2015

Golongan Tarif Tariff Class	Tegangan Voltage	TTL Tariff	BPP Basic Cost of Electricity Production	Subsidi Subsidy
P.1 s/d 2.200 s/d 5.500 VA	TR	1.018,1	1.473,0	454,9
P.1/> 6.600 s/d 200 kVA	TR	1.337,4	1.473,0	135,6
P.2/> 200 kVA	TM	966,5	1.273,5	307,0
P.3	TR	926,6	1.473,0	546,4
T/> 200 kVA	TM	737,5	1.273,5	536,0
C/> 200 kVA	TM	1.169,7	1.273,5	604,8
L	TM	1.169,7	1.273,5	103,8

The subsidies are calculated from negative difference between the selling prices of electricity on average (IDR/kWh) of each tariff group minus the basic cost of electricity production (IDR/kWh) on the voltage at each tariff group multiplied by sales volume (kWh) for each tariff group.

Photovoltaic panel economic calculations start with the initial cost of the PV panel for 1100 W is €5 x 1100 = €5500 with annual return is €275. The payback period is within 20 years, hence the installation of PV panels are still not profitable in this project in the current years. The other consideration is low tariff of utility grid because the subsidy from national government. In the future the PV price will become decrease in conjunction with government’s policy to withdraw the subsidy gradually.

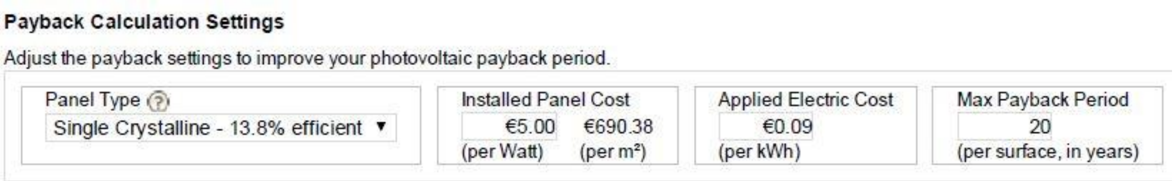

Figure 81 Payback Period Calculation using Green Building Studio

CONCLUSION

This thesis mostly have done with BIM software, Revit MEP 2015 include design and calculation, due to the main purpose of the development BIM is in 3D mode, not many plan view scheme can be shown in the thesis.

Designing the automation systems in the residential single family house has more flexibility than the other type of building, because it depends on the owner how complex or simple he/she wants the house being automated. More than that, the time schedule of the system activated will be highly vary, it could not be rigid since many different activities from different ages done in a house. This situation rise the challenge for the designer for always being creative to improve his/her skills and ideas in order to satisfy the owner’s demand and expectation.

Advanced building automation system, a more or less get along with the building management system. The benefits of management control are relate to maintain cost and evaluation of the system from time to time due to optimization and economic value. Distributed controls are needed in each space of the house which are passed by the system to get more detail monitoring information. All the distribution controls possible to communicate through the main control panel. Leaking process could be minimized so the system function keep work properly and the house has longer sustainability.

Overall result of the thesis should can be applied and contributed in Indonesia near future for new residential building as one of the reference or as the second opinion towards the national government’s program about saving energy in building.

BIBLIOGRAPHY

[1] Worldbank, “Average precipitation in depth.” [Online]. Available: http://data.worldbank.org/indicator/AG.LND.PRCP.MM. [Accessed: 07-May-2015].

[2] P. Torcellini, S. Pless, M. Deru, and D. Crawley, “Zero Energy Buildings: A Critical Look at the Definition,” in *ACEEE Summer Study Pacific Grove*, 2006, p. 15.

[3] A. G. K. Walter T. Grondzik, *Mechanical and electrical equipment for buildings*, 12th ed. wiley, 2014.

[4] U. States, “ASHRAE Standard 90.1,” 2007.

[5] P. E. C. Com and D. O. Chong, “APEC Building Codes, Regulations, and Standards,” 2013.

[6] “Greenship homes.” [Online]. Available: http://www.greenshiphomes.org/. [Accessed: 05-May-2015].

[7] “HERS index.” [Online]. Available: http://www.hersindex.com/understanding. [Accessed: 15-May-2015].

[8] ASHRAE, “ASHRAE Handbook-Fundamentals,” *ASHRAE Handbook-Fundamentals*, 2005.

[9] B. GIVONI, “Comfort, climate analysis and building design guidelines,” *Energy Build.*, vol. 18, no. 1, pp. 11–23, 1992.

[10] ASHRAE, “ANSI/ASHRAE Standard 62.2-2013, Ventilation and Acceptable Indoor Air Quality in Low- Rise Residential Buildings,” 2013.

[11] “National Ambient Air Quality Standards.” [Online]. Available: http://www.epa.gov/air/criteria.html. [Accessed: 25-May-2015].

[12] J. H. & M. Wasley, *Healthy by Design Revised: Building and Remodeling Solutions for Creating Healthy Homes by Rousseau, David*, First. Winter Ventures, 1999.

[13] J. F. Nicol and M. A. Humphreys, “Adaptive thermal comfort and sustainable thermal standards for buildings,” in *Energy and Buildings*, 2002, vol. 34, no. 6, pp. 563–572.

[14] “ANSI/ASHRAE Standard 55-2010, Thermal Environment Conditions for Human Occupancy,” 2010.

[15] C. S. Clemens Richarz, *Energy efficiency refurbishments: Principles, Details, Case studies*. 2013.

[16] A. Olgyay, V., & Olgyay, *Design with climate: bioclimatic approach to architectural regionalism*. 978-0442011109, 1992.

[17] J. E. Brumbaugh, *Audel HVAC fundamentals*. wiley, 2004.

[18] Ramsey and Sleeper, *Architectural Graphic Standards, 10th ed*. Wiley, 2000.

[19] E. J. F. Kreider, B. Raton, and C. R. C. P. Llc, *Handbook of Heating, Ventilation, and Air Conditioning*. CRC Press, 2001.

[20] A. Sitompul, "Renewable energy development in Indonesia: Potential and policy frameworks," 2013.

[21] ASHRAE, "ASHRAE Handbook - HVAC Applications," 2007.

LIST OF ABBREVIATIONS

ACH	Air Change per Hour
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ANSI	American National Standards Institute.
APEC	Asia-Pacific Economic Cooperation
BIM	Building Information Modelling
CEN	European Committee for Standardization
COP	Coefficient of Performance
ESEER	European Seasonal Energy Efficiency Ratio
EPA	Environmental Protection Agency's
GBS	Green Building Studio
GBCI	Green Building Council of Indonesia
HERS	Home Energy Rating System
HVAC	Heating Ventilation Air Conditioning
IAQ	Indoor Air Quality
IEGC	International Energy Conservation Code
IESNA	Illuminating Engineering Society of North America
ISO	International Standard Organization
IWEC	International Weather for Energy Calculations
IDR	Indonesian Rupiah
LED	Light Emitting Diode
LEED	Leadership in Energy & Environmental Design
MRT	Mean Radiant Temperature
NREL	National Renewable Energy Laboratory
PMV	Predicted Mean Vote

PPD	Predicted Percentage of Dissatisfied
PPM	Parts per million
SEER	Seasonal Energy Efficiency Ratio
SHGC	Solar Heat Gain Coefficient
SI	System International
U.S	United States

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APPENDICES

Attached in CD with thesis electronic version electronic